RESEARCH REPORT

FIELD TESTS OF VENTILATION SYSTEMS INSTALLED TO MEET THE 1993 OBC AND 1995 NBC

FINAL REPORT

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FINAL REPORT

FIELD TESTS OF VENTILATION SYSTEMS INSTALLED TO MEET THE 1993 OBC AND 1995 NBC

Prepared For

CANADA MORTGAGE AND HOUSING CORPORATION

Prepared By

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Abstract

A field study of the ventilation systems in houses built under the 1995 National Building Code of Canada (NBC) revealed that the houses were not meeting many of the NBC ventilation requirements. It also identified some deficiencies with NBC Section 9.32 requirements, particularly regarding protection from depressurization for chimney-vented combustion appliances. The study concludes that builders and installers need to improve their knowledge of the NBC residential ventilation requirements, that NBC Section 9.32 is in need of some changes and that stricter enforcement of the residential requirements is needed.

Lessons learned in the field study were incorporated into three demonstration houses by installing and testing the three most common ventilation system strategies. The project demonstrated that ventilation systems which comply with the NBC, and the recommended changes to the NBC, can provide safe and effective ventilation in houses.

Acknowledgements

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Executive Summary

Requirements for residential ventilation systems became more complex and comprehensive in the 1995 National Building Code of Canada (NBC), thus more challenging for builders and installers to meet. Canada Mortgage and Housing Corporation (CMHC) commissioned a study to determine the types of ventilation systems being installed in new houses and to gauge how well these systems were meeting the word and the intent of the Code. Inspections and measurements were made on ventilation systems in thirteen new houses in Manitoba, four in Saskatchewan, twelve in Alberta, seven from the Atlantic provinces, and two in the Yukon. Eleven houses built to the 1993 Ontario Building Code (OBC) were also inspected.

In western and northern Canada, most new houses had CMHC/NBC Option 1 ventilation systems (outdoor air intake coupled to a forced-air furnace return duct). In Atlantic Canada, where energy costs are high, all study houses had HRVs, primarily CMHC/NBC Option 6 systems (fully ducted HRVs). In Ontario, most had CMHC/OBC Option 1 systems (exhaust-only systems with a forced-air furnace, no spillage-susceptible combustion appliances), but in some areas, up to 40% of installations included HRVs.

Depressurization of houses with spillage-susceptible combustion appliances was the most significant problem identified in study houses. CAN/CGA-B149 states that spillage-susceptible gas appliances cannot be installed in environments with "mechanically ventilated systems that allow more than 5 Pa depressurization". Although most study houses complied with "Protection from Depressurization" requirements in NBC 9.32, thirty-one of the 38 NBC study houses were predicted to be depressurized by at least 5 Pa when operating the dryer, rangehood and principal exhaust system; all but one house were predicted to be depressurized by at least 5 Pa when operating all installed exhaust devices. Most gas-heated houses had spillage-susceptible combustion appliances.

A second problem identified was that mean winter design condition return air temperatures for some CMHC/NBC Option 1 systems will, at times, fall below 15.5°C, and in some installations, may fall below 12°C, with a thermostat set at 18°C. Lower setback temperatures or temperature variations across ducts may result in local return air temperatures below 10°C during cold weather. Cold return air temperatures can increase condensation and corrosion in furnace heat exchangers, causing premature heat exchanger failure and possibly affecting warrantees.

Most systems included a number of non-compliant details. Whereas almost all contractors said they did some "formal" ventilation system design, site observations show that most do not follow the duct sizing tables or design methods referenced in the NBC nor do they commission ventilation systems. It appears that many do not even check the operation of finished systems.

Although few duct systems were designed, airflows for remote fans and HRVs usually met or exceeded target airflow rates. However, more than half the non-powered outdoor air intakes (CMHC/NBC Option 1 systems), bath fans and rangehoods had airflows less than 90% of the NBC-specified target flow rates.

In the course of the study, the researchers observed many non-compliant details and encountered contractors with alternate interpretations of specific NBC requirements. Some installers noted that building inspectors often had other interpretations and were not unanimous in their interpretations of NBC requirements. The fact that there are alternate interpretations of some requirements indicates that there are ambiguities in the Code which need to be cleared up. Specific examples include the location and nature of outdoor air intake connections to furnace return air ducts.

Some NBC requirements seem unnecessarily restrictive. For example: duct sizing tables do not allow for reducing branch duct diameters; central (remote) exhaust fans are not permitted because they are not rated for sound; and fan-powered outdoor air supplies must be connected to a furnace return air duct downstream of all returns. On other aspects, more stringent requirements appear to be in order. For example, automatic dampers or requirements to measure and adjust airflow in outdoor air intakes may be warranted.

Workmanship on the heating and ventilation systems in many of the houses had the appearance of being completed in a hurry by the low bidder, especially CMHC/NBC Option 1 Systems (i.e., an unpowered outdoor air intake connected to a furnace return). Observed system deficiencies and non-compliant details indicate that many builders and installers have not studied or do not understand Code requirements. They generally do not check system installation and operation upon completion or choose to ignore or overlook requirements which are not enforced, and enforcement of residential ventilation requirements appears to be weak. Frequent problems or deficiencies included: controls (in houses where ventilation systems are coupled to forced-air heating systems) which do not operate the ventilation systems as required; badly laid out, convoluted duct runs; hoods and controls not propcrly labelled; undersized intake and exhaust hoods and screens; out-of-spec connections of outdoor air intakes to furnace returns; crushed sections of flex duct; incomplctc rangchood venting, etc.

"To Code" examples of the three most common ventilation strategies were designed, constructed and tested. They demonstrated that the intent of the NBC (i.e., to provide safe and effective ventilation) can be met by complying with requirements of Section 9.32 in the NBC, provided that spillage-susceptible combustion appliances are not installed.

In summary, some topics in the NBC need to be revised, particularly there is a need to harmonize depressurization requirements in the NBC with those in Gas Codes. There is a need for installer training and stricter enforcement of Code requirements regarding depressurization of spillage-susceptible combustion appliances and ventilation system installation. Overall, installers appear to lack an appreciation of "the house as a system" concept.

Résumé

Le Code national du bâtiment (CNB) de 1995 comporte des exigences de ventilation pour les maisons qui sont très complexes et détaillées par rapport aux éditions antérieures, de telle sorte que les constructeurs et les installateurs éprouvent des difficultés à s'y conformer. La Société canadienne d'hypothèques et de logement (SCHL) a commandé une étude dans le but de caractériser les types de systèmes qu'on installe aujourd'hui dans les maisons neuves et d'évaluer jusqu'à quel point ces systèmes sont conformes à la lettre et à l'esprit du Code. On a effectué des inspections et des essais des systèmes de ventilation dans treize maisons neuves au Manitoba, quatre en Saskatchewan, douze en Alberta, sept dans les provinces Atlantiques et deux au Yukon. Onze maisons construites selon les exigences du code du bâtiment de l'Ontario (OBC) de 1993 ont également fait l'objet d'essais.

Dans l'ouest et le nord du Canada, le système de ventilation installé dans la majorité des maisons neuves correspond à l'option 1 SCHL/CNB (prise d'admission d'air extérieur jumelée au conduit de reprise du générateur de chaleur à air pulsé). Dans la région de l'Atlantique, où les frais d'énergie sont très élevés, toutes les maisons à l'étude étaient équipées d'un VRC, ce qui correspondait dans la plupart des cas à l'option 6 SCHL/CNB (VRC munis de conduits). En Ontario, la majorité des installations correspondait à l'option 1 SCHL/OBC (systèmes d'évacuation d'air seulement et générateur d'air pulsé, sans appareils à combustion sensibles aux refoulements), mais dans certaines régions, jusqu'à 40 % des installations étaient dotées de VRC.

Le problème le plus courant constaté dans les maisons à l'étude a été la dépressurisation en présence d'appareils à combustion sensibles aux refoulements. La norme CAN/CGA-B149 stipule qu'il est interdit d'installer des appareils à combustion sensibles aux refoulements dans un milieu doté d'un système de ventilation mécanique « qui produit une dépressurisation de plus de 5 Pa ». Même si la plupart des maisons à l'étude étaient conformes aux exigences de la section 9.32, Protection contre la dépressurisation, on a prédit que 31 des 38 maisons à l'étude conformes au CNB subiraient une dépressurisation d'au moins 5 Pa lors du fonctionnement de la sécheuse, de la hotte de cuisinière et du ventilateur extracteur principal. On a estimé que toutes les maisons sauf une subiraient une dépressurisation d'au moins 5 Pa lors du fonctionnement de tous les dispositifs d'extraction. La plupart des maisons chauffées au gaz comportaient des appareils à combustion sensibles aux refoulements.

Un deuxième problème noté a trait aux températures moyennes de l'air de reprise aux conditions de calcul d'hiver qui, pour certains systèmes de l'option 1 SCHL/CNB, pourraient chuter sous la barre des 15,5 °C et même, dans certaines installations, sous les 12 °C lorsque le thermostat est réglé à 18 °C. Si on choisit des températures programmées encore plus basses ou s'il se produit des variations de température majeures dans les conduits, les températures locales de l'air de reprise pourraient descendre sous les 10 °C par temps froid. Un air de reprise trop froid peut accroître la condensation et la corrosion dans l'échangeur de chaleur du générateur d'air chaud, ce qui pourrait entraîner la défaillance prématurée de l'échangeur et invalider les garanties.

La majorité des installations comportait un certain nombre d'éléments non conformes. Alors que la plupart des entrepreneurs ont affirmé consacrer du temps à la conception des installations de

ventilation, les observations faites sur place révèlent que la plupart d'entre eux n'ont pas suivi les tableaux de dimensionnement des conduits ou les méthodes de calcul des conduits dont fait état le CNB et ne mettent pas officiellement en service les systèmes de ventilation. Par ailleurs, il semblerait que les entrepreneurs ne vérifient même pas le fonctionnement des systèmes une fois l'installation complétée.

Quoique que très peu d'installations aient fait l'objet de calculs, les débits d'air des ventilateurs autonomes et des VRC, pour la plupart, égalaient ou excédaient les valeurs cibles. Cependant, plus de la moitié des prises d'admission d'air extérieur non motorisées (systèmes conformes à l'option 1 SCHL/CNB), des ventilateurs d'extraction des salles de bains et des hottes de cuisinière avaient des débits d'air qui atteignaient moins de 90 % du débit cible stipulé dans le CNB.

En cours de travaux, les chercheurs ont relevé de nombreux éléments non conformes et ont fait la rencontre d'entrepreneurs qui interprétaient différemment certaines exigences du CNB. Certains installateurs ont remarqué que les inspecteurs en bâtiment n'interprétaient pas tous de la même façon les exigences du CNB. L'absence d'uniformité dans l'interprétation du CNB indique qu'il est ambigu. Par exemple, il faudrait préciser l'emplacement et la nature des raccords entre la prise d'air extérieur et le conduit de reprise du générateur à air pulsé.

Certaines des exigences du CNB semblent inutilement restrictives, par exemple : les tableaux de dimensionnement des conduits ne permettent pas de réduire le diamètre des conduits secondaires, les ventilateurs d'extraction principaux (autonomes) ne sont pas admis, parce qu'ils n'ont pas une cote de niveau sonore et les alimentations en air extérieur dotées d'un ventilateur doivent être raccordées au conduit de reprise des générateurs d'air pulsé en aval de tout autre conduit de reprise. Par ailleurs, pour d'autres aspects, des exigences plus sévères semblent s'imposer. Ainsi, il faudra peut-être installer des volets motorisés dans les prises d'air extérieur ou exiger de mesurer et d'ajuster les débits.

La qualité d'exécution du système de chauffage et de ventilation dans de nombreuses maisons donnait l'impression d'un travail bâclé par le plus bas soumissionnaire, plus particulièrement dans le cas de l'option 1 SCHL/CNB (c'est-à-dire une prise d'air extérieur non motorisée raccordée au conduit de reprise du générateur d'air chaud). D'autres observations liées à des déficiences des systèmes ou des détails non conformes portent à croire que de nombreux constructeurs et installateurs n'ont pas étudié ou ne comprennent pas les exigences du Code. Ils ne vérifient pas l'installation et le fonctionnement des systèmes une fois mis en place ou ils décident de passer outre aux exigences qui ne sont pas appliquées. En outre, l'application réglementaire des exigences de ventilation dans les maisons ne semble pas très poussée. Les problèmes suivants sont fréquents : les commandes (dans les maisons où le système de ventilation est couplé au générateur d'air chaud) qui ne font pas démarrer les systèmes de ventilation comme prévu, des parcours de conduits alambiqués et mal disposés, des hottes et des commandes mal étiquetées, des prises d'air, des hottes d'extraction et des grillages sous-dimensionnés, des raccords non conformes entre la prise d'air extérieur et le conduit de reprise du générateur d'air chaud, des segments de conduits souples écrasés, des hottes de cuisinière sans conduits d'évacuation, etc.

On a conçu, installé et mis à l'essai des exemples conformes au Code de chacune des trois stratégies de ventilation les plus communes. Ils ont montré qu'on peut respecter l'esprit du CNB (c'est-à-dire fournir une ventilation efficace et sans risque) en se conformant aux exigences de la section 9.32 du CNB, pourvu que des appareils à combustion sensibles aux refoulements ne soient pas présents.

En résumé, certains aspects du CNB exigent une révision. En outre, les exigences traitant de la dépressurisation gagneraient à être harmonisées avec celles des codes régissant les installations au gaz. On devra former les installateurs et veiller à l'application rigoureuse des exigences du Code à l'égard des appareils à combustion sensibles aux refoulements et à l'égard de l'installation des systèmes de ventilation. Dans l'ensemble, les installateurs ne semblent pas connaître le principe de l'approche systémique de la maison.

