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Effectiveness Of Hard Connected duct Into A Forced Air Duct system As A Means Of providing Ventilation and Make-up Air

EVALUATION OF THE EFFECTIVENESS OF A HARD CONNECTED DUCT INTO THE RETURN AIR SYSTEM OF A FURNACE FORCED AIR DUCT SYSTEM AS A MEANS FOR PROVIDING VENTILATION AND MAKE-UP AIR

FINAL REPORT

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DECEMBER 21, 1991

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EXECUTIVE SUMMARY

The primary purpose of this project was to determine if furnace heat exchangers were prematurely or excessively rusting due to condensation when fresh air ducts are hard connected to the return air system. In addition, occupants were to be interviewed to ascertain whether such systems were causing cool drafts. The energy impact of this type of ventilation system and the practicality of installing high inside wall supply outlets was also to be investigated. A test house was to be set-up to measure air flows, temperatures and pressures during various modes of ventilation system operation.

Heat Exchanger Inspections

No signs of premature heat exchanger corrosion, that could be linked to condensation resulting from cool ventilation air, were found in the Alberta, British Columbia and Ontario houses inspected. Unfortunately, only one system was found that ran continuously (the worst case scenario), most operated only when the furnace came on. Even if most of the systems examined in Alberta (the coldest climatical area investigated) had been running continuously, measurements of the fresh air flow rate and calculations of the resulting mixed air temperature in the return system at outdoor design conditions indicated that flow rates were not sufficient to cause the mixed air temperature to fall below the dew point (approximately 13 °C). This was largely because the ventilation flow rates were much less than that required by the Building Code.

The fresh air ducts in B.C. were not insulated and apparently were not experiencing any condensation, likely because of the mild climate. All ventilation ducts in the Alberta sample were insulated and vapour barriered. The ventilation ducts examined in Ontario usually had some fibreglass insulation wrapped around the first few feet from the wall penetration and no vapour barrier. The occupants reported that the ducts had condensation on them most of the winter and that the insulation with no vapour barrier acted like a sponge to hold the water.

Owner Survey

The owners of all of the houses inspected during this project were surveyed to determine their awareness of the ventilation system present, their perspective of its performance and how they operated the system. Most of those surveyed knew their house had a fresh air ventilation system, this may be partially accounted for by the fact that the majority of those surveyed in British Columbia and Alberta worked for the utility. Most of the Ontario homeowners interviewed knew that they had a fresh air ventilation system because they either consciously had the system added to eliminate a moisture problem, or as was the case of a number townhouses with the high ventilation rates, the owners were experiencing very high utility bills. Those few systems that had a manual control were seldom activated by the owners, perhaps because most of them would have been required to open the furnace cabinet to activate the fan switch. The twelve home owners interviewed in Ontario did not have much understanding of the purpose of fresh air ventilation or the operation of their system. Most, with exception of British Columbia home owners, felt that their house was too dry in winter - some had added humidifiers as a result. This may, though not necessarily, be an indication of ventilation levels that are too high. Few comfort complaints were received, possibly because most of the systems only operate when the furnace is producing heat.

High Inside Wall Supply Outlets

Since high inside wall supply outlets can introduce air as cool as 13°C into a space without causing comfort problems, compared to 18°C for normal floor diffusers, less tempering of the fresh air is required during cold weather. Though high inside wall outlets would have a higher initial cost, they would reduce the operating cost of the ventilating system.

A heating contractor in Toronto and another in Edmonton provided cost estimates of the additional cost, per run, to install the high inside wall outlets that would allow cooler air to be delivered to occupied rooms without causing comfort problems. The Edmonton contractor estimated the additional cost to be $50 to $52 per run and the Ontario contractor $40 to $65.

A typical 187 ft^2 house would require approximately 10 high inside wall outlets for a total additional cost (over floor outlets) of $500. Calculations show that if the ventilation air for that same house, located in Toronto, had to be tempered electrically so that the mixed air temperature in the return air system was above 18°C, the tempering cost would be $218 annually, at today's rates. The cost to temper that same air by natural gas would be $97, $121 less. The cost to electrically temper (duct heater) the air sufficiently to 13°C for high inside wall outlets would be only $26 annually. That is only about $14 more than the cost to temper the air with natural gas. These costs assume a continuous ventilation rate of 1/3 ach. The use of high wall outlets would save $192 in electrical energy annually. Since this cooler supply air would still have to be heated, the approximate cost to do so with natural gas would be about $84. Therefore, the total savings for the home owner, if high wall outlets were used would be $194-$84 = $110 annually. This would provide a six year payback for the additional cost of the ten high wall outlets. Of course an HRV could be used to temper the fresh air to 13°C, rather than an electric duct heater, for an even greater annual operating saving, however, the payback period would be much longer because of the high initial HRV cost (approximately $1300 installed) compared to that of a duct heater ($400 installed).