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Introduction

Section 9.32, "Ventilation", in the 1995 National Building Code of Canada (NBC), introduced new requirements for the design and installation of residential ventilation systems. These requirements are more complex than in previous Building Codes, and, as such, more problematic for builders and installers to meet than the previous Building Codes. After several provinces had adopted 1995 NBC for their provincial Building Code, CMHC commissioned a study titled *Field Tests of Ventilation Systems Installed to Meet 1995 NBC* in order to:

- identify the types of systems being installed to the 1995 NBC;
- estimate ventilation system costs;
- determine if the systems being installed comply with the NBC requirements, and if not, to identify and quantify the shortcomings;
- determine if systems meeting the word of the Code also comply with the intent of the Code.

The project was extended to include an evaluation of houses with ventilation systems intended to meet the residential ventilation requirements in the 1993 Ontario Building Code (OBC). The objective of including OBC houses in the study is to determine whether application of the OBC avoids particular compliance problems identified in many houses with ventilation systems designed to meet the 1995 National Building Code.

Following the first round of testing, a further task was undertaken to develop, construct and test examples of the three most common ventilation systems strategies to demonstrate whether the Code requirements could be met with diligent application.

Methodology

1. Description of Work Undertaken

The project was composed of the following tasks:

Task 1, Determine Information to be Collected - a review was made to identify information needed to evaluate ventilation systems relative to project objectives.

Task 2, Develop and Test a Field Test Protocol - methodologies to acquire and process the needed information were identified, data collection sheets were prepared, the methodology was tested on one house and preliminary analysis was performed on the data to ensure that necessary information was being gathered.

Task 3, Trial Test the Field Protocol - the modified Field Protocol was applied to other houses in order to further field test and streamline the protocol, data sheets and data processing methods before "bulk application".

Task 4, Select and Field Test Houses in Other Regions - between January and April, 1999, houses built to the 1995 NBC in other areas of Canada were tested. In all, thirty-eight NBC houses were tested: thirteen in Manitoba, four in Saskatchewan, twelve in Alberta, seven from the Atlantic provinces, and two in the Yukon.

Task 5, Test Ontario Houses - eleven OBC houses were tested in July, 1999.

An effort was made to ensure that the study include a diversity of system types, house sizes and installers. R-2000 houses were not included in the survey sample. Except for the Atlantic region, most test houses were unoccupied. This allowed the research team to fulfil their obligation of reporting hazardous conditions to the owner/builder without "stirring up" the builder's customers. Builders and installers that arranged houses were provided with written reports describing ventilation system deficiencies found during the inspections and tests.

Some builders and ventilation system installers were surveyed regarding the types of ventilation systems they install, how they select system types, system costs, and problems encountered in meeting the Code or system performance. Codes officials and inspectors were not interviewed in this study.

The information gathered for test houses was processed and analyzed to determine if the ventilation systems installed in the houses complied with the prescriptive requirements in the respective Building Codes. The data were analyzed by region and by ventilation system configuration to reveal regional installation problems or systematic deficiencies occurring with particular system configurations, regional cost differences, and to determine the need to modify Code requirements or develop improved training programs for ventilation system installers, builders and Building Code enforcement personnel. The lessons learned in the field study were incorporated into the design and construction of ventilation systems which were used to demonstrate safe and effective ways of ventilating houses.

2. Field Test Protocol

Field tests of residential ventilation systems installed to meet Section 9.32 in the 1993 OBC and the 1995 NBC went beyond examining compliance with 9.32; they included evaluation of compliance with depressurization limits in Fuel Codes, furnace manufacturers' requirements, and the intent of the NBC and OBC, not just the word of the Code.

The field test protocol included:

- identifying system deficiencies or Code violations based on visual examinations;
- conducting airtightness tests following CAN/CGSB-149.10 "Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method";
- measuring airflow performance of forced-air heating systems by pitot traverse, and exhaust appliances and make-up air systems using flow collars or flow measuring stations;
- measuring supply airflows into bedrooms using a flow hood;
- measuring house pressures with exhaust appliances running individually and in combination;
- recording furnace and fan nameplate data;
- recording DHW system nameplate data;
- recording nameplate data of decorative and wood heating appliances;
- sketching ventilation system ductwork layouts, including duct sizes;
- plotting temperature profiles downstream of ventilation air intakes in forced-air heating system return ducts;
- estimating mixed air temperatures based on relative airflows, both at winter design temperatures and at minimum outdoor air temperatures;
- collecting data for HOT2000 simulations or design condition heat loss calculations on selected houses, and;
- completing Option Checklists (from the CMHC manuals *Complying with the Ventilation Requirements in the 1995 National Building Code* and *Complying with the Ventilation Requirements in the 1993 Ontario Building Code*, as appropriate) for each house.

Photos were taken of the front elevation and notable features or conditions in each house. Supply and exhaust fan sound levels were not measured.

The methodologies to acquire and process the data for test houses were tested in one house to ensure that all necessary information was being gathered; to eliminate the collection of information which was not relevant to the project; to allow an assessment and modification of data collection forms; and to identify ways of streamlining the data acquisition process.

A copy of the forms used for data acquisition are in Appendix A.

Field test data was entered into a spreadsheet program to facilitate inspection and comparison of data from all houses and to allow analysis and manipulation of the data. Spreadsheets were used to:

- calculate airflow in the furnace return based on velocity pressures from a pitot traverse;
- estimate the mean mixed air temperature in the furnace return, downstream of the outdoor air intake, at specific outdoor air temperatures;
- predict house depressurization based on the airtightness characteristics of study houses from the CGSB airtightness tests and the airflows measured for installed exhaust devices.

3. Demonstration of Effective Ventilation Systems

Information gathered in this study indicate that the ventilation systems being applied in new NBC houses are almost exclusively NBC/CMHC Option 1, 3 or 6 type systems. Key characteristics of each of these ventilation system types is presented in Table 1. The lessons learned in the field study were incorporated into the design and construction of one example of each of these three ventilation system types to demonstrate safe and effective ways of meeting the residential ventilation requirements in the 1995 NBC. Upon completion, the field testing procedures were applied to the demonstration houses to confirm their performance.

Table 1

Description of Ventilation Systems Commonly Installed in Study Houses

NBC Option 1, Outdoor Air Supply Duct Coupled to a Forced-Air Furnace Return

A principal exhaust fan exhausts from the kitchen, bathrooms or other location to meet basic exhaust needs. An outdoor air intake connected to the furnace return duct supplies ventilation air. Controls operate the furnace circulation fan to distribute ventilation air when the principal exhaust fan is on. Supplemental exhausts from wet rooms not served by the principal exhaust meet episodic exhaust needs.

NBC Option 3, HRV Coupled to a Forced-Air Furnace, Extended Principal Exhaust Ductwork

HRV exhausts from the kitchen, bathrooms or other location to meet basic exhaust needs and supplies outdoor air to the furnace return duct. Controls operate the furnace circulation fan when the HRV is on, to distribute ventilation air. High-speed HRV operation and/or supplemental exhaust from wet rooms not served by the HRV meet episodic exhaust needs.

NBC Option 6, HRV Not Coupled to a Forced-Air Furnace

HRV exhausts from the kitchen, bathrooms or other location to meet basic exhaust needs and supplies outdoor air directly to bedrooms and living areas. High-speed HRV operation and/or supplemental exhaust from wet rooms not served by the HRV meet episodic exhaust needs.

OBC Option 1, Exhaust-Only Ventilation

A principal exhaust fan exhausts from the kitchen, bathrooms or other location to meet basic exhaust needs. Outdoor air enters the house through infiltration. A manual switch adjacent to the principal exhaust switch allows the occupant to operate the furnace fan to circulate outdoor (infiltration) air throughout the house. Supplemental exhaust from wet rooms not served by the principal exhaust provides additional exhaust capacity for episodic needs. This prescriptive option cannot be used in houses with spillage-susceptible combustion appliances.

OBC Option 2, HRV Coupled to a Forced-Air Heating System, Extended Exhaust Ductwork

HRV exhausts from the kitchen, bathrooms or other locations to meet basic exhaust needs and supplies outdoor air to the furnace return duct. Manual switch near the HRV control allows the occupant to operate the furnace circulation fan to distribute ventilation air. High-speed HRV operation and/or supplemental exhaust from wet rooms not served by the HRV meet episodic exhaust needs. This prescriptive option cannot be used in houses with non-solid-fuel spillage-susceptible combustion appliances. For wood-burning appliances (i.e., solid-fuel), this system is permitted, provided a CO alarm is also installed.

Results and Discussions

1. Builder and Installer Interviews

Builders and ventilation system installers were informally interviewed regarding the process through which ventilation systems were selected, laid out or designed and commissioned.

As a rule, builders call for quotes for ventilation systems that meet Code. Installers develop a proposed strategy, cost it out, and provide the builder with a quote. Lowest bidder gets the job, so installers focus on meeting the Code at minimum cost. The same process is usually followed where the builder or customer selects an upgraded ventilation system.

1.1 Manitoba and West

In western and northern Canada, the majority of ventilation systems were CMHC/NBC Option 1 systems (outdoor intake coupled to a forced-air furnace return duct). Similarities within a region and differences between regions indicate that once a contractor in a region has developed and received approval for a ventilation system design concept, other installers in that region copy that approach.

In some cases, a builder's request for proposals includes additional instructions such as inclusion of heat recovery ventilation, high-efficiency or direct-vent combustion appliances or extra quiet ventilation fans. The request for system upgrades most often came from the home buyer. In these cases, CMHC/NBC Option 3 type systems (HRV exhausting from wet rooms, supply side coupled to a forced-air furnace return duct) were applied. All study houses from Manitoba and west had forced-air heating systems.

In interviews, western Canada installers indicated that more than 90% of their installations were CMHC/NBC Option 1 systems. The method of selecting test houses did not attempt to sample in proportion to installation frequency, but rather to get a representative sample of each system type. As such, 23% (i.e., 7 out of 31) of the houses tested from Manitoba and west had CMHC/ NBC Option 3 type systems.

CMHC/NBC Option 1 systems were estimated to cost $250 to $600, depending on the house and equipment selected. Installed costs for CMHC/NBC Option 3 (HRV) systems were estimated at $1,500 to $3,000. In all cases, the HRV installed was a builder model (i.e., a basic, modestly priced model).

Most contractors said they spent time doing "formal" designs, including duct layouts on floor plans and calculations regarding fan selection. Some indicated that layout was done on site. Based on site observations, it can be said that the "formal" design process rarely follows the duct sizing tables in 9.32 or duct design methods referenced in Part 6 of the 1995 NBC.

In Alberta, six out of eight contractors said they had installed make-up air systems to offset large volume exhaust devices. Typically, these were a fan with electric preheat, motorized dampers, sensors and interlock relays. Make-up air systems in two study houses took the form of an additional outdoor air duct connected to the furnace return; one had electric preheat. In Manitoba, the depressurization issue had only been addressed by one builder, who installed direct-vent combustion appliances to avoid the possibility of flue gas spillage. One installer estimated the cost to install a make-up air system at $700 including fan, heater, ductwork and controls.

Most installers do not formally commission ventilation systems. Based on the number of deficiencies related to principal exhaust fan controls and switches, it may be concluded that many installers do not even check the operation of the systems they install after the electrician has completed wiring.

In general, contractors felt that Code enforcement officials did not have a clear understanding of the Code; that there were a lot of grey areas; and that Code officials were not willing to accept or endorse a system approach. There were also complaints that different inspectors in an area sometimes had different interpretations of Code requirements.

1.2 Ontario

In Ontario, the mix of ventilation system types varied regionally. Most ventilation systems were CMHC/OBC Option 1 systems (exhaust-only systems with a forced-air furnace, no spillage-susceptible combustion appliances). In the Windsor and Kingston areas, these were reported to comprise well over 90% of installations. In the London and Toronto areas, builders indicated that up to 40% of installations included HRVs, with the balance of the systems being CMHC/OBC Option 1 systems. The survey sample included eight CMHC/OBC Option 1 systems, one CMHC/OBC Option 2 system (i.e., HRV exhausting from wet rooms and supplying outdoor air to the return duct of a forced-air furnace, no spillage-susceptible combustion appliances) and two "almost" CMHC/OBC Option 2 systems. The furnaces and DHW tanks in the "almost" Option 2 systems were vented through a B-vent. As such, the ventilation system design in these houses would fall under Part 6 of the OBC or CSA F326.

CMHC/OBC Option 2 systems were estimated to cost $2,000 to $3,000 more than Option 1 systems. Based on site observations, it can be said that most duct sizing is not done in accordance with Part 6 of the OBC nor does it follow the alternative duct sizing tables presented in Section 9.32 of the 1993 OBC. Ducts for bath fans are sized to match the fan outlet, regardless of duct length or whether smooth of flex duct was used. Similarly, HRV ductwork was sized to match the supply and exhaust ports, with branch ducts being reduced as permitted in 9.32, except that the lengths of ducts and number of fittings would often greatly exceed the limits in the tables.

1.3 Atlantic Canada

In Atlantic Canada, the cost of energy makes heat recovery ventilation attractive. As a result, HRVs have significant market penetration. All study test houses in Atlantic Canada had HRVs. One was a passive HRV in a CMHC/NBC Option 3 system (HRV coupled to a forced-air heating system), the other six were CMHC/NBC Option 6 systems (fully ducted HRV). The passive HRV was a heat exchange core which relied on pressures in the furnace supply and return air ductwork for air exchange. The exhaust inlet to the HRV was connected to the furnace supply air duct; the supply outlet was connected to the furnace return air duct. This configuration does not comply with many requirements set out in the 1995 NBC for residential ventilation systems and had an airflow of less than 25% of the total ventilation capacity for the house.

Duct system layouts did not conform to the sizing tables in the NBC, nor would they comply with the HRAI ventilation manual duct sizing procedure. Despite the fact that the ducts appeared to be undersized or longer than sizing tables would permit, the total ventilation capacity of five of the CMHC/NBC Option 6 systems met or exceeded the target airflows for the house and the other was within 90% of target airflows.

2. Field Tests

2.1 House Depressurization and Vented Combustion Appliances

The most significant problem found in study houses relates to the risk that exhaust devices installed in study houses were capable of depressurizing houses enough to cause flue gas spillage from vented combustion appliances.