Test House Results

A test house located in Edmonton was used to complete a number of tests relating to the performance of the combined heating/ventilating system. The following was learned from the tests conducted:

* Both the ventilation and combustion air duct act as make-up air ducts when the furnace blower is not operating;

* The make-up air flowing into through the ventilation duct travels into the heating system return air duct and moves towards the furnace where it pools because the furnace acts as a large "P" trap;

* When the outdoor temperature is below 0°C, the temperature of this air in the return duct and in the furnace can fall below the dew point, possibly leading to condensation on the ducts and the furnace as well as the flue gases of a standing pilot, if present;

* When the furnace blower operates at a rate sufficient to bring in enough outdoor air for 1/3 ach, it will slightly pressurize a tight house (3.3 pa);

* When the furnace blower operates, the house pressurizes and the combustion air duct exhausts indoor air to the outdoors;

* When such exhausting occurs, it can lead to short circuiting with the ventilation air inlet, if the ventilation air inlet is located close to the combustion air inlet;

* When an open vent or chimney is present, it also exhausts air reducing the amount of air being exhausted by the combustion air duct; and

* Operation of the furnace blower induces sufficient fresh air flow into the house to help compensate for air being exhausted by exhaust devices, reducing the possibility of combustion product spillage and/or the duration of such spillage:

RÉSUMÉ

L'objet premier de cette recherche consistait à déterminer si l'échangeur de chaleur des générateurs rouillait de façon prématurée ou excessive sous l'effet de la condensation lorsque les conduits d'admission d'air étaient raccordés au circuit de reprise d'air. Il était de plus question de s'enquérir auprès des occupants s'ils ressentaient des courants d'air froid, en plus d'investiguer les répercussions d'une telle installation de ventilation sur la consommation d'énergie et la valeur concrète d'aménager des sorties d'alimentation en partie supérieure des murs intérieurs. Une maison devait faire l'objet de mesures des mouvements d'air, des températures et des pressions pendant divers modes de fonctionnement du système de ventilation.

Inspection de l'échangeur de chaleur
Aucun signe de corrosion prématurée de l'échangeur de chaleur, pouvant être reliée à la condensation par suite de l'admission d'air de ventilation froid, n'a été décelé dans les maisons inspectées en Alberta, en Colombie-Britannique et en Ontario. Malheureusement, une seule installation, a-t-on constaté, fonctionnait continuellement (le pire des scénarios), alors que la plupart ne se mettaient en marche qu'au départ du générateur. Même si la majorité des installations étudiées en Alberta (zone climatique la plus froide des régions investiguées) avaient été soumises à un fonctionnement continuel, les mesures du mouvement d'air frais et les calculs de la température de l'air en résultant dans le circuit de reprise, selon les conditions théoriques extérieures, indiquaient que les débits n'étaient pas suffisants pour faire chuter la température de l'air mélangé sous le point de rosée (soit environ 13°C), explication largement attribuable au fait que les débits d'air de ventilation étaient de beaucoup inférieurs à ce que requiert le Code du bâtiment.

Les conduits d'admission d'air frais des maisons de la Colombie-Britannique, pourtant dépourvus d'isolation, ne manifestaient pas de signe de condensation, en raison surtout du climat doux. Par contre, tous les conduits de ventilation de l'échantillon de l'Alberta étaient pourvus d'isolant et d'un pare-vapeur. Les conduits de ventilation examinés dans les maisons de l'Ontario avaient généralement été enveloppés d'isolant de fibre de verre sur une distance de quelques pieds depuis l'endroit où ils traversaient le mur, mais laissés sans pare-vapeur. Les occupants ont signalé que de la condensation se formait sur les conduits pendant la majeure partie de l'hiver et que l'isolant, en l'absence de pare-vapeur, retenait l'eau comme une éponge.

Enquête auprès des propriétaires
Les propriétaires de toutes les maisons inspectées lors de cette recherche ont été interrogés sur leur degré de connaissance du système de ventilation en place, la performance qu'ils lui attribuaient et la façon de le faire fonctionner. La plupart savaient que leur maison était équipée d'un système de ventilation doté d'un conduit d'admission d'air frais, ce qui s'explique en partie par le fait que la majorité des personnes interrogées en Colombie-Britannique et en Alberta travaillaient pour les services publics. Les propriétaires de l'Ontario savaient, pour la plupart, qu'ils possédaient un tel système de ventilation, soit parce qu'ils l'avaient eux-mêmes fait installer pour enrayer l'excès d'humidité, soit, comme c'était le cas de certaines maisons en bande caractérisées par un taux de ventilation élevé, qu'ils faisaient face à une facture de services publics très élevée. Les quelques installations pourvues d'une commande manuelle étaient rarement mises en marche

par le propriétaire, peut-être parce qu'il leur aurait fallu ouvrir le bâti du générateur pour actionner la commande du ventilateur. Les douze propriétaires interrogés en Ontario ne saisissaient pas trop le pourquoi de l'air frais de ventilation ou du fonctionnement du système. Pourtant, la plupart, à l'exception des propriétaires de la Colombie-Britannique, estimaient l'air de leur maison trop sec en hiver, de sorte que certains avaient même fait l'acquisition d'un humidificateur. Cette situation pourrait, mais pas nécessairement, être une indication du niveau de ventilation trop élevé. Peu de plaintes pour raison d'inconfort ont été reçues, possiblement parce que la plupart des systèmes ne fonctionnaient que lorsque le générateur produisait de la chaleur.

Sorties d'alimentation en partie supérieure des murs intérieurs
Étant donné que les sorties aménagées en partie supérieure des murs intérieures peuvent introduire à l'intérieur de l'air à une température de 13°C sans causer d'inconfort, comparativement à 18°C pour les diffuseurs de sol ordinaires, le besoin de tempérer l'air frais par temps froid se fait moins sentir. La mise en place de telles sorties coûte certes plus cher au départ, mais offre l'avantage de réduire les frais de fonctionnement du système de ventilation.

Un entrepreneur de chauffage de Toronto et un autre d'Edmonton ont fourni une estimation du coût supplémentaire à engager, par parcours, pour l'installation en partie supérieure des murs intérieurs des sorties alimentant en air frais les pièces occupées sans toutefois causer de sensation d'inconfort. L'entrepreneur d'Edmonton en établit le coût supplémentaire entre 50 et 52 dollars, et l'entrepreneur de l'Ontario entre 40 et 65 dollars.

Une maison type de 187 pi^2 requiert environ 10 sorties murales, représentant un supplément (par rapport aux sorties au niveau du plancher) de 500 dollars. Les calculs démontrent que si l'air de ventilation de la même maison située à Toronto devait être tempéré à l'électricité pour que la température de l'air dans le circuit de reprise se trouve au-dessus de 18°C, il en coûterait 218 dollars par année, au prix d'aujourd'hui. Tempérer le même air au moyen du gaz naturel coûterait 97 dollars, soit 121 dollars de moins. Il en coûterait seulement 26 dollars par année pour ramener à une température de 13°C, grâce à un réchauffeur de conduit électrique, l'air des sorties en partie supérieur des murs intérieurs, soit uniquement environ 14 dollars de plus qu'en tempérant l'air au moyen du gaz naturel. Ces coûts supposent une ventilation continue à raison de 0,3 renouvellement d'air à l'heure. L'utilisation de sorties murales élevées permettrait de réaliser des économies annuelles de 192 dollars en frais d'électricité. Puisqu'il faudrait tout de même tempérer l'air frais admis, il en coûterait environ 84 dollars en utilisant le gaz naturel. Par conséquent, l'installation de sorties murales ferait réaliser au propriétaire des économies annuelles de 110 dollars (194 $ - 84 $). Le délai de récupération du supplément engagé en raison des dix sorties murales correspondrait à six ans. Bien sûr, le recours à un échangeur-récupérateur de chaleur, plutôt qu'à un réchauffeur de conduit électrique, pour tempérer l'air frais à une température de 13°C ferait davantage économiser en frais de fonctionnement annuels, mais le prix d'un échangeur-récupérateur de chaleur (environ 1 300 $ installé) comparativement à un réchauffeur de conduit (400 $ installé) allongerait beaucoup le délai de récupération.

Résultats des essais
Une maison d'Edmonton a été la scène d'essais de performance de l'installation combinée de chauffage et de ventilation. Voici les résultats constatés :

- Les conduits de ventilation et d'air comburant tiennent lieu de conduits d'air de compensation lorsque le souffleur du générateur ne fonctionne pas.

- L'air de compensation introduit par le conduit de ventilation chemine dans le conduit de reprise du système de chauffage et se déplace en direction du générateur où il s'accumule puisque le générateur sert de vaste piège en forme de P.

- Lorsque la température extérieure tombe au-dessous de 0°C, la température de l'air présent dans le conduit de reprise et le générateur peut chuter sous le point de rosée, risquant d'occasionner la formation de condensation à la surface des conduits et du générateur, tout comme celle des gaz d'évacuation de la veilleuse en attente, le cas échéant.

- Le souffleur du générateur qui fonctionne à un débit suffisant pour assurer 0,3 renouvellement d'air à l'heure soumettra la maison étanche à une légère surpression (3,3 Pa).

- Lorsque le souffleur du générateur fonctionne, la maison subit une surpression et le conduit d'air comburant évacue l'air de l'habitation dehors.

- En pareille situation, le «conduit d'évacuation» peut court-circuiter la prise d'air de ventilation, si celle-ci se trouve à proximité de la prise d'air compurant.

- Un conduit d'évacuation ouvert ou la cheminée peut également évacuer de l'air, réduisant ainsi la quantité extirpée par le conduit d'air comburant.

- Le fonctionnement du souffleur du générateur entraîne un débit d'air frais suffisant dans la maison pour compenser l'air évacué par les dispositifs d'extraction, réduisant les risques d'émanations des produits de combustion ou, le cas échéant, la durée des émanations.

INTRODUCTION

The 1990 National Building Code and 1990 Ontario Building Code require the installation of a mechanical ventilation system in every new house. The system must be capable of providing at least 0.3 air changes per hour. In addition, if spillage susceptible combustion appliances are installed in the house, provisions for make-up air must be installed to ensure potential depressurization levels in excess of 5 Pa do not occur.

The simplest method of complying with the 1990 ventilation requirements is to install a combination of bathroom and kitchen fans capable of providing sufficient ventilation capacity; and a passive duct installed (usually in the basement) of sufficient size so as to not cause excessive depressurization. While this "minimum" design may appear to be simple in concept, it is becoming clear that for most houses with even modest ventilation capacity, the passive intake will have to be extremely large to satisfy the depressurization limits for the house. Concerns of cold drafts and/or homeowners blocking off these passive ducts have been raised. Additional concerns that passive intakes can also act as an exhaust duct (under certain wind conditions) suggests that this approach to comply with the Code may not be appropriate.

An alternative approach that will satisfy both the ventilation and make-up air requirements is to draw fresh air from outdoors through a duct connected to the furnace return air system. The incremental cost of this system over the "minimum system" is small. This provides a means of distributing fresh air throughout the house using the distribution ducts of the forced air system. In addition, since this system will tend to pressurize the house, it increases the "margin of safety" for depressurization. It is anticipated that this system will be a popular option for builders to comply with current codes once they recognize the impracticalities of the "minimum" system.

However, even this system is not without its limitations. First, if the forced air system is operated continuously to provide continuous ventilation, there is concern that cold drafts will occur, particularly if floor diffusers are installed. Second, if the furnace fan is not operated continuously, the make-up air provisions may be less than adequate, since the make-up air will be supplied only when the furnace is operating, possibly exacerbating start up spillage and/or backdrafting. Third, a pre-heater may be required to temper the air sufficiently to ensure that the mixed air in the return plenum is above 13°C to minimize potential condensation on the heat exchanger. This is of particular concern since there is no formal standard to-date for electric pre-heaters designed to operate in extremely cold air streams. In addition, high electrical costs may result, especially where the difference in electrical and gas fuels rates are substantial.