Section 9.32 in the 1995 National Building Code includes requirements regarding protection against excessive depressurization of the house if soil gas is deemed to be a problem or if spillage-susceptible combustion appliances are present. Protection against depressurization takes the form of requiring that make-up air be provided to reduce net exhaust from any installed device to less than 75 L/s.

Section 9.33 of the 1995 NBC references CAN/CGA-B149.1-M95, *Natural Gas Installation Code*, and CAN/CGA-B149.2-M95, *Propane Installation Code*, which state in their respective clause 7.6.1, "When it is determined that the operation of another ***appliance*** or other ***equipment***, including an exhaust fan, ***air supply*** fan, or circulating fan adversely affects the venting, combustion, or burning characteristics of a gas ***appliance***, either the condition shall be corrected, or the fuel supply to the affected ***appliance*** shall be discontinued." Appendix B states that vent sizing tables for appliances connected to spillage-susceptible flues "cannot be used for mechanically ventilated systems that allow more than 5 Pa depressurization nor can spillage-susceptible appliances be installed in this type of environment".

The actual level of depressurization which occurs in a house will depend on house airtightness and net exhaust flow rates. Table 2 summarizes the range of exhaust airflows measured for the various exhaust appliances installed in the study houses. Of the installed exhaust appliances, only one dryer and one range fan had a net exhaust flow rate exceeding 75 L/s, although most rangehoods had a rated exhaust flow rate of 80 to 85 L/s (170 to 180 cfm). As such, it appears that make-up air would rarely be required to meet the "as-installed" exhaust flows under section 9.32 in the 1995 NBC.

Table 2

Exhaust Airflows from Study Houses (L/s)

	Smallest	Average	Largest	NBC or Default
Rangehoods and Range Fans	13	42	159	50
Bath Fans	7	20	35	25
Clothes Dryers	37	55	85	75
NBC Option 1 PE System (net, low)	0	9	43	
(net, high)	20	37	76	
Vented Central Vacuum		32		

Table 3 lists the airtightness characteristics of the study houses, the exhaust airflow rate that is predicted to result in 5 Pa depressurization of these houses, and the predicted level of depressurization that would result by operating various installed exhaust devices in the study houses. Actual depressurization tests were done on some study houses, but because they require calm winds, could not be performed on many study houses. In houses without a clothes dryer installed, the blower door was used to simulate a clothes dryer.

As the level of depressurization in a house increases, the airflow of exhaust fans will drop. At 5 Pa of house depressurization, the impact on most installed fans is expected to be small, but at depressurization levels of 10 Pa or more, the airflow of low performance fans (e.g., bath fans or rangehoods) will drop markedly. As such, predicted levels of depressurization based on individual fan airflows and house airtightness characteristics often overstate the actual depressurization levels which occur when operating the specified exhaust appliances.

Thirty-one of the thirty-eight NBC study houses were predicted to be depressurized by at least 5 Pa by operating the dryer, rangehood and principal exhaust system; all but one were predicted to be depressurized by at least 5 Pa by operating all installed exhaust devices. The exception had a balanced ventilation system, no supplemental exhausts; a clothes dryer with modest exhaust flow rate was the only installed device with a net exhaust airflow.

Seven of the eleven OBC study houses were predicted to be depressurized by at least 5 Pa by operating the dryer and rangehood; eight were predicted to be depressurized by at least 5 Pa by operating all installed exhaust devices. The exceptions included both houses with B-vented appliances; these houses had modest exhaust flow rates and were not very airtight. In one, the backdraft damper in the rangehood did not operate. Had the damper opened, it is probable that operating all exhausts would depressurize this house to more than 5 Pa.

The data collected on house airtightness and exhaust device airflow rates is generic; any rangehood could be matched to any house (airtightness) along with any ventilation system and any dryer and any central vac, etc. Thus, operation of a combination of commonly installed exhaust appliances in houses (e.g., bath fans, rangehoods, principal exhaust fans, clothes dryers, externally vented central vacs) could cause depressurization in excess of 5 Pa in any of the study houses.

Table 3

House Depressurization Data and Predicted Depressurization Levels

House	5 Pa Limit?	Airtightness Coefficients C	n	Q5 (L/s)	Predicted Impact of Operating PE, Dryer and Rangehood Airflow (L/s)	dP (Pa)	All Installed Exhausts Airflow (L/s)	dP (Pa)	Notes
MB01	Y	25.18	0.679	75	166	16	192	20	
MB02	Y	43.14	0.644	122	134	5.8	168	8.3	1
MB03	Y	25.04	0.670	74	149	14	166	17	
MB04	Y	30.51	0.643	86	118	8.2	156	13	
MB05	N	15.59	0.669	46	95	15	95	15	3
MB10	Y	16.54	0.686	50	127	20	159	27	
MB11	Y	31.50	0.662	91	143	9.8	150	11	
MB12	Y	34.63	0.642	97	147	9.5	201	15	1
MB13	Y	26.13	0.69	79	98	6.8	124	9.6	
MB14	N	26.12	0.65	74	127	11	127	11	
MB15	Y	56.05	0.646	158	195	6.9	195	6.9	2, 3
MB16	Y	40.35	0.682	121	165	7.9	191	9.8	1
MB17	N	70.48	0.596	184	239	7.8	239	7.8	1
NB20	N	22.30	0.719	71	75	5.4	75	5.4	
NB21	N	22.60	0.686	68	42	2.5	42	2.5	
NS22	Y	27.96	0.667	82	57	2.9	63	3.4	
NS23	N	18.48	0.741	61	106	11	168	20	
NS24	N	27.76	0.748	93	75	3.8	134	8.2	3
PEI25	N	30.01	0.587	77	75	4.8	123	11	
NB26	N	16.76	0.735	55	79	8.2	88	9.5	
Ca40	Y	42.17	0.795	151	125	3.9	180	6.2	
Ca41	Y	27.79	0.708	87	146	10	217	18	
Ca42	Y	75.15	0.606	199	130	2.5	200	5.0	
Ca43	Y	47.28	0.673	140	135	4.8	198	8.4	
Ca44	Y	34.74	0.595	91	134	9.7	179	15	
Ca45	Y	22.22	0.683	67	95	8.4	97	8.7	
Ca46	Y	34.08	0.645	96	124	7.4	158	11	
RD47	Y	29.12	0.714	92					3
Ed48	Y	38.28	0.667	112	89	3.5	169	9.3	
Ed49	Y	28.27	0.733	92	108	6.2	153	10	
Ed50	Y	37.21	0.637	104					3
Ed51	Y	26.51	0.585	68					3
Sk60	Y	7.49	0.589	19	122	114	122	114	
Sk61	Y	5.05	0.689	15	158	148	158	148	
Sk62	Y	11.04	0.693	34	112	28	112	28	1
Sk63	Y	10.64	0.711	33	120	30	120	30	1
YK30	N	26.01	0.597	68	136	16	204	32	
Yk31	N	16.12	0.670	47	74	9.7	91	13	
OBC101	N	32.86	0.692	100	155	9.4	213	15	
OBC102	N	44.41	0.564	110	143	8.0	167	11	
OBC103	N	49.02	0.573	123					
OBC104	N	73.64	0.576	186	161	3.9	200	5.7	
OBC105	N	45.54	0.617	123	191	10	209	12	
OBC106	N	48.44	0.677	144	129	4.2	129	4.2	
OBC107	Y	83.16	0.620	226	115	1.7	115	1.7	
OBC108	Y	44.99	0.704	140	94	2.8	94	2.8	3
OBC109	N	49.99	0.593	130	155	6.7	193	9.8	
OBC110	N	23.49	0.691	71	113	9.7	147	14	3
OBC111	N	31.28	0.707	98	143	8.6	164	11	

Notes: 1. Stucco not yet installed.
2. Building paper and stucco not yet installed.
3. Kitchen fan not yet installed or not functional.

Most test houses in western Canada had mid-efficiency furnaces and natural draft hot water tanks vented into a B-vent. Operating installed exhaust devices could bring any of these houses into violation of the CAN/CGA-B149 depressurization limit of 5 Pa for B-vents. Compliance with 9.32.3.8, "Protection Against Depressurization", in the 1995 NBC, does not, in any way, ensure compliance with Gas Code restrictions regarding house depressurization, particularly if spillage-susceptible combustion appliances are present. Those responsible for enforcing Gas Appliance Installation Codes have not been enforcing those Code requirements related to depressurization.

There were two oil-fired heating systems in the Atlantic Canada house sample. One was a forced-air system, the other was a hot water boiler system. Both were power vented with sidewall venting. During house depressurization tests, both systems were able to establish and maintain positive venting of flue products with the house depressurized to 50 Pa.

It is our understanding that Codes relating to solid-fuel and oil-fired combustion appliances do not identify specific depressurization limits. Combustion products from oil and solid-fuel combustion appliances are considered to be at least as hazardous to human health as combustion products from gas-fired combustion appliances, so the combustion product spillage issue should be addressed in Codes for solid- and liquid-fuel appliances.

Three approaches were identified to meet depressurization restrictions in Gas Codes. These are:

- reduce net exhaust flows by providing make-up air, thus reducing or eliminating house depressurization;
- avoid the need to meet depressurization limits by not installing spillage-susceptible combustion appliances, and;
- increase leakage area of the house by installing passive make-up air inlets.

CSA F326 permits the use of passive make-up air inlets, but few consider them to be a practical option in cold climates. The cost and complexities encountered by attempting to provide make-up air within the constraints of 9.32 are sufficiently great to make the option of not installing spillage-susceptible combustion appliances attractive. The authors of the 1993 OBC residential ventilation requirements elected to only allow spillage-susceptible combustion appliances in houses with ventilation systems designed under Part 6 of the OBC or to CSA F326, and not allow spillage-susceptible combustion appliances to be installed in houses using the prescriptive approach for ventilation system design.

Balanced ventilation systems (i.e., HRVs) alone do not eliminate the depressurization issue, because clothes dryers and central vacuum systems, which are not intended for ventilation, can depressurize the house. Four study houses were predicted to reach or exceed 5 Pa depressurization by operating the clothes dryer with the smallest exhaust flow in the study (i.e., 37 L/s). The largest clothes dryer in the study (i.e., 85 L/s) was predicted to depressurize over half the study houses by at least 5 Pa. The largest installed kitchen fan in the study (i.e., 159 L/s) was predicted to depressurize over 90% of the study houses by at least 5 Pa.

Depressurization was predicted using measured exhaust airflows and CGSB airtightness test results. This approach will tend to overpredict depressurization levels because house depressurization will decrease exhaust from low performance fans and increase airflow through air intakes which were sealed during the CGSB test. It is the writer's opinion that these offsetting flows would only result in a few of the study houses being wrongly "failed" on the 5 Pa depressurization criteria. As such, make-up air should be considered for all new houses with spillage-susceptible combustion appliances.

2.2 Depressurization and Soil Gas

The Section 9.32 requirements regarding protection against excessive depressurization for spillage-susceptible combustion appliances also apply if soil gas is deemed to be a problem. Protection against depressurization takes the form of requiring that make-up air be provided to reduce net exhaust from any installed device to less than 75 L/s. There has been some debate as to whether a passive soil gas mitigation system comprising of a polyethylene membrane under the basement slab or crawlspace floor and slab perimeter sealing eliminates the need to provide make-up air for large exhaust devices in areas that soil gas is deemed to be a problem. This needs to be resolved.

2.3 Fireplaces, Solid-Fuel Burning Appliances and Power-Vented Combustion Appliances

Only one study house had a solid-fuel burning appliance installed. As such, commentary cannot be passed on whether the requirements in 9.32 pertaining to solid-fuel combustion appliances are being properly or uniformly applied.

Twenty-nine of the forty-nine study houses included vented, decorative, non-solid-fuel combustion appliances. All were "airtight" or direct-vent gas or propane-fuelled fireplaces. The writer is uncertain as to whether or not direct-vent, "sealed" gas fireplaces are classified as spillage-susceptible from the perspective of applicable Codes. This needs to be clarified.

All but three NBC houses with gas heating had fan-assisted furnaces. Fan-assisted furnaces were usually vented through a B-vent. The exceptions had direct-vent furnaces and power-vented or electric DHW tanks. On the other hand, all but two of the OBC houses had direct-vent furnaces and power-vented DHW tanks. The two OBC exceptions had fan-assisted furnaces and natural draft DHW tanks connected to B-vents.

Two NBC study houses had power-vented oil furnaces which may be considered to be spillage-resistant. The resistance of power-vented and fan-assisted combustion appliances to depressurization-induced spillage should be evaluated to determine their suitability for use as a solution to the depressurization-induced spillage problem discussed above.

2.4 Return Air Temperature and Furnace Heat Exchanger Corrosion

In the past, there has been a concern voiced that cold return air passing over a furnace heat exchanger will result in condensation on the combustion side of the heat exchanger during furnace warm-up, accelerating corrosion and failure of the heat exchanger. Section 9.33 in the NBC requires that heating equipments, including furnaces, be installed according to manufacturers' instructions, which typically contain restrictions regarding minimum allowable return air temperatures.

To address this concern, 1995 NBC subsection 9.32.3.6 requires that cold (outdoor) air introduced into a forced-air heating system be mixed with house air before passing over the furnace heat exchanger. Prescriptive methods of compliance for ventilation air mixing are presented in the Code. In colder climates and when house temperatures are less than 18°C, compliance with these prescriptive methods may not sufficiently temper return air to meet the intent of the Code or to comply with furnace manufacturer return air temperature restrictions.

It was intended that temperature profiles be measured in return air ducts downstream of outdoor air intakes during cold weather house tests. Such profiles may have provided insight into the degree of mixing, or temperature stratification in return ducts. However, mild winter temperatures limited the amount of useful data collected in this regard.