Last but not least, a number of concerns have been raised regarding the potential for premature corrosion of furnace heat exchangers as a result of this approach to ventilation and make-up air. Many HVAC installers have also raised the issue that this design may in fact void manufacturer warranties for the furnace.

While this system appears to satisfy the ventilation requirements in principal, there is no long term evidence to demonstrate its effectiveness. This is especially true for applications where the system is intended to be operated on a continuous basis.

OBJECTIVES

The objective of this project is to collect field data to address concerns regarding the potential limitations of this system, and to identify or recommend improvements to the system to ensure optimum performance. Specifically the project will address the following issues:

1) Is there any evidence of accelerated corrosion of furnace heat exchangers as a direct result of this ventilation system.

2) Is there any evidence of complaints of drafts as a result of this system.

3) What are the opportunities and impacts for installing high wall diffusers for this type of system. High wall diffusers have the advantage of minimizing potential for drafts and in some circumstances may eliminate the need for a duct heater. What are the relative energy impacts of floor versus high wall diffusers. What are the differential costs.

4) What are the actual flow rates for this system. Are the assumed suction pressures (20 pa) in the return air system consistent with designs installed in the field.

5) What is the minimum distance for the connection of the fresh air duct to the return air to ensure proper mixing of the two air streams. Are current guidelines based on definitive field data.

6) What are the energy impacts of a fresh air duct hard connected to the return air system.

METHODOLOGY

Heat Exchanger Inspections

During the heating season, furnace heat exchangers may be exposed to low temperature air during the furnace off-cycle when a fresh air duct is hard connected to the return air system. In many parts of the country the dew point, in a basement environment, will be approximately 13°C. There was some concern that the fresh air that enters a heating system during the off-cycle could cause the heat exchanger temperature to drop below that level, causing condensation to form and premature heat exchanger failure due to corrosion. The portion of the heat exchanger immediately above the pilot light of a gas furnace may be the area most susceptible to corrosion. The best way to inspect for such corrosion is through visual inspection.

Three gas utilities, Union Gas in Southwestern Ontario, North Western Utilities in Edmonton and B.C. Gas in British Columbia, cooperated to provide locations and personnel to inspect furnace heat exchangers, measure air flows and to survey owners of homes with ducts connecting the outdoors with the return air system of a furnace.

Heat exchangers were visually inspected for any signs of excess rusting. The service technicians' general overall experience with systems with and without hard connected fresh air ducts, provided the basis of comparison for the heat exchanger inspections.

Since it was important to know the operating parameters of the inspected systems, the following measurements, checks and calculations were made:

1) The total heating system airflow was calculated using the temperature rise method (Btuh output divided by 1.1 times the temperature rise).

2) The size of the fresh air duct was recorded and the air flow was measured using a Dwyer Series 470 Thermal Anemometer.

3) The total system air flow and the ventilation air flow were used to calculate the anticipated mixed air temperature in the return air system at the January outside design temperature. The formula used was as follows:

$$MAT = T1 - ((T1-T2) * V2/(V1+V2))$$

Where:
- MAT = mixed air temperature
- T1 = indoor air temperature
- T2 = outdoor air temperature at design conditions
- V1 = volume of dwelling air being mixed with fresh air
- V2 = volume of outdoor air being mixed with indoor air

4) The operating method of the system was defined according to one of the following:

a. The furnace blower only operated when the thermostat called for heat and the fan switch reached a sufficient level to activate the furnace blower.

b. Method "a." and as required through the use of a manually operated switch.

c. Method "a." and in addition, when a humidistat activated the blower because the indoor humidity level had exceeded a preset level.

d. A combination of "a.", "b." and "c.".

5) Furnace age was recorded.

6) The amount of rust on the heat exchanger was recorded and compared to other furnaces that were not used as an air handler for ventilation air.

7) The presence of insulation and a vapour barrier on the fresh air duct was recorded.

Owner Survey

The owners of each house tested were surveyed to determine:

1) The owner's awareness of the presence of a ventilation system;

2) The method of ventilation system control practised by the owner;

3) The presence of any comfort problems created by the ventilation system (relevant if the ventilation system is activated at times when the furnace was not also operating and tempering the ventilation air); and

4) If the house is too dry during the winter (a possible sign of excess ventilation).

An additional ten other homeowners with a fresh air duct hard connected to the return air system were surveyed

Cost of High-Wall Supply Outlet Installation

Good design practice and the HRAI Digest (referenced in the National and Provincial Building Codes) requires that the discharge air temperature from floor diffusers exceed 18 °C (65 °F). The reason for this is that these diffusers do not provide sufficient cold air throw and air mixing at the pressures and velocities encountered in residential applications. They are designed to deliver warm buoyant air. In most parts of the country, if incoming fresh air is not tempered through the use of a duct heater or a heat recovery ventilator, the mixed air temperature in the distribution system will be below 18 °C during the coldest portion of the heating season. When the delivered air temperature is below 18 °C, high inside wall diffusers must be used. If these high wall supply outlets are used, they can deliver air as cool as 13 °C without causing discomfort. Tempering of ventilation air can be done through the addition of an HRV (expensive) or a duct heater (costly to operate). If in those parts of the country where the outside design temperature exceeds -12 °C and where high inside wall outlets are used, there would be no need for an HRV or a duct heater, since the mixed air temperature would exceed 13 °C. In colder areas where some tempering would still be required, the amount of required tempering would be much less.

The temperature of the mixed outdoor air and recirculating indoor air in the return air system of a furnace must exceed 13 °C (55 °F) to ensure that no condensation occurs on the ducts or furnace heat exchanger (CSA F326). In addition, some furnace manufacturers require that the minimum temperature of the air passing over the heat exchanger is at least 13 °C for conventional furnaces and 15.5 °C (60 ° F) for mid-efficiency furnaces.

To determine the practicality of using high inside wall supply outlets, two heating contractors, one in Toronto and one in Edmonton, were asked to calculate the additional labour and material costs, per duct run, to install such outlets, instead of the traditional floor outlets.

To calculate the approximate operating cost of a duct heater used to temper fresh air, a typical house with 186 m^2 (2000 ft^2) of living space (not including basement) located in Toronto was selected. The average monthly outdoor temperature provided by Environment Canada was used to calculate the average mixed air temperature in the return air duct. The total kilowatts required to temper this air to both 18°C for use with normal floor registers and to 13°C for delivery by high inside wall outlets was calculated. The kilowatt hour cost reflects Ontario Hydro's current 1991 rate. In addition, the cost of tempering the fresh air to 18°C with natural gas was calculated using 1991 rates provided by Union Gas. Knowing the gas rate to heat this air allowed the extra cost for the operation of duct heater to be calculated. In all cases, it was assumed that the ventilation was continuous at a rate of 1/3 ach. (See the "Operating Cost of a Duct Heater Used to Temper Ventilation Air" table in Appendix B.)

Test House

A test house, owned by Howell-Mayhew Engineering Inc. (HME) in Edmonton, was used to conduct a series of tests that could only be effectively conducted in such a controlled and instrumented environment.

Test measurements were carried out in the Cold Climate Demonstration House, an R-2000 bi-level house. The data was gathered and processed with a computerized monitoring system using CoPilot software developed by HME. The following sensors were used to measure a number of parameters:

1. Temperature - T-type thermocouples measured the:

a) fresh air entering at the weather hood;

b) combustion air entering at the weather hood;

c) fresh air entering the return air plenum;

d) combustion air leaving the cold air trap;

e) return air at the upper level inlet grill;

f) return air entering the furnace plenum;

g) mixed fresh/return air entering the furnace;

h) heated supply air in the furnace plenum;

i) supply air to the main floor room nearest the furnace;

j) supply air to an main floor room far from the furnace;

k) supply air to a lower level room.

2. <u>Air Flows</u> - Modus pressure transducers and CES flow measuring stations measured the:

a) fresh air into the return air plenum;

b) combustion air into the mechanical room;

c) the furnace flow.

3. <u>Pressure</u> - A micromanometer measured rim joist pressure.

One-time as well as continuous measurements were carried out to determine airflows and temperatures at different exhaust flow rates and to determine the migration of the fresh air during the furnace off cycle. The characteristics of the house and ventilation system were as follows:

1. <u>Furnace:</u> vertically vented medium efficient, power-vented, gas-fired

2. <u>Water heater:</u> power-vented, gas-fired

3. <u>Fresh/supply air duct:</u> 125 mm (5") diameter insulated flexible duct, 7.6 m (25 feet) long, hard ducted into the furnace return air plenum, one 90° bend, four 45° bends

4. <u>Combustion air duct:</u> 125 mm (5") diameter insulated flexible duct, 9 m (30 feet) long terminating in a cold air trap, one 90° bend, four 45° bends

5. <u>Exhaust fan:</u> HRV operating as an exhaust only system and drawing from bathrooms and kitchen

<u>Continuous Airflow and Temperature Monitoring</u>

The purpose of this monitoring was to determine the flow path of the fresh air during the furnace off cycle. To determine where this fresh air went once it entered the fresh air duct, temperature measurements were made at various locations in the heating system, including the furnace.

RESULTS

Heat Exchanger Inspections

During the spring of 1991, the furnaces of 13 homes in Ontario, 8 in B.C. and 11 in Alberta were inspected. The houses were a wide variety of ages and all had fresh air ducts hard connected to the return air system of the furnace. The furnace heat exchangers were examined for signs of premature rust that may have been caused by condensation that resulted from the introduction of cold outdoor air. The fresh air duct flow rate was measured and the total flow through the furnace was calculated using the temperature rise method to determine if the mixed air temperature in the return system would be sufficiently cool during the heating season to cause the formation of condensation on the heat exchanger.

The British Columbia Sample

The B.C. Building Code provides two ventilation flow rate options for houses with up to 200 m^2 total floor area, approximately .28 ach if controlled automatically by a dehumidistat and half of that if continuously supplied. For houses over 200 m^2, 40 l/s must be provided automatically regardless of house size, or if continuous ventilation is provided, 30 l/s is required for a 300 m^2 house and 40 l/s for a 400 m^2 or larger house.

All of the ventilation ducts in British Columbia were not insulated, however, because of the milder climate, there were no reports of condensation on these ducts. The flow rates of ventilation air often varied in houses that were identical with similar duct systems because the volume dampers had been partially closed to reduce the air flow. No heat exchangers with premature rusting were found, however, B.C. Gas did provide a video tape of such a heat exchanger. The video showed a heat exchanger corroded at the point where the standing pilot flame gases contacted the heat exchanger where they had condensed.

Most of the ventilation systems encountered were only operational when the furnace was on and producing heat. Those that did operate during the furnace off cycle were, in most cases, operating in temperate climates where the mixed air temperature would never be below the dew point. For this reason, there was very little opportunity to assess systems that operate continually at the flow rates and temperatures that may occur under the new 1990 NBC.