Return air duct temperature profiles were recorded in twenty-two study houses. The data indicated that temperature variations across the return air ducts are not extreme. The biggest temperature variation measured in the twenty-two houses was 4°C, at an outdoor air temperature of -7°C and a house temperature of 25°C. The temperature at the warmest point in the return air duct was equal to the temperature of return from the house.

A theoretical calculation was done to estimate the "worst case" impact of outdoor air on return air entering a furnace heat exchanger at winter design condition temperatures for houses with CMHC/NBC Option 1 systems. The temperature was calculated for the amount of air being returned from the house (based on pitot traverse measurements) mixed with the amount of air measured in the outdoor air intake. A temperature of 18°C was used for return air from the house; two outdoor air temperatures were used, the 2½% January design temperature and an extreme outdoor temperature. The same calculations were repeated using the target outdoor air supply airflow for the house.

Based on these calculations and observations based on field test data, it is expected that average furnace return air temperatures in many houses with CMHC/NBC Option 1 ventilation systems may occasionally fall below 15.5°C, and, on rare occasions, may fall to mean air temperatures below 12°C. Variation from this mean, across the duct, may result in local return air temperatures below 10°C during cold weather in some CMHC/NBC Option 1 or Option 2 installations, especially if house temperatures are setback a significant amount.

Data was obtained from some furnace manufacturers regarding this concern. Return air temperature restrictions varied, some specify minimum return air temperatures of 50°F (10°C), others specify 60 to 65°F (15.5 to 18.3°C), while one manufacture's literature specified a 60°F minimum with an allowable setback temperature of 55°F (12.8°C).

2.5 Regional Differences in Systems Applied

There were regional differences in the types of ventilation systems installed. In the Atlantic region, all test houses had HRVs, and fully ducted systems predominated. On the prairies, CMHC/NBC Option 1 systems (exhaust fans and unpowered outdoor air intake to the furnace return) were the norm. In Manitoba and Saskatchewan, it was common for the principal exhaust fan to be a central fan serving the bathrooms, with a separately ducted rangehood exhausting the kitchen. In Manitoba, the central exhaust fan was usually intended for two-speed operation. In other regions, it was usually set for single-speed operation. In Alberta, it was common for the principal exhaust fan to draw exhaust from the furnace return or one bathroom, with supplemental exhaust in each other bathroom and the kitchen. In Ontario, CMHC/OBC Option 1 systems (exhaust-only) appear to predominate, with CMHC/OBC Option 2 systems (HRV exhausting from wet rooms, supply side coupled to a forced-air furnace return duct, no spillage-susceptible combustion appliances) or CSA F326 systems, similar to CMHC/OBC Option 2 systems, having significant representation in some market areas.

2.6 Coordination of Principal Exhaust Fan and Furnace Operation

The NBC requires that the furnace circulation fan operate whenever the principal exhaust (PE) fan operates if ventilation air is distributed by a forced-air heating system. This requirement was not successfully met in many cases. Situations encountered included:

- wiring errors (e.g., both leads to the PE fan connected to neutral);
- furnace fan relay located down line from the principal exhaust fan speed control (two-speed PE fan). When the PE fan operates on low speed, voltage is not sufficient to trip the relay;
- poor communication between the ventilation system installer (responsible for developing the control strategy) and the electrician (responsible for the wiring to implement the strategy) results in wiring not done correctly;
- hose between a pressure switch and the principal exhaust fan ductwork used to initiate furnace fan operation was not properly connected;
- furnace fan is operated continuously rather than controlled by the principal exhaust fan;
- furnace fan operates when the principal exhaust fan is switched from some locations, but not from others;
- where the principal exhaust fan meets both the minimum principal exhaust fan capacity requirements and the total ventilation system capacity requirements, furnace fan operates when the principal exhaust fan operates on low (i.e., principal exhaust) speed, but not when the principal exhaust fan operates on high (total ventilation system capacity) speed.

The OBC has avoided these control coordination problems by specifying separate controls for the principal exhaust fan and the furnace circulation fan. In all OBC houses, the furnace circulation fan was controlled from the thermostat by switching the "fan" button from "auto" to "on". The advantage of this approach is that it was executed without problems in the study houses. The disadvantage is that it does not positively link the supply of ventilation air to the house with distribution of ventilation air throughout the house.

2.7 Duct Sizing Rules

The Building Code calls for duct systems to be sized using a detailed design method. In circumstances where the scope of a duct system falls within specific restrictions set out in 9.32, the duct system may be sized following prescriptive duct design tables in 9.32. Based on analysis of the duct systems installed in the study houses, it is concluded that very few installers undertake detailed duct system designs, nor do they apply the prescriptive duct sizing tables in 9.32. Most duct systems did not fall within the scope of the prescriptive duct sizing tables in that duct lengths and the number of elbows exceed the limits of the tables.

Despite this, airflows measured at principal exhaust fans and HRVs met or exceeded minimum capacity requirements in most houses. Although airflows measured at the fan or HRV were in compliance with Code requirements, exhaust draws from specific rooms did not necessarily conform to the NBC-specified target exhaust rates, indicating that leakage into exhaust ducts, upstream of the fan, may be significant.

Of twenty-three study houses with non-powered outdoor air intakes (CMHC/NBC Option 1 systems), only one complied with NBC sizing requirements. Two exceeded the allowable 6 m length restriction, nineteen had undersized diameters and four had more than two elbows. Five had airflows which met or exceeded NBC-specified target flow rates for the house, another three were within 10% of target flow rates. Airflows measured in the fifteen remaining outdoor air intakes averaged 60% of the target flow rate.

The ductwork sizing tables for principal exhaust fans (i.e., NBC Table 9.32.3.4, OBC Table 9.32.3.4.(9)) do not allow for reductions in size for branch ducts. Installers do downsize branch ducts. If prescriptive duct sizing rules are to remain in the Building Code, reduced duct sizing for branch ducts should be considered for inclusion.

2.8 Total Ventilation Capacity and Two-Speed Principal Exhaust Fans

In seven Manitoba houses with CMHC/NBC Option 1 ventilation systems, the principal exhaust fan was also intended to meet the total ventilation capacity. In four of these, the principal exhaust fan did not have sufficient capacity to meet the TVC requirement for the house.

In eighteen study houses with HRVs, the HRV was intended to meet the total ventilation capacity. In five of these (including a house with a passive HRV), high-speed capacity of the HRV was less than 90% of the TVC.

In seven cases where high-speed operation of the principal exhaust fan or HRV alone could not meet TVC requirements, a rangehood or bath fans installed in the house had sufficient capacity that the principal exhaust fan or HRV plus the rangehood or bath fans could meet the TVC requirement. In one of the remaining houses, the backdraft damper in the rangehood was stuck shut. If it had operated correctly, it is expected that total airflow would have been sufficient to meet the TVC requirement. (The rangehood's rated capacity would comply with TVC requirements.) However, no rangehoods in the study met the NBC requirements for sound rating.

2.9 Supplemental Exhaust Rates Less than Code Target Values

Airflows were measured for forty-seven supplemental bathroom fans in the study houses. Supplemental fans in twelve bathrooms exhausted more than 90% of the NBC-specified target exhaust rate of 25 L/s. The exhaust flow rate from the thirty-five bathroom fans which were under 90% of target exhaust rate averaged about 18 L/s. Virtually all supplemental bathroom exhaust fans were standard ceiling-mount fans. On average, as-installed exhaust flow rates of supplemental bath fans were about 75% of their HVI-rated capacities.

The study included thirty-eight kitchen exhaust fans and rangehoods. Exhaust fans and rangehoods in seventeen kitchens exhausted more than 90% of the NBC-specified target exhaust rate of 50 L/s. The exhaust flow rate from rangehoods and fans in kitchens which were under 90% of target exhaust rate averaged 32 L/s (not including four rangehoods in which exhaust was inhibited by improper installation or backdraft damper operation). On average, as-installed exhaust flow rates for all rangehoods were about 56% of their HVI-rated capacities. The most common rangehood, rated at 80 L/s (170 cfm), had an average installed exhaust rate of 45 L/s.

Flow rates for most bath and kitchen exhaust fans were measured at the fan inlet. In situations where exhaust ductwork runs inside the building envelope, duct leakage may result in the amount of air that is actually exhausted from the house being (considerably) less than measured at the exhaust inlet.

2.10 Many Fans Not HVI Certified

Remote-mounted in-line and squirrel-cage fans were commonly applied for principal exhausts in study houses in western Canada. Whereas these are generally considered to be premium quality fans, many were not HVI certified for airflow. Furthermore, HVI does not have a method of test for rating the sound level of remote-mounted fans. As such, these fans did not comply with NBC requirements.

In Calgary, installers worked with the building inspections department to gain approvals to use in-line fans in residential ventilation systems installed to meet the 1995 NBC.

Fans located in unoccupied spaces such as furnace rooms and basements have the same sound rating requirements as fans located in occupied spaces. It may be appropriate for sound ratings to be relaxed for remote fans.

None of the rangehoods in the study houses were within the 3.5 sone maximum sound rating that would allow them to provide part of the total ventilation capacity in either OBC or NBC houses.

2.11 Outdoor Air Connection Details Need Clarification

Acceptable locations for outdoor air supply connections to furnace returns need to be clarified. The appendix to 9.32 in the NBC illustrates approved methods of connecting outdoor air intakes to furnace return air ducts. The return air drop illustrated in the NBC is an S-shaped drop, while return air drops in all study houses had sharp-edged, rectangular, horizontal trunks connecting into rectangular, vertical drops. The outdoor air connection in the illustration enters the wide flat side of the drop, while in the study houses, outdoor air intakes are often connected into the narrow side of the drop.

The NBC calls for the outdoor air connection to be attached downstream of all return branch ducts. In many installations, the furnace return has trunk ducts running in two directions from the return drop. It is common for the outdoor air duct to be connected to one of these trunks. As such, the outdoor air duct may be closer to the furnace than any return branch connection, but further from the drop than the connection of the other return trunk. Does this comply?

The NBC requires that the outdoor air supply connected to a furnace return be downstream of all return branch ducts. This requirement makes sense for outdoor air ducts which rely on suction from the furnace fan to draw in supply air. However, it appears to not be necessary if outdoor air is fan supplied. Furthermore, there are arguments against requiring close connections when outdoor air is supplied by a fan (e.g., via an HRV). This NBC requirement should be re-visited.

Sentence 9.32.3.6.(9) states "All connections between the ventilation system and the heating system shall be in accordance with Articles 9.33.4.1. and 9.33.5.2." Article 9.33.4.1 requires that the design on heating and air-conditioning systems comply with local Codes or good practice as described in ASHRAE, HRAI, the Hydronics Institute and SMACNA publications. Article 9.33.5.2. requires that appliance installation comply with Installation Codes such as CAN/CGA-B149.1-M, "Natural Gas Installation Code" and CAN/CGA-B139-M, "Installation Code for Oil Burning Equipment". There is a potential for conflict between specific requirements in 9.32 and the requirements referenced in 9.33. Any such conflict could be avoided, and 9.32 could be simplified by not including ventilation system requirements which are addressed in other sections of the NBC.

The above points are not applicable to OBC houses because outdoor air intakes are not required in any CMHC/OBC system options.

2.12 Exhaust and Inlet Hoods and Screens

Hoods that provide outdoor air to the house are required to be labelled as ventilation air inlets. The purposes of this requirement include alerting trades locating other services (e.g., oil fill pipes, gas meters, dryer exhausts, etc.) and warning occupants not to store pollutants near the ventilation air supply to the house. In most cases, hoods were not labelled.

The NBC requires that the area of screens or grilles in intake and exhaust hoods be three times the duct areas served if the mesh size is less than 6 mm. The OBC requires that the cross-sectional area of grilles and screens in intake and exhaust hoods always be three times the duct area served. These requirements were not usually met. Both Codes require that screens be removable for cleaning if the mesh is less than 6 mm. Based on screen blockages observed during the field investigations and the difficulty experienced in trying to clean the screens, it is recommended that all screens and grilles at the outside wall be three times the duct area and that all screens and grilles be removable for cleaning.

Both Codes require rodent screens in exhaust hoods, if there are no backdraft dampers at the outside wall. Sentence 9.32.3.12.11) specifies mesh size restrictions for these screens. My interpretation of the Code is that if a screen or grille is not required but is installed, it need not comply with these restrictions. This should be corrected.

2.13 Grease Filters in Kitchens

Kitchen exhaust grilles are to be equipped with grease filters, unless the duct serving the grille is accessible for cleaning over its entire length. This requirement was frequently not met. At what distance from a range is a grease filter no longer required? Does or should this requirement change if there is an externally vented rangehood in the kitchen in addition to an exhaust grille on the wall? Is the option of having the duct accessible for cleaning a realistic alternative? What criteria should an inspector apply to determine if a duct is cleanable? These kitchen exhaust system requirements need to be revised and clarified.

2.14 Workmanship

Workmanship on the heating and ventilation systems in many of the houses had the appearance of being completed by the low bidder. Often, system layout appeared to be done on site and "as you go" without planning. Many duct layouts were far more convoluted than necessary.

There were several non-compliant ventilation system details in most study houses. These included hoods and controls not properly labelled, controls which didn't function as required (NBC houses only), undersized intake and exhaust hoods, undersized or not to Code ducts, out-of-spec connections of outdoor air intakes to furnace returns (NBC houses only), crushed sections of flex duct, etc.

In two study houses, the installer had failed to remove the knockout between the rangehood and exhaust duct (knockouts allow the installer to select vertical or horizontal discharge). In three others, a backdraft damper was stuck shut. In another, the ductwork to vent the rangehood had not been installed.

The fact that most houses had a number of notable non-compliant details indicates that the installers are not knowledgeable of the ventilation system requirements in their respective Building Codes or aren't taking the time to ensure that the systems they install are compliant or are ignoring requirements which are not enforced. There is knowledge of general requirements to: supply and distribute ventilation air; exhaust all wet rooms; provide make-up air for large exhaust devices (NBC houses only), and; provide occupants with the means to control ventilation. There does not appear to be an awareness of duct system design requirements, the specifics of Code compliant controls (NBC houses only), when make-up air systems are needed (NBC houses only) or when combustion spillage may occur.