The Alberta Sample

The Alberta Building Code requires that all dwelling units be equipped with a fresh air ventilation system capable of providing at least 1/2 ach through a combination of exhaust fans and a fresh air duct connected to the furnace return air system. The Alberta Gas Code requires that combustion air be provided to furnaces that use house air for combustion. Most of the fresh air supply ducts and the combustion air ducts examined were insulated and vapour barriered (See Photos 3 and 4).

Only two of the heat exchangers examined showed any sign of premature rusting in relation to the heat exchangers regularly seen by the service technicians on furnaces that were not part of fresh air ventilation systems, both of those in Alberta. Neither of the furnaces should be experiencing any condensation because of the ventilation system, as the fresh air flow was very low and the mixed air temperature would be above 18 °C at design temperature, well above the minimum of 13 °C that would normally cause condensation problems. The extra rust may be attributable to the type of metal alloy used for the heat exchangers by those particular furnace manufacturers. Though some rust was found on most, it was very light and typical of most furnaces of the same age.

The ventilation systems encountered were only operational when the furnace was on and producing heat.

The Ontario Sample

There was great difficulty finding a sufficient number of heating systems with fresh air ducts connected to the return air trunk duct in Ontario. This is primarily because fresh air ventilation was not a Building Code requirement in Ontario until 1991. At the time of testing, few if any houses had been completed in accordance with the new Code requirements.

Thanks to the service personnel at Union Gas, two detached dwellings were found with such fresh air vents, though they were modulated somewhat by B.D. Waite humidity control volume dampers (See photo 2) and an additional eleven townhouses with 200 mm (8 inch) fresh air ducts were inspected. These 65 m^2 - 88 m^2 (700 ft^2 - 950 ft^2) townhouses were considerably over ventilated (by any standard or code). Calculations indicate that the mixed air temperatures would be below the dew point at design temperatures in several of these houses (See Table 2) and in fact both the ventilation duct and the furnace return air trunk duct were covered with condensation in cold weather according to several owners. However, since these houses had little or no exhaust devices to induce air flow during the furnace off cycle and because the furnace blower only operated during the heating cycle, the heat exchanger was not likely exposed to any condensation. No premature rusting of heat exchangers was found in any of the Ontario houses sampled.

The Ontario houses with large 200 mm (8") fresh air ducts, had high ventilation rates. The ventilation ducts were only insulated for the first 1 to 2 metres. The insulation had no vapour barrier and like the bare ducts themselves, became soaked in condensation during the winter.

Photo 1 - House in Guelph Ontario With a Hard Connected Fresh Air Duct Connected to the Return Air System

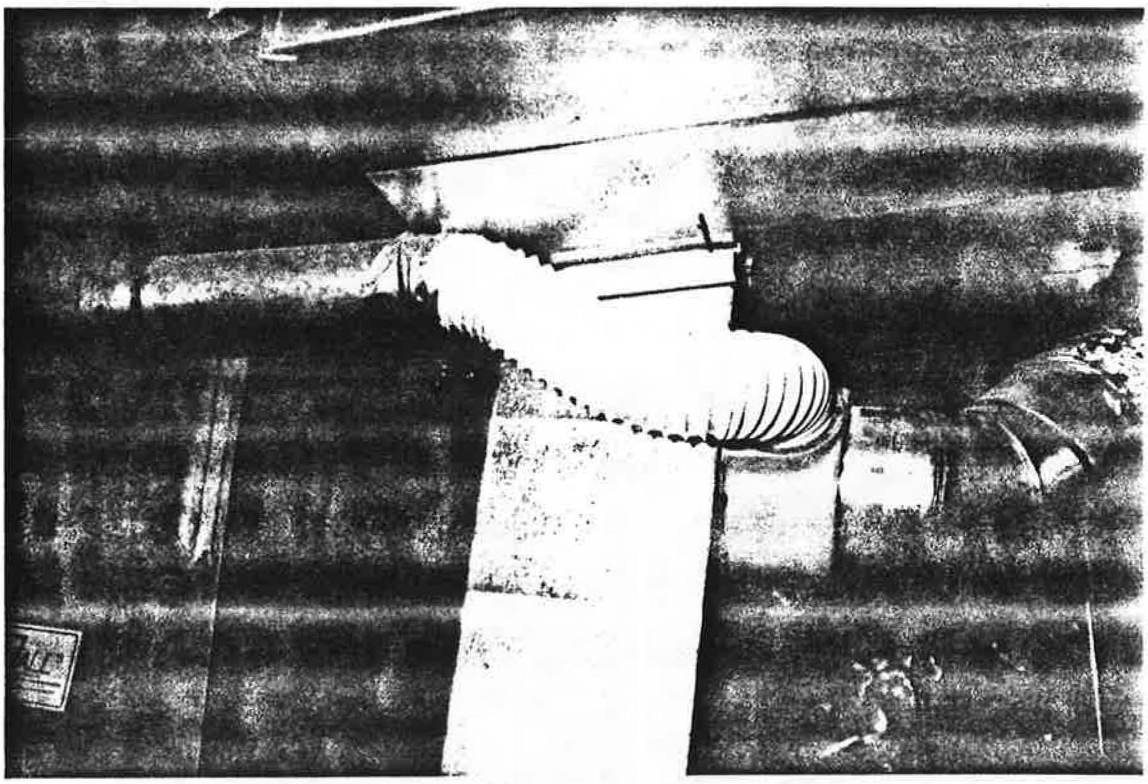


Photo 2 - Fresh Air is Drawn-in when the Furnace Blower Operates and When the Humidity in the Return System is Sufficiently High So That a Waite Humidity Activated Damper Opens

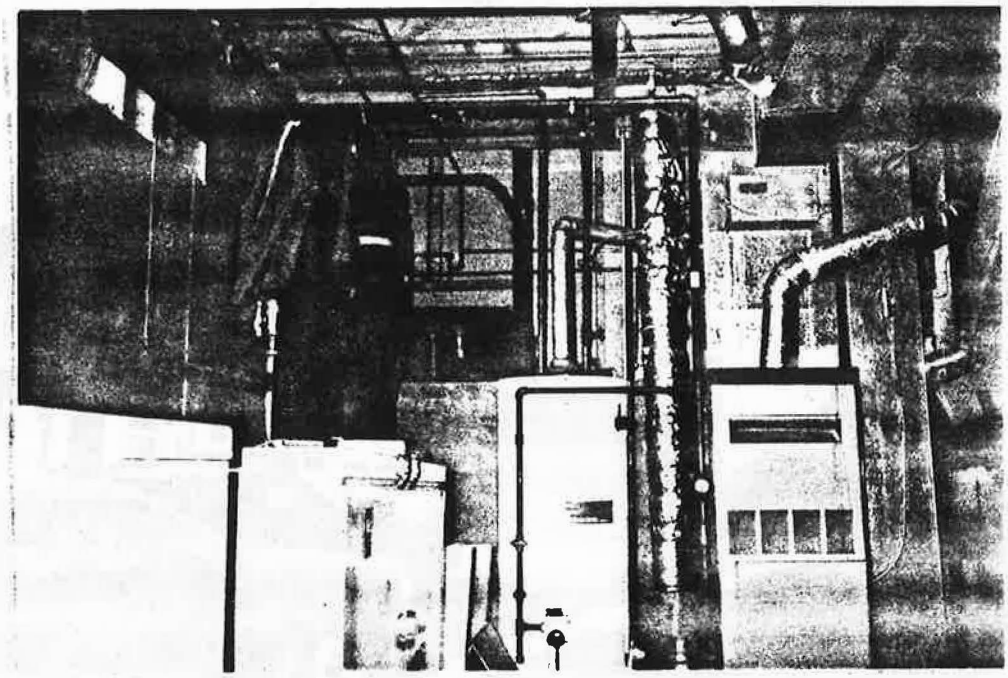


Photo 3 - Insulated Combustion Air Duct - Edmonton
(In most cases in Alberta, both the combustion and fresh air ducts were insulated.)

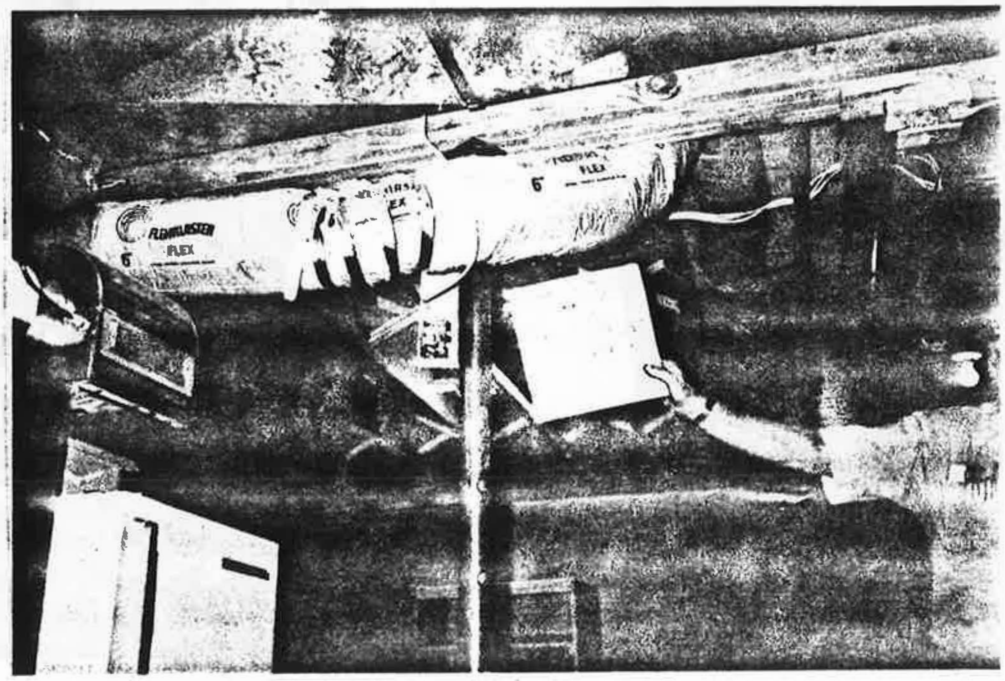


Photo 4 - Insulated Fresh-Air Flex Duct - Edmonton

Homeowner Surveys

Most of those surveyed knew their house had a fresh air ventilation system. This may be partially accounted for by the fact that the majority of those surveyed in British Columbia and Alberta worked for the utility. Those few systems that had a manual control were seldom activated by the owners, perhaps because most of them would have been required to open the furnace cabinet to activate the fan switch. The twelve home owners interviewed in Ontario did not have much understanding of the purpose of fresh air ventilation or the operation of their system. Most, with exception of British Columbia home owners, felt that there house was too dry in winter - some had added humidifiers as a result. This may, though not necessarily, be an indication of ventilation levels that are too high. Few comfort complaints were received, possibly because most of the systems only operate when the furnace is producing heat.