The builder often assigns an area in the basement of a new house for the installation of heating and ventilation equipment. In many cases, the location assigned is such that compliance with prescriptive duct sizing rules in the NBC are not possible, and the space allotted complicates the system layout. Allowing installers some flexibility in placing mechanical equipment in houses could result in "cleaner" system layouts. More comprehensive duct sizing tables would make it possible for more duct configurations to fit into the prescriptive duct sizing criteria. However, given that prescriptive duct sizing tables weren't followed in most cases, this may be a moot point.

Most of the installers interviewed had attended training or seminars on the ventilation system requirements in their respective Building Codes. This included HRAI training courses, the NRC seminars on Section 9.32 of the 1995 NBC and presentations at local trades association meetings. Whereas most of the installers being interviewed indicated they had formal training related to residential ventilation requirements, conversations with installers encountered on site, doing installations, indicated that many of them had not attended training or seminars.

Some installations were well executed, but in general, the installations indicated that those working in the field did not have a full understanding of Code requirements or the need for the requirements. It may be desirable to require that the operation and performance of residential ventilation systems be certified by a qualified person, and to be considered to be qualified, one must have attended an accredited residential ventilation trades training course and passed a course exam.

3. Demonstration of Effective Ventilation Systems

The ventilation systems being applied in new NBC houses were almost exclusively NBC/CMHC Option 1, 3 or 6 type systems. Key elements and characteristics of these systems are described in Table 1, in "Methodology" Section 3 "Demonstration of Effective Ventilation Systems". In an effort to see whether compliant houses could be built, the lessons learned in the field study were incorporated into the design and construction of an example of each of these system types.

The principal change from common practice was that no chimney-vented combustion appliances were installed in the test houses, eliminating the need to address house depressurization. The demonstration houses were field tested to confirm their performance.

The common options for avoiding chimney-vented combustion appliances include electric space and DHW heating, direct-vent furnaces with electric or power-vented DHW systems, and combo systems which use power-vented water heaters or direct-vent boilers to provide both space heating and DHW. Combo systems provide space heat using fan coils in a forced-air system and/or radiant heating and/or hot water baseboard heat. The relative cost of electricity makes fuel-fired space heating economically attractive in most markets. The high cost of power-vented domestic hot water tanks can make electric DHW tanks attractive to some consumers while the slow recovery time of electric DHW tanks makes them an unacceptable alternative to others.

Using a direct-vent furnace increases heating system installation costs but avoids the need to consider make-up air systems that cost $700 or more. The net energy cost impact of using a direct-vent furnace and electric hot water tank versus a mid-efficiency furnace and conventional hot water tank will depend on occupant lifestyle, but overall it is expected that the decrease in energy costs for space heating will more or less offset the increased DHW energy costs. Using a direct-vent furnace and power-vented hot water tank will have higher installed costs but lower energy costs in most markets.

Systems using power-vented DHW tanks for space heating will have generally higher space heating energy costs than would be the case using mid- or high-efficiency furnaces. Direct-vent boilers used in combo systems generally cannot achieve operating efficiencies much above 80%, even if they are rated at higher efficiencies. In order to achieve higher efficiencies, flue gas temperatures must be cooled below their dewpoint (about 55°C), so boiler fluid temperatures must be even cooler. Flue gas exit temperatures are generally limited by practical limitations in boiler and heating system design. The energy cost impact of using a direct-vent boiler combo system for space and domestic water heating will depend on occupant lifestyle, but is expected to result in slightly lower energy costs in most markets, compared to using a direct-vent furnace and power-vented hot water tank.

3.1 CMHC Option 1

Initial arrangements made with a builder for a house to demonstrate the CMHC Option 1 System were not successful in demonstrating good practice. It did effectively highlight some of the challenges that must be overcome before ventilation systems will meet Code. The builder was eager to participate in the project. The installing contractor voiced enthusiasm for the project, but at an initial meeting, said he required compensation for his time and the increased cost associated with the proposed design. An offer was made to pay him to evaluate two or three variations of the proposed design. The NBC called for a 175 mm (7 inch) outdoor air intake for the house being considered. The builder said "Nobody installs a 7 inch. This house would get a 5 inch." "But the Code calls for 7 inch!" " I can't afford to do it until my competition does it. I'm not going to pay for that." The design variation evaluations did not materialize and the installer did not return calls until the builder followed up on the project. A new variant of ventilation system, which did not reflect many NBC requirements or our discussions, had been installed.

A second attempt was more successful. The installer selected to demonstrate a CMHC Option 1 System had volunteered to participate in the project. The energy systems in the demonstration house included a direct-vent furnace and an electric DHW tank. The exhaust system ductwork was designed using the equivalent length method. The outdoor air intake was sized following the prescriptive tables in 9.32.

A two-speed, central exhaust fan serving the bathrooms met both the principal exhaust and total ventilation capacity (TVC) airflow requirements. The central exhaust fan installed in the house had a higher than desired airflow rate at its minimum (principal exhaust) speed (i.e., installed capacity of 44 L/s versus a target of 27.5 L/s). This over-capacity was attributed to the fact that the fan specified for this installation was out of stock at the time of the installation, so a larger capacity fan was used. Installation of a balance damper in the exhaust duct would allow exhaust airflow to be reduced to the target principal exhaust airflow rate. The fan was not sound rated by HVI, so does not fully comply with NBC requirements.

A dehumidistat, with "on" and "off" positions, located beside the thermostat labelled "Central Ventilation Switch", operated the central fan at its lower speed setting (i.e., the principal exhaust fan speed), allowing the occupant to operate the central fan manually (i.e., "on" or "off") or automatically (i.e., by setting it in the dehumidistat operating range). Timer switches in each bathroom operated the central fan at high speed or TVC. A pressure switch in the principal exhaust fan inlet turns on the furnace fan when it senses suction. The installer favours this method because it separates the furnace fan wiring from the principal exhaust fan wiring.

Outdoor air supply was provided by a fresh air intake connected to the furnace return. The 150 mm (6 inch) flex duct used for the outdoor air supply duct was sized according to Sentence 9.32.3.6.(4) and Table 9.32.3.6.A in the NBC and connected to the return air drop. Unadjusted, the maximum airflow in the outdoor air duct was 44 L/s. As such, it exceeded the target flow rate and could be adjusted downward with the balance damper or left as is to provide balanced airflow with the principal exhaust fan.

A rangehood provided supplemental kitchen exhaust. As is typical of similar rangehoods, the installed rangehood was rated at 80 L/s and had an "as-installed" exhaust airflow rate of 47 L/s (100 cfm).

The furnace installation manual states "the mixed air temperature across the heat exchanger MUST not fall below 60°F (15°C)". At the target airflow rate (i.e., 27.5 L/s), estimates indicated that average mixed air temperatures entering the furnace heat exchanger will not fall below 15°C at the 2½% January temperature (i.e., -33°C) unless house return air temperatures are below 17.5°C. At 44 L/s (i.e., the unadjusted airflow measured in the outdoor air duct), average mixed air temperatures will not fall below 15°C at the 2½% January temperature unless return air temperatures fall below 19°C. A 1°C drop in house temperature is predicted to reduce average mixed air temperatures by almost 1°C.

A number of strategies could be implemented to avoid low mixed air temperatures or reduce the amount of time at which mixed air temperatures are below the manufacturer's stated limit. These include:

- conditioning outdoor air before it enters the return air duct (e.g., using a HRV or an electric heating coil to preheat outdoor air);
- reducing outdoor air intake airflows to the minimum allowed;
- installing an automatic damper in the outdoor air intake duct to limit airflow to those times when the principal exhaust fan is operated (as opposed to whenever the furnace circulation fan is operated);
- maintaining house temperatures above the critical temperature, especially during very cold weather, and;

- introducing outdoor air into the house via another route (e.g., adopting the OBC approach of ventilation by infiltration).

3.2 CMHC Option 3

The energy systems in the Option 3 demonstration house included a direct-vent furnace, an electric DHW tank and a direct-vent gas fireplace.

An HRV, which meets both principal exhaust and total ventilation capacity (TVC) airflow requirements, draws exhaust from the bathrooms and supplies outdoor air to the furnace return. A downdraft range fan provides supplemental kitchen exhaust. The HRV ductwork was designed using the equivalent length method.

The HRV installed in the house had a higher than desired airflow rate at its minimum (principal exhaust) speed (i.e., 45 L/s supply and 49 L/s exhaust versus a target of 37.5 L/s). Maximum high-speed airflow rates were 85 L/s supply and 75 L/s exhaust versus a target airflow rate of 75 L/s. The performance of the HRV was such that it could not be balanced at both low- and high-speed operation. Near balance was selected for low-speed operation, where it is expected the HRV will operate most of the time. As the house was very humid at the time of inspection, a decision was made not to reduce low-speed airflows because this would also reduce high-speed airflows.

The HRV can be set for either "on/off" or continuous operation at either low or high speed at the central HRV control located in the main floor hall, beside the thermostat. Manual switches in each bathroom and a dehumidistat built into the central HRV control can turn the HRV to high speed, regardless of the operating mode selected. The HRV and furnace were interconnected; whenever the HRV operates, it turns on the furnace circulation fan.

A downdraft exhaust, integral with the gas range, provided supplemental kitchen exhaust, but did not bear an HVI certification sticker, indicating its performance was not certified as required in the NBC. However, the measured exhaust airflow was 123 L/s, well in excess of the minimum required 50 L/s.

The furnace installation manual states the furnace is "designed for a minimum continuous return air temperature of 60°F or intermittent operation down to 55°F such as when used with a night setback thermostat." Estimates indicated that average mixed air temperatures entering the furnace heat exchanger should not be less than 55°F (i.e., 12.8°C) at the 2½% January temperature (i.e., -33°C) unless house return air temperatures fall below 15.5°C, with the HRV operating on high speed; or below 60°F (i.e., 15.6°C) unless return air temperatures are below 18.3°C. With the HRV operating on low speed at the 2½% January temperature, mixed air temperatures should not fall below 60°F unless return air temperatures fall below 17.2°C; or below 55°F unless return air temperatures fall below 14.3°C. A 1°C drop in return air temperature will cause almost a 1°C mixed air temperature drop.

The furnace selected for this house and the HRV have the combined effect of greatly reducing the likelihood that mixed air temperatures entering the furnace will violate the manufacturer's stated temperature limits.

3.3 CMHC Option 6

In the Option 6 demonstration house, space heat was provided by a hydronic, in-floor radiant heating system. Domestic hot water was indirectly heated by the same direct-vent boiler. The house had an airtight gas fireplace in the family room.

An HRV which meets both principal exhaust and total ventilation capacity (TVC) airflow requirements, draws exhaust from the bathrooms and supplies outdoor air directly to each bedroom and the main living area on the main floor. A rangehood provides supplemental kitchen exhaust. Warm side HRV ductwork was sized using the equivalent length method. Cold side HRV ducts were sized to match the diameter of the cold side ports on the HRV, although the design called for ducts two sizes larger.

The HRV can be set for either "on/off" or continuous operation (at one of four fan speeds), selected at the HRV. Touch pad timer switches in each bathroom can be used to increase the HRV speed setting, regardless of the operating mode selected. A dehumidistat in the central hall on the main floor can be used as a manual switch or set to automatically operate the HRV at its high-speed setting, overriding the other switches.

On low speed, the HRV installed in the house closely met the desired principal exhaust airflow rate (i.e., 38 L/s supply and 36 L/s exhaust versus a target of 37.5 L/s) without damper adjustment. Maximum high-speed airflow rates were 58 L/s supply and 56 L/s exhaust versus a target airflow rate of 75 L/s. Although the cold side ducts were undersized, the HRV specifications indicate that it should have had adequate high-speed airflow capacity to meet the TVC.

The installed rangehood was rated at 85 L/s and had an "as-installed" exhaust airflow rate of less than 47 L/s (100 cfm). The rangehood was sound rated at 4.5 sones. Currently, HVI is rating some rangehood products for sound at both low and high speed. If the rangehood in this house were sound rated at low speed, it would likely have a sone rating of less than 3.5 and an airflow rate of more than 20 L/s. In such a case, this house would have been in compliance with the TVC requirements in the 1995 NBC.

Conclusions and Recommendations

1. Depressurization and Vented Combustion Appliances

The most significant problem found in study houses was the risk that depressurization by exhaust devices can cause flue gas spillage from vented combustion appliances.

The study clearly showed that compliance with 9.32.3.8, "Protection Against Depressurization", in the 1995 NBC, does not, in any way, ensure compliance with the B149 Gas Appliance Installation Codes requirements which limit depressurization of spillage-susceptible gas appliances to 5 Pa, and this B149 requirement is not being enforced.

Codes relating to solid-fuel and oil-fired combustion appliances do not identify specific depressurization limits. Given that combustion products from oil and solid-fuel combustion appliances can be at least as hazardous to human health as combustion products from gas-fired combustion appliances, Code-specified depressurization limits for all spillage-susceptible combustion appliances should be developed.

Of the available methods of addressing the issue of depressurization with respect to combustion appliances, the option of not installing spillage-susceptible combustion appliances was considered to be the most attractive option for most applications. The passive make-up air inlets permitted by CSA F326 are not considered to be a practical option in cold climates. Make-up air systems are complex and costly.

Requiring balanced ventilation does not avoid the depressurization issue, because clothes dryers and outside exhausted central vacuum systems, which are not part of the ventilation system, can depressurize the house. Operating the clothes dryer with the highest exhaust flow in the study was predicted to depressurize over half the study houses by at least 5 Pa; the kitchen exhaust with the highest exhaust flow was predicted to depressurize over 90% of the study houses by at least 5 Pa. This clearly demonstrates that exhaust devices which are not intended for ventilation or which are often installed after occupancy, and do not require inspection or testing, can significantly depressurize houses.

It is recommended that, except as permitted for solid-fuel appliances in Sentences 9.32.3.8.1) and 9), houses in which spillage-susceptible combustion appliances are installed be required to meet the requirements in CSA F326.

There is uncertainty as to whether or not direct-vent, "sealed" gas fireplaces are classified as spillage-susceptible or spillage-resistant. Section 9.32 in the OBC clearly places them in the same category as other direct-vent appliances. However, because of loose construction tolerances, they may be spillage-susceptible at modest levels of house depressurization. Gas fireplaces are usually "tuned" to give a red or orange flame, which significantly increases carbon monoxide production, and thus health risk in the event that spillage does occur.

2. Depressurization and Soil Gas

The Section 9.32 requirements deal with protection against excessive depressurization for houses in which soil gas is deemed to be a problem, unless a soil gas mitigation system is installed. There are mixed interpretations of the NBC requirements relating to soil gas mitigation systems. Specifically, if soil gas is deemed to be a problem, does complying with the passive soil gas mitigation system strategies identified in the NBC eliminate the need to provide make-up air for large exhaust devices? This needs to be clarified.

3. Furnace Return Air Temperatures

Low return air temperatures can cause condensation and corrosion on the fire side of furnace heat exchangers, causing premature failure of the heat exchanger. For this reason, furnace manufactures specify minimum allowable return air temperatures. Some manufacturers specify minimum return air temperatures of 50°F (10°C), others specify 60 to 65°F (15.5 to 18.3°C), while at least one specified 60°F with an allowable setback temperature of 55°F (12.8°C).

The temperature of air entering a furnace varies with outdoor temperature, return air temperature and the ratio of outdoor air to return air. In NBC houses, typically the mixed air temperature will move away from the return air temperature by 5% to 12% of the temperature difference between the outdoor air supply and the return air. Cold outdoor air and cool house temperatures can result in mixed air temperatures below 15°C and occasionally below 12°C.

It is recommended that unpowered outdoor air intakes be equipped with automatic dampers which only open on demand for ventilation. This will prevent over-ventilation and will reduce the amount of time that the risk of condensation in furnace heat exchangers exists by limiting the introduction of outdoor air into the furnace return to those periods during which the principal exhaust fan is operated.

4. Fans, Airflow Requirements and Duct Sizing

Most HRVs and central exhaust fans met the ventilation flow rates specified in the NBC, although duct sizes were generally smaller than those derived from applying the effective length method. In most houses, HRV and central fan supply and exhaust airflows measured at room grilles were substantially less than those measured at the fans or HRV. This implies that duct leakage can be significant and that better duct air-sealing methods may be warranted.

Most duct systems fell outside the prescriptive duct sizing tables in the NBC. Where duct systems were within the scope of the prescriptive duct sizing tables in 9.32, the tables were rarely applied. A more comprehensive and flexible prescriptive duct sizing method would fit more duct configurations into the prescriptive duct sizing criteria. However, given that prescriptive duct sizing tables weren't followed in most cases, this may be a moot point. As an alternative to sizing ducts, installers should be allowed to prove compliance by measuring airflows and showing that they comply with target airflows.

Duct sizing tables do not allow for reductions in size for branch ducts. Installers do downsize branch ducts. The prescriptive duct sizing rules should be modified to allow reduced duct sizing for branch ducts.

5. Unpowered Outdoor Air Intakes

Undersized ducts and inappropriate connections to the furnace return for the outdoor air intakes without auxiliary supply fans resulted in deficient supply airflows for most CMHC/ NBC Option 1 systems. Airflows through outdoor air intakes are highly unpredictable and application-specific. Airflow in undersized outdoor intake ducts can significantly exceed target airflows, while airflow in apparently oversized intakes may fall short.

If they are to remain as a required component in CMHC/NBC Option 1 ventilation systems, it is recommended that outdoor air intakes be required to have balancing dampers and flow measuring stations permanently installed and that installers be required to adjust the damper to achieve target airflows.

6. Fan-Powered Outdoor Air Intakes Connected to Forced-Air Heating Systems

The NBC requires that outdoor air intakes connected to forced-air heating systems be connected downstream of all return air ducts. One reason for this requirement is to ensure that unpowered outdoor air intake ducts (which rely on suction from the furnace fan to draw in supply air) are connected to the furnace return at a location that will provide relatively strong suction. A second reason is to ensure that outdoor air is mixed with sufficient return air to prevent condensation on duct surfaces during cold weather.

This requirement is valid for unpowered outdoor air intakes, but may not be necessary, or appropriate, for installations in which an HRV supplies outdoor air to the furnace return. This NBC requirement should be re-visited.

7. Ventilation System Controls

Ventilation system controls need to be better understood by electrical and HVAC installation trades, particularly where a forced-air heating system distributes ventilation air. Communication between trades is essential if controls are to function as required.

It is recommended that installers be required to commission ventilation systems, including testing the operation of all fans from all switches or combination of switches, as is required in CAN/CSA-F326. Form A in CAN/CSA-F326 or the HRAI "Residential Mechanical Ventilation Record" are samples of forms which installers could utilize to document their commissioning process.

8. Workmanship

To ensure satisfactory workmanship on residential ventilation systems, builders should select installers who have recently attended a residential ventilation trades training course which includes testing or skills assessment. The installing contractor should be required to commission their systems to confirm that they meet Code requirements. A signed copy of a proof of commissioning document should be provided to the owner and/or to a regulatory body or certification agency which has the resources to assess whether the ventilation system is Code compliant, and if not, the authority to require an installer to correct the deficiencies. Random third-party audit inspections by a regulatory body or certification agency would lead to fewer ventilation system deficiencies.

9. Screens and Hoods

Based on screen blockages observed during field investigations, it is recommended that all screens, grilles and filters in ventilation systems be three times the duct area served and that all screens and grilles be accessible and removable for cleaning.

The NBC requires rodent screens in exhaust hoods, if there are no backdraft dampers at the outside wall. Section 9.32.3.12.11) specifies mesh size restrictions for these screens. One interpretation of the Code is that a screen or grille which is not required but is installed, is not required to comply with these restrictions. This should be corrected.

10. Kitchen Exhaust

Kitchen exhaust grilles are to be equipped with grease filters, unless the duct serving the grille is accessible for cleaning over its entire length. At what distance from a range is a grease filter no longer required? Does or should this requirement change if there is an externally vented rangehood in the kitchen in addition to an exhaust grille on the wall? Is the option of having the duct accessible for cleaning a realistic alternative? What criteria should an inspector apply to determine if a duct is cleanable? This section of 9.32 should be reviewed and revised.

11. Fan Certification

Remote fans commonly applied for principal exhausts in study houses were not HVI-certified for airflow or for sound level. Currently HVI does not rate the sound level of remote-mounted fans, but the NBC requires them to meet the sound rating requirements for bath and kitchen fans.

It is recommended that sound ratings not be required for remote fans until a method of test is developed and applied. It is also recommended that installers be allowed to demonstrate compliance with target airflows by measuring airflows for fans which are not certified.

12. Trades Training and Certification

Ventilation system installers either are not aware of, or do not understand, or choose to overlook, many of the ventilation system requirements in Section 9.32 of the 1995 NBC. The fact that non-compliance with many Code requirements is typical rather than exceptional indicates that many requirements for residential ventilation systems are not being enforced. This was highlighted by the installer in the demonstration project whose response to meeting a Code requirement was "I can't afford to do it until my competition does it."

Stricter enforcement of Code requirements would reduce the number of non-compliant details in most houses. It may be that Code requirements are not being enforced because building and gas appliance inspectors are not inspecting the installations or it may be because they do not understand or are not aware of the requirements.

Builder focus on cost before function is a significant factor affecting ventilation system performance. Some installers noted that they only work for the few builders that were willing to pay for a better installation. Others noted that they do not work in the new house market because the prices are too low to allow them to install the quality of systems that they insist on installing.

There is a need for both installers and inspectors to be better educated on the reasons for the requirements in the Code, that is, in building science or the "house as a system" concept. Better trained inspectors could more effectively enforce the Code. Stricter enforcement of Code requirements would push the quality of new residential ventilation systems up toward the minimum standards in the Code.

HRAI has assumed a leadership role in developing and delivering residential ventilation system training programs for installers and inspectors. It is the writer's opinion that the low uptake rate for the courses offered is not a reflection of the HRAI's ability to deliver quality training, but rather is due to the apparent lack of incentives for installers to take training, or conversely, penalties for not taking training.

Stricter enforcement is needed to push the market away from current situations in which low bidder always gets the job regardless of qualifications or quality. A commitment to stricter enforcement would drive demand for training courses for inspectors. Stricter enforcement would likely drive demand for training courses for installers.

13. Code Requirements Need to be as Simple as Practically Possible, but Not Simpler

In general, contractors have complained about the complexity of the Code. They said those responsible for enforcement do not fully understand the Code; that there are a lot of grey areas and, in some instances, inspectors have inconsistent interpretations of Code requirements.

Building inspectors have expressed a concern about the complexity of the Code. Regulations which are difficult to understand will be difficult for the trades to apply and may be difficult for them to assess compliance.

Although the demonstration houses substantially met the intent of the ventilation requirements in the 1995 NBC, they did not fully comply with the Code requirements.

The above argues for clear, concise, simple Code requirements. The Code must be written in precise language to eliminate ambiguity and be supplemented by appendices with more definition or documentation of what constitutes compliance. An objective should be to make the Code as simple as possible, without making significant sacrifices in terms of ventilation system effectiveness.

Not all OBC houses complied, but, in general, were closer. Compliant OBC houses were very close to non-compliant NBC houses.

Appendix A

Field Monitoring Data Collection Sheets

Overview of Field Monitoring Data Collection Sheets

- House Identification and Checklist - basic data on the house, date of testing, etc.

- Primary Heating System - allows assessment of the need for make-up air systems. Furnace output allows assessing the degree of heating system oversizing. Blower operation may be relevant to ventilation air distribution.

- Furnace Fan Performance, Airflow and Pressure Drop - is used to assess airflow in the furnace return, temperature profiles in the furnace return, static pressure drops in the heating system ductwork and static pressure at the outdoor air intake to a furnace return.

- DHW Heating Equipment - allows assessment of the need for make-up air systems.

- Solid-Fuel Combustion Appliances - notes whether solid-fuel appliances have doors which substantially close off the firebox and whether the requirements for CO detectors are being met.

- Vented Supplemental Heating and Decorative Non-Solid-Fuel Burning Appliance Data - allows assessment of whether make-up air systems are required.

- Mechanical Ventilation System - establishes type of ventilation system installed, airflow capacity requirements, installed capacities, method of control. This sheet's focus is the principal exhaust system.

- Exhaust and Ventilation Air Distribution - airflow to or from critical rooms, including supply to bedrooms in houses using a forced-air heating system to distribute ventilation air. Sketches allow assessment of whether or not the ductwork meets Code limitations.

- Supplemental Exhaust Systems - records performance data on supplemental fans and duct layouts to determine compliance with the Code.

- Other Exhaust Appliances - records pertinent data on appliances which exhaust air.

- Make-Up Air Systems - records data to help assess if make-up air systems are required, and if so, do installed systems comply with NBC requirements.

- Airtightness Test Information - will be used for HOT2000 and to estimate depressurization caused by exhaust. Predicted levels of depressurization (based on blower door test results) will be compared to those measured in the Depressurization Tests.

- Depressurization Tests - house depressurization caused by each exhaust device and by specific combinations of exhaust devices will be recorded, weather permitting. Wind conditions may make this impractical, especially for devices with low net airflows. In these cases, only predicted levels of depressurization will be available.

- HOT2000 - will allow an assessment of furnace oversizing, and for houses with a CMHC/NBC Option 1 system, an indication of hours of uncontrolled ventilation in the heating season.

- CMHC System Option Checklists - completed to help identify system deficiencies.

House Identification and Data Checklist

House ID#* ______________________ Date of Survey ______________________

Occupant Name ______________________ House Type ______________________

House Address ______________________ Completion Date ______________________

______________________ Occupancy Date ______________________

____

Builder Name ______________________ HVAC Contractor Name ______________________

Business Address ______________________ Business Address ______________________

______________________ ______________________

______________________ ______________________

Occupant, Builder, Installer Observations or Comments ______________________

____

____

____

____

Data Checklist

- ☐ Plans or Takeoffs for HOT2000 Completed
- ☐ Primary Heating System Data Sheet
- ☐ Solid Fuel Data Sheet
- ☐ Vented Supplemental and Decorative Combustion Appliance Data Sheet
- ☐ Blower Door Test Completed and Vents/Flues have been Unsealed
- ☐ Depressurization Test
- ☐ DHW System Description Data Sheet
- ☐ Furnace Return Duct Traverses and Temperature Profiles
- ☐ Principal Exhaust System Documentation including Duct Layout Drawings
- ☐ Supplementary Exhaust System Documentation
- ☐ Make-up Air System Documentation
- ☐ Option Checklist Completed

* MB 01 to 19
NB 20 to 29
YK 30 to 39
AB 40 up

____
Name(s) of Inspector(s)

02/09/99

Primary Heating System
(other than Solid Fuel)

House ID# ____________
Survey Date ____________

Primary Energy: Natural Gas Oil Propane Electric Other ____________
Method of Heat Delivery: Forced Air Baseboard Radiant Other ____________

____________	____________	____________	____________
Manufacturer	Make	Model	Year of Manufacture

Energy Input ____________ Units ________ Heat Output ____________ Units ________

Furnace/Boiler Location ______________________ (Basement, Main Floor, Crawlspace, etc.)

Enclosed Space/Furnace Room? Y/N

Thermostat Auto Setback? Y/N

Fuel Burning Equipment Data

Natural Gas or Propane

- ☐ Furnace/Boiler with continuous pilot
- ☐ Furnace/Boiler with electric ignition
- ☐ Furnace/Boiler electric ignition, vent damper
- ☐ Induced draft fan furnace/boiler
- ☐ Condensing furnace/boiler
- ☐ Gas-fired furnace/heat pump system

Flue Type ____________
Location: Interior/Exterior
Combustion Air Intake
Distance from Burner ____________
Diameter ____________
Effective Length ____________
(hood = 60')

Oil

- ☐ Furnace/Boiler
- ☐ Furnace/Boiler with flue vent damper
- ☐ Furnace/Boiler with flame ret. head
- ☐ Mid-Efficiency furnace/boiler (no dil. air)
- ☐ Condensing furnace/boiler (no chimney)
- ☐ Direct vent, non-condensing

Make-Up Air Required for Exhausts over 75 L/S? Y/N (see MU air sheet for system details)

Distributes Ventilation Air? Y/N

Interconnected with Ventilation System/Principal Exhaust? Y/N

Forced Air System Data

Blower Operation: Continuous One Speed Continuous High/Low Speed Intermittent

Design Supply Air Temperature Rise ________ Minimum Allowable Return Air Temperature ________

Belt Drive or Direct Drive Blower? Number of Fan Speeds ________ Blower H.P. ________

Air Conditioner Installed? Y/N

Evaporator Coil Location ______________________ Configuration ____________

02/09/99

Fan Performance, Airflow and Pressure Drop Data

House ID# ______________

Survey Date ______________

Vp / Temp

Test Condition ____

Duct Size	MASK FILTER SLOT							
______ X ______								
Return Side Static		____________						
Return Static at OAI		____________						
Supply Side Static @ Furnace		____________						
Supply Side Static after AC Coil		____________						
Outdoor Air Temperature		____________ °C						
Air in OAI at Return		____________ °C						
Temperature of Return Air		____________ °C						

Test Condition ____

Duct Size	MASK FILTER SLOT							
______ X ______								
Return Side Static		____________						
Return Static at OAI		____________						
Supply Side Static @ Furnace		____________						
Supply Side Static after AC Coil		____________						
Outdoor Air Temperature		____________ °C						
Air in OAI at Return		____________ °C						
Temperature of Return Air		____________ °C						

Sketch furnace return layout and location of ventilation system connections to heating system ductwork. Does outdoor air connection comply?

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DHW Heating Equipment

House ID# ________

Survey Date ________

Manufacturer, Make & Model ______________________________

Year of Manufacture ______________

Location: Basement, Main Floor, Crawlspace, Other ______________________

In Enclosed Space? Y/N

Equipment Type:

Electric

- ☐ Conventional Tank
- ☐ Instantaneous
- ☐ Tankless heat pump
- ☐ Heat pump

Natural Gas

Propane

- ☐ Conventional tank
- ☐ Tankless coil
- ☐ Instantaneous
- ☐ Induced draft fan
- ☐ Direct vent (sealed)
- ☐ Condensing

☐ No pilot, electric or electronic ignition

Flue Type ______________

Flue Location: Interior/Exterior

Flue Diameter ______________

Combustion Air Intake

Distance from Burner ______________

Oil

- ☐ Conventional tank
- ☐ Tankless coil

Diameter ________ Effective Length ________

(hood = 60')

Flex, smooth, or ______________

Make-Up Air Required for Exhausts over 75 L/S? Y/N (see MU Air sheet for system details)

Tank Capacity ______________ Units ________

Rated Input ________ Units ______ Rated Recovery ________ Units ______

DHW Temperature ________ ° Units (C or F)

Location where temperature measured ______________________

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Solid Fuel Combustion Appliances

House ID# ____________

Survey Date ___________

Are solid fuel combustion appliances installed in house? Y/N

Appliance #1: Location ______________________________________ (room & floor)

Type of Appliance ____

Doors substantially close off fire box? Y/N

CO detector(s) installed? Y/N Location ______________________________

Make-Up Air Required for Exhausts over 75 L/S? Y/N
(see make-up air sheet for system details)

Rated Output ________________ Units _____
Flue Type _______________________________
Flue Location: Interior/Exterior
Flue Diameter ____________________________

Combustion Air Intake Diameter ______________ Effective Length (hood = 60')

Solid Fuel Appliance #2: Location ______________________________ (room & floor)

Type of Appliance ____

Doors substantially close off fire box? Y/N

CO detector(s) installed? Y/N Location ______________________________

Make-Up Air Required for Exhausts over 75 L/S? Y/N
(see make-up air sheet for system details)

Rated Output ________________ Units _____
Flue Type _______________________________
Flue Location: Interior/Exterior
Flue Diameter ____________________________

Combustion Air Intake Diameter ________________ Effective Length (hood = 60')

Vented Supplemental Heating and Decorative Non-Solid Fuel Burning Appliances Data

House ID#____________
Survey Date __________

Are vented supplemental heating and/or decorative non solid fuel burning appliances installed? Y/N

Appliance #1: Location ____ (room & floor)

Manufacturer, Make & Model ____

Year of Manufacture ____________________

Rated Input ________________ Units __________

Rated Output ________________ Units __________

Type:

Natural Gas Sealed or Unsealed? Electric ignition or Pilot?
Propane ☐ Other (specify) ____________________ Flue Type: Direct, B or Masonry
____________________ Flue Location: Interior/Exterior
Flue Diameter ____________

Separate Combustion Air Intake? Y/N

Make-Up Air Required for Exhausts over 75 L/S? Y/N
(see make-up air sheet for system details)

Appliance #2: Location ____ (room & floor)

Manufacturer, Make & Model ____

Year of Manufacture ____________________

Rated Input ________________ Units __________

Rated Output ________________ Units __________

Type:

Natural Gas Sealed or Unsealed? Electric ignition or Pilot?
Propane ☐ Other (specify) ____________________ Flue Type: Direct, B or Masonry
____________________ Flue Location: Interior/Exterior
Flue Diameter ____________

Separate Combustion Air Intake? Y/N

Make-Up Air Required for Exhausts over 75 L/S? Y/N
(see make-up air sheet for system details)

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Mechanical Ventilation System

House ID# ____________

Survey Date ___________

Minimum Total Ventilation System Capacity:

	# rooms				
Kitchen, living, dining	[ ]	x 5 L/s =	________ L/s	50% TVC	________
Bedrooms	[ ]	x 5 L/s + 5 =	________ L/s	75% TVC	________
Other habitable rooms	[ ]	x 5 L/s =	________ L/s	45% TVC	________
Utility rooms	[ ]	x 5 L/s =	________ L/s	55% TVC	________
Bathrooms	[ ]	x 5 L/s =	________ L/s		
Basement	[ ]	=	________ L/s		
Total Ventilation System Capacity			________ L/s		

Ventilation System Type Installed:

CMHC Option 1 Fresh air intake to furnace return
2 Powered outside air supply, no heat recovery
3 HRV with simplified ductwork
4 HRV with extended ductwork
5 Fully ducted, without heat recovery
6 Fully ducted, with heat recovery

Principal Exhaust Serves:
☐ Kitchen
☐ Bathroom(s)
Bathrooms ________
☐ Other Spaces (specify)
____

F326 design ☐ (describe system) ____

____

____

____

____

Principal Exhaust and Ventilation Air Supply Flow Rate Measurements at Fan or Outside Wall:

	Outdoor Supply Air Flow L/s	Principal Exhaust Flow L/s
Continuous Flow Rate		
For two-speed systems, high speed airflows		

Complete the CMHC checklist for this system type.

Exhaust and Ventilation Air Distribution

House ID# ____________

Survey Date ____________

	Supply to Bedrooms			Exhaust from Bathrooms		
	Room	Fan	Airflow	Room	Fan	Airflow
1	MBR					
2						
3						
4						
5						

Sketch layouts for principal exhaust and ventilation supply air ductwork. Show all fittings, duct diameters, duct lengths and note where flex duct is used. Record nameplate data for fans and HRVs. Indicate distance along the furnace return air duct from FAI connection to the furnace cabinet.

Supplemental Exhaust Systems

House ID# __________

Supplemental Bathroom Exhausts:

Sketch Ductwork

#1 Location ______________________________ Type ______________

Manufacturer, Make, Model ___________________________________

Airflow - Measured _____________ Rated_______ HVI Sones _______

Control Type & Location _____________________________________

#2 Location ______________________________ Type ______________

Manufacturer, Make, Model ___________________________________

Airflow - Measured _____________ Rated_______ HVI Sones _______

Control Type & Location _____________________________________

#3 Location ______________________________ Type ______________

Manufacturer, Make, Model ___________________________________

Airflow - Measured _____________ Rated_______ HVI Sones _______

Control Type & Location _____________________________________

#4 Location ______________________________ Type ______________

Manufacturer, Make, Model ___________________________________

Airflow - Measured _____________ Rated_______ HVI Sones _______

Control Type & Location _____________________________________

Supplemental Kitchen Exhaust:

Sketch Ductwork

Location __________________________________ Type ______________

Manufacturer, Make, Model _____________________________________

Airflow - Measured ______________ Rated________ HVI Sones _________

Control Type & Location ____

Gas or Electric Cooktop/Range ___________________________________

Rangehood Vented Outdoors? Y/N

Make-up air required to offset any of the above exhausts? Y/N

Data for Other Exhaust Appliances

House ID# ____________
Survey Date ____________

Clothes Dryer Installed? Y/N
Vented Outdoors? Y/N Gas or Electric ________________
Measured Airflow ______________________ Units ________________

Central Vacuum Installed? Y/N Roughed In? Y/N
Vented Outdoors? Y/N
Measured Airflow ______________________ Units ________________

Other (specify) ____
Measured Airflow ______________________ Units ________________

Other (specify) ____
Measured Airflow ______________________ Units ________________

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HOT2000 Data

House ID# ____________
Survey Date ____________

Address ______________________________ House Type ______________________________

Town or City ______________________________ Year of Construction ______________________

Province ______________________________ AC? Y/N

Significant Features ____

HOT2000 Inputs - if drawings not available

Component	Dimension	R-value	Dimension	R-value	Dimension	R-value
Deep basement Above-grade wall						
2 feet below grade						
Lower wall						
Slab perimeter						
Slab centre						
Other foundation	sh/cr/sl		sh/cr/sl		sh/cr/sl	
Above-grade wall						
Below-grade wall						
Slab perimeter						
Slab centre						
Main walls						
Overhanging floors						
Ceiling						
Doors						

Windows-orientation	WxH	OH W&H	descript	WxH	OH W&H	descript

Sheltered or Exposed

Estimated Volume ____________________ Airtightness ____________________

Design HL = ______________ Btuh Aux. HT Required = ______________ MMBtu

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Airtightness Test Information

House ID# ____________
Survey Date ____________

Weather Data:
Temperature Outdoors [ ] C
Wind Speed [ ] kph
Wind Direction [ ]
Barometric Pressure [ ] KPa

Test Equipment - Nozzle Used ______________
House Size:
Envelope Area [ ] m²
Volume [ ] m³
House Temperature [ ] C

Test #1 - Condition ______________________________
Indoor/Outdoor House Pressure Difference at Start of Test [ ] Pa

Date ______________________
Time ______________________

House Pressure (Pa)	Nozzle Pressure (Pa)	House Pressure (Pa)	Nozzle Pressure (Pa)

Indoor/Outdoor House Pressure Difference at End of Test [ ] Pa

TABLE 2
PREPARATION OF INTENTIONAL OPENINGS

fireplace flue	no preparation
fireplace	
- with damper	CLOSE
- with doors	CLOSE
- without damper	see par. 6.1.15
doors on enclosed furnace room*	CLOSE
fireplace combustion air intake damper	CLOSE
fuel fired furnace and/or stove flues	SEAL
fuel fired furnace and/or stove flues in enclosed furnace room*	no preparation
furnace combustion air intake	
- with damper	CLOSE
- without damper	SEAL
ventilation air intake	
- with damper	CLOSE
- without damper	SEAL
fuel fired hot water system flues	SEAL
floor drains	FILL
plumbing traps	FILL
exhaust fans	
- with motorized damper	CLOSE
- without motorized damper	no preparation
air to air heat exchangers designed to operate continuously	
- intake and exhaust openings	SEAL
other air to air heat exchangers	
- intake and exhaust openings with motorized damper	CLOSE
- intake and exhaust openings without motorized damper	no preparation
dryer vents	
- with exhaust divertor	WINTER POSITION
- with motorized damper	CLOSE
- without motorized damper	no preparation
windows and doors	LATCH
exhaust systems common to more than one unit	SEAL
window air conditioners	SEAL
attic hatch	CLOSE

*An enclosed furnace room is a room expressly built to contain a furnace and/or stove, with a combustion air intake to the outside of the building, and to prevent air flow to and from the remainder of the building.

CAN/CGSB-51.71-95 Spillage Test

House ID# ____________
Survey Date ____________

CAN/CGSB-51.71-95 Protocol Followed? Y/N
(If No, note variations overleaf.)

Test Condition	Measured Flow (L/s)	Indoor-Outdoor ▲p at Furnace	▲p with Open Fireplace
All Fans Off			
Furnace Fan On[1] - Furnace Room Open			
Furnace Fan On[1] - Furnace Room Closed			
Principal Exhaust System			
Clothes Dryer			
Range Hood			
Externally Exhausted Central Vac			
Other (specify)			
Background Worst Case[2] (WC)			
WC plus Dryer			
WC plus Rangehood			
WC plus Dryer and Rangehood			
WC plus Dryer and Largest Other Exhaust			
WC plus Dryer and All Exhausts GT 75 L/s			

[1] Furnace at highest speed selectable from thermostat.
[2] Background Worst Case is the combination of furnace room closure, furnace fan operation, principal exhaust fan operation and other fans intended for continuous use which results in greatest depressurization in the area of the furnace.

Depressurization Limits for Combustion Appliances (see Table 2 in Standard)

Appliance/Category	Continuous Limit (Pa)	Intermittent Limit (Pa)

Make-Up Air System

House ID# ____________
Survey Date ___________

Radon deemed to be a problem? Y/N
Spillage susceptible combustion appliances present? Y/N
(identify) ____
Exhaust flow rates greater than 75 L/s operated from single control? Y/N
(specify) ____
Are make-up air system(s) required by 9.32? Y/N By B149? Y/N
Are make-up air system(s) installed? Y/N
If yes, provide the following details:

MUA System #1
Serves (appliance) ______________ Appliance exhaust rate ______________
Measured make-up airflow ______________________________
Control method ______________________________
Make-up air delivered to (location) ______________________________
Make-up air tempered? Y/N
If yes, describe - method, set point, capacity: ______________________________
____

MUA System #2
Serves (appliance) ______________ Appliance exhaust rate ______________
Measured make-up airflow ______________________________
Control method ______________________________
Make-up air delivered to (location) ______________________________
Make-up air tempered? Y/N
If yes, describe - method, set point, capacity: ______________________________
____

Appendix B

A Comparison of OBC and NBC Residential Ventilation System Requirements

A Comparison of OBC and NBC Residential Ventilation System Requirements

The OBC and NBC sections regarding residential ventilation are similar in that both have the intent of ensuring that ventilation systems that are installed in new houses:

- are capable of continuous operation at prescribed airflow rates;
- exhaust directly from bathrooms and kitchens;
- have a means to distribute (fresh) ventilation air throughout the house without adversely affecting occupant comfort;
- use fans which meet specific sone (noise) ratings;
- don't depressurize houses excessively if soil gas is deemed to be a problem or if spillage-susceptible combustion appliances are present;
- have controls that the occupant can understand and are simple and convenient to use;
- do not adversely affect the operation or life expectancy of furnaces.

Neither HVI nor CSA rate operating life expectancy for fans. The majority of exhaust fans in both NBC and OBC study houses were low-cost ceiling fans. Installers, electricians, residential building managers, etc. have suggested a life expectancy of less than one year of continuous operation for most ceiling fans, based on their observations. As such, standard ceiling-type fans should not be considered as being capable of providing continuous operation.

Doing a detailed duct design or following the prescriptive rules for unpowered outdoor air intake ducts connected to furnace return ducts does not ensure that actual airflows will be anywhere near target airflow rates. Balanced ventilation can not usually be achieved simply through design. In most cases airflow measurement and adjustment are necessary.

Un-motorized outdoor air intakes can be set up to provide balanced flow when the furnace fan and the principal exhaust fan operate. The NBC requires that the furnace fan operate whenever the principal exhaust fan operates, however, it does not require that the principal exhaust fan operate whenever the furnace fan operates. As such, a house with an NBC/CMHC Option 1 system could be pressurized most hours of the year, if the occupant chooses to operate the furnace fan continuously. Continuous pressurization of a house during cold weather can increase deposition of moisture in building envelopes.

A positive aspect of the NBC which is not shared with the OBC is the requirements aimed at the positive supply and distribution of ventilation air throughout the house when the "ventilation fan" is turned on. Operating the exhaust-only systems allowed in the OBC ensure that outdoor air will en*ter the house, but there is no assurance that once inside the house, the outdoor air will be distributed to occupied areas. For example, it could enter the room which is being exhausted, and even with the furnace circulation fan operating, it may be exhausted without being distributed.

The OBC ventilation requirements have several positive aspects relative to the NBC. The OBC requirement that houses with prescriptive design ventilation systems not use spillage-susceptible combustion appliances effectively avoids the issue of flue gas spillage. OBC exhaust-only systems in the NBC/CMHC Option 1 house pressurization problem noted above avoids the problem of outdoor air depressing return air temperatures. The OBC prescriptive requirements are simpler for installers to apply and inspectors to assess compliance.

The OBC specifies separate controls for the ventilation system and the furnace fan in houses which use the furnace fan to distribute ventilation air. It is unlikely that many homeowners are aware that they should run the furnace fan when operating the principal exhaust fan in order to improve ventilation in the house.

The energy cost of running the furnace fan to distribute ventilation air is an issue that has been discussed at length in the R-2000 program. Direct distribution of ventilation air is a more efficient approach.

Appendix C

Reports on Demonstration Houses

House MB101
CMHC Option 1
Outdoor Air Supply Duct without Auxiliary Fan, Coupled to a Forced-Air Furnace Return

House Description: a 1,200 square foot bungalow with three bedrooms, two bathrooms and an unfinished basement located in Winnipeg, Manitoba. At the time of testing, the house was a display home.

Overall Ventilation System Description: a two-speed central exhaust fan serving the bathrooms meets both the principal exhaust and total ventilation capacity (TVC) airflow requirements. The outdoor air supply is provided by a fresh air intake connected to the furnace return. A rangehood provides supplemental kitchen exhaust.

Exhaust Systems Description: a two-speed, in-line fan in the basement draws exhaust from the bathrooms. The fan was not sound rated by HVI, so does not fully comply with NBC requirements. (Currently, there is not a standard method of test to sound rate remote-mounted fans.) However, local building inspectors accept these fans as meeting the NBC intent of providing quiet fans.

The required supplemental kitchen exhaust was provided by a builder-model rangehood, vented directly to the outdoors, with an HVI rating of 80 L/s (170 cfm) at 25 Pa.

Ventilation System Controls: a dehumidistat beside the thermostat labelled "Central Ventilation Switch" turns the central fan on to its lower speed setting or the principal exhaust fan speed. Timer switches in each bathroom turn the central fan on to high speed or TVC.

An adjustable speed control sets the low-speed principal exhaust flow rate for the central fan. The timer switches in the bathrooms are wired in parallel with the speed control. They bypass the speed control to operate the principal exhaust fan at full speed.

A pressure switch in the principal exhaust fan inlet turns on the furnace fan when it senses suction. The installer favours this method because it separates the low-voltage wiring controlling the furnace fan from the line-voltage wiring controlling the principal exhaust fan.

System Performance: TVC for this house is 55 L/s. The target principal exhaust airflow rate was 27.5 L/s. Because of an availability problem, the principal exhaust fan installed in the house was larger than the model specified for the house. Duct sizing should have been modified to compensate for the larger capacity fan; the principal exhaust fan had a higher than desired airflow rate at its minimum speed. The minimum airflow rate achievable was 44 L/s. On high speed, the principal exhaust fan airflow rate was 83 L/s. Installation of a balance damper in the exhaust duct would allow this airflow to be reduced to the target principal exhaust airflow rate and would bring the high-speed operation closer to the TVC.

The 150 mm (6 inch) flex duct used for the outdoor air supply duct was sized according to Sentence 9.32.3.6.(4) and Table 9.32.3.6.A in the NBC and connected to the return air drop. The duct was not crushed or choked at bends or supports. Maximum airflow in the outdoor air duct was 44 L/s. As such, it exceeded the target flow rate and could be adjusted downward with the balance damper or left as is to provide balanced airflow with principal exhaust fan.

The 1995 NBC states that required supplemental kitchen exhaust fans must have "a rated capacity of not less than 50 L/s". As is typical of similar rangehoods, the installed rangehood was rated at 80 L/s and had an "as-installed" exhaust airflow rate of 47 L/s (100 cfm).

Air Temperatures Across the Furnace Heat Exchanger: the furnace installation manual states "the mixed air temperature across the heat exchanger MUST not fall below 60°F (15°C) or flue gases will condense in the heat exchanger. This will shorten the life of the heat exchanger and possibly void your warranty."

Calculations using "as-installed" furnace airflows and the target principal exhaust flow rate (i.e., 27.5 L/s) indicate that average mixed air temperatures passing over the furnace heat exchanger could fall below 15°C at house temperatures below 17°C and outdoor temperatures below -28°C. At house temperatures above 17.5°C, outdoor air temperatures would have to fall below -39°C for average mixed air temperatures to fall below 15°C. The 2½% January design temperature in Winnipeg is -33°C; the 1% January temperature is -35°C.

At 44 L/s (i.e., the unadjusted airflow measured in the outdoor air duct), mixed air temperatures passing over the furnace heat exchanger would fall below 15°C at house temperatures below 18°C and outdoor temperatures below -24°C.

To avoid condensation in the heat exchanger and possible warranty problems, the outdoor air supply to this house should be adjusted to the target value of 27.5 L/s.

House Depressurization Issues: house construction included the soil gas control measures specified in the 1995 NBC. As such, the house does not require avoidance of depressurization in order to reduce soil gas entry. In order to avoid B-149 (i.e., Gas Code) make-up air requirements, the builder did not install any B-vented combustion appliances. The house has a direct-vent (i.e., sealed combustion) gas furnace and electric hot water tank. No other vented combustion appliances were installed.

The direct-vent furnace adds modestly to heating system installation costs but avoids the need to consider make-up air systems that cost $700 or more. The impact of the furnace and electric hot water tank combination on energy cost will depend on the lifestyle of the occupants, but overall it is expected to be small, with the decreased energy costs for space heating more or less offsetting the increased DHW energy costs.

House MB103
CMHC Option 3
Heat Recovery Ventilator Coupled to a Forced-Air Heating System

House Description: a custom built, two-storey over a full basement located near Winnipeg, Manitoba. The 1,250 square foot main floor includes a bathroom, laundry room, kitchen, dining, living and family rooms. The 950 square foot second floor includes three bedrooms and two bathrooms. The basement was unfinished.

Overall Ventilation System Description: an HRV which meets both principal exhaust and total ventilation capacity (TVC) airflow requirements, draws exhaust from the bathrooms and supplies outdoor air to the furnace return. A downdraft range fan provides supplemental kitchen exhaust.

Ventilation System Controls: the HRV can be set for either "on/off" or continuous operation at either low or high speed at the central HRV control located in the main floor hall, beside the thermostat. Manual switches in each bathroom and a dehumidistat in the central HRV control can turn the HRV to high speed, regardless of the operating mode selected.

System Performance: TVC for this house is 75 L/s. The target principal exhaust airflow rate was 37.5 L/s. On low speed, HRV airflows were 45 L/s (95 cfm) supply and 49 L/s (105 cfm) exhaust. On high speed, HRV airflow rates were 85 L/s supply (180 cfm) and 75 L/s exhaust (158 cfm). The airflow performance of the HRV is such that it cannot have balanced airflows at both low- and high-speed operation. Near balance was selected for low-speed operation, where it is expected the HRV will operate most of the time.

This house requires a supplemental kitchen exhaust fan with "a rated capacity of not less than 50 L/s". The gas range was equipped with a downdraft exhaust which did not bear an HVI certification sticker, indicating its performance was not certified. However, the measured exhaust airflow was 123 L/s (260 cfm), well in excess of the required minimum.

House Depressurization Issues: house construction included the soil gas control measures specified in the 1995 NBC. As such, the house does not require avoidance of depressurization in order to reduce soil gas entry. In order to avoid B-149 (i.e., Gas Code) make-up air requirements, the builder did not install any B-vented combustion appliances. The house has a direct-vent (i.e., sealed combustion) gas furnace and a power-vented domestic hot water tank. A direct-vent, gas fireplace is installed in the living/family room area. No other vented combustion appliances were installed.

The ventilation system in this house demonstrates that CMHC Option 3 ventilation systems designed and installed to comply with the requirements of the 1995 NBC provide safe and effective ventilation.

House MB106
CMHC Option 6
Heat Recovery Ventilator NOT Coupled to a Forced-Air Heating System

House Description: a bungalow partly over a basement and partly over a crawlspace located in Winnipeg, Manitoba. The 2,000 square foot main floor includes three bedrooms, two bathrooms, a water closet and the main living areas. The 1,000 square foot basement includes a bedroom, bathroom, office, game room and mechanical room. This house is wheelchair accessible.

Overall Ventilation System Description: an HRV draws exhaust from the bathrooms and supplies outdoor air to each bedroom and to the main living area. The HRV meets both principal exhaust and total ventilation capacity (TVC) airflow requirements. A rangehood with an HVI rating of 85 L/s (180 cfm) at 25 Pa provides supplemental kitchen exhaust.

Ventilation System Controls: the HRV can be set for either "on/off" or continuous operation (at one of four fan speeds), selected at the HRV. Touch pad timer switches in each bathroom can be used to increase the HRV speed setting. A dehumidistat in the central hall on the main floor can be used as a manual switch or set to automatically operate the HRV at its high-speed setting, overriding the other switches.

System Performance: TVC for this house is 75 L/s. The target principal exhaust airflow rate was 37.5 L/s. On low speed, HRV airflows were 38 L/s (80 cfm) supply and 36 L/s (77 cfm) exhaust without damper adjustment. On high speed, HRV airflow rates were 58 L/s supply (123 cfm) and 56 L/s exhaust (119 cfm).

The HRV specifications indicate that it should have adequate high-speed airflow capacity and turn down to meet both TVC and principal exhaust airflow rate requirements. Modifications to ductwork which might increase system airflows on high speed would also increase low-speed airflows, which may result in excessive ventilation. As installed, the HRV will have adequate ventilation for most needs in this house, and should be able to provide very good overall indoor air quality.

The 1995 NBC states that required supplemental kitchen exhaust fans must have "a rated capacity of not less than 50 L/s". The installed rangehood was rated at 85 L/s and had an "as-installed" exhaust airflow rate of less than 47 L/s (100 cfm). The rangehood was sound rated at 4.5 sones. If it were also rated at low speed, it would likely have a sone rating of less than 3.5 and an airflow rate of more than 20 L/s. As such, it could be considered to cover the TVC shortfall.

House Depressurization Issues: house construction included the soil gas control measures specified in the 1995 NBC. As such, the house does not require avoidance of depressurization in order to reduce soil gas entry.

In order to avoid B-149 (i.e., Gas Code) make-up air requirements, the builder did not install any B-vented combustion appliances. The house has a direct vent (i.e., sealed combustion) gas boiler furnace serving an indirect-fired, domestic hot water tank and a multi-zone, in-floor radiant heating system. A direct-vent, gas fireplace is installed in the living/family room area. No other vented combustion appliances were installed.

The owner/occupant of this house is a plumbing and hydronic heating contractor. The heating and plumbing systems demonstrate his expertise. The installation is well executed and includes high-quality components and features. The ventilation system in this house demonstrates that ventilation systems designed and installed to comply with the requirements of the 1995 NBC provide safe and effective ventilation.