SUMMARY OF OWNER SURVEY

HOUSE # & LOCATION	AWARE OF VENTILATION SYSTEM	CAPABILITY OF MANUAL OPERATION	HOW OFTEN USED MANUALY	VENTILATES ONLY WHEN FURNACE ON	DISC. CAU! SYST	SUPPLY AIR TEMP.*	HOUSE TOO DRY IN WINTER	CONDENSATION ON VENT. DUCT IN WINTER	OTHER COMMENTS
Guelph 1	yes	yes/fan switch	never	yes	none	64.6	no	no	Waite humidity controlled damper
Guelph 2	yes	yes/fan switch	never	yes	none	58.3	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 3	yes	yes/fan switch	never	yes	none	45.3	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 4	yes	yes/fan switch	never	yes	none	38.5	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 5	no	yes/fan switch	never	yes	none	44.6	yes	??	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 6	no	yes/fan switch	never	yes	none	58	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 7	yes	yes/fan switch	never	yes	yes	59.2	yes	yes	kitchen floor cold from cold air in RA joist space
Guelph 8	yes	yes/fan switch	never	yes	none	42.1	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 9	yes	yes/fan switch	never	yes	none	50.9	no	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 10	yes	yes/fan switch	never	yes	none	47.9	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 11	yes	yes/fan switch	never	yes	none	48.2	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 12	yes	yes/fan switch	never	yes	none	52.5	yes	yes	Insulation on vent. duct with no vapour barrier is soaked in winter
Guelph 13	yes	yes/fan switch	never	yes	none	65.1	no	no	Waite humidity controlled damper
BC 1	yes	yes/fan switch	never	yes	yes	68.3	no	no	
BC 2	yes	none	na	yes	none	68	no	no	Owner- system works well
BC 3	yes	yes	continuously	no	none	68.4	no	no	2 speed blower
BC 4	yes	Dehumidistat	?	yes+humidistat	yes	68.4	no	no	
BC 5	yes	yes	continuously	no	none	51.4	no	no	
BC 6	yes	no	na	yes	none	69.3	no	no	Had cond. problems before vent. system installed
BC 7	yes	yes	occasional	no	none	68.6	no	no	
BC 8	yes	Dehumidistat	Dehumid.not used	yes	none	67	no	no	
Alta 1	yes	?	?	?	?	64.5	yes	no	HRV installed
Alta 2	yes	yes/fan switch	never	yes	none	67.9	yes	no	
Alta 3	yes	yes/fan switch	never	yes	none	63.2	yes	no	
Alta 4	yes	yes/fan switch	never	yes	none	62.9	yes	no	Owner wants humidifier
Alta 5	yes	yes/fan switch	never	yes	none	53.1	yes	no	Blocks vent. in winter
Alta 6	yes	yes/fan switch	never	yes	none	64.2	yes	no	
Alta 7	yes	yes/fan switch	never	yes	none	64.4	no	yes	
Alta 8	yes	yes/fan switch	never	yes	none	65.4	yes	no	
Alta 9	yes	yes/fan switch	never	yes	none	64.7	no	no	Never use humidifier
Alta 10	yes	yes/fan switch	never	yes	none	62.1	no	no	Was too dry, now humidifies
Alta 11	yes	yes/fan switch	never	yes	none	67.1	yes	no	Humidifies
Alta 12	yes	yes	continuously	no	none	na	yes	no	
Alta 13	yes	no	na	yes	none	na	no	no	
Alta 14	yes	no	blocked in wtr	yes	none	na	no	no	
Alta 15	Inappropriate ventilation system for this study								
Alta 16	no	no	na	yes	none	na	yes	?	Added humidifier
Alta 17	yes	no	na	yes	none	na	yes	no	
Alta 18	yes	no	na	yes	none	na	no	?	
Alta 19	yes	no	na	yes	yes	na	yes	at damper	damper 3/4 closed in wtr
Alta 20	yes	no	na	yes	none	na	no	?	
Alta 21	yes	no	na	yes	none	na	yes	?	

* Supply air temperature is only applicable if furnace blower is operated at its highest blower speed when the furnace is off.

SUMMARY OF FURNACE INSPECTIONS

HOUSE AND LOCATION	FURNACE OUTPUT BTUH	FURNACE TEMP. RISE	CALCULATED TOTAL SYSTEM CFM	VENT. DUCT SIZE INCHES	MEASURED VENT. AIR VELOCITY FPM	VENT. AIR VOLUME CFM	OUTSIDE WTR DESIGN TEMP. DEG. F	CALCULATED MIXED RETURN AIR TEMP. F.	HEAT EXCHANGER RUST COMPARISON	VENT. DUCT INSULATED	SYSTEM OPERATION METHOD
Guelph 1	57000	60	864	5	429	60	-2	64.6	average	no	furnace
Guelph 2	61500	50	1118	8	450	156	-2	58.3	average	1st 6 ft	furnace
Guelph 3	61500	55	1017	8	750	260	-2	45.3	average	1st 5 ft	furnace
Guelph 4	61500	70	799	8	700	243	-2	38.5	average	1st 3 ft	furnace
Guelph 5	61500	60	932	8	700	243	-2	44.6	average	1st 10 ft	furnace
Guelph 6	61500	54	1035	8	425	147.6	-2	58.0	average	1st 10 ft	furnace
Guelph 7	61500	70	799	8	300	104	-2	59.2	average	no	furnace
Guelph 8	61500	60	932	8	750	260	-2	42.1	less rusty	no	furnace
Guelph 9	61500	45	1242	8	750	260	-2	54.9	average	1st 6 ft	furnace
Guelph 10	61500	54	1035	8	700	243	-2	53.1	less rusty	1st 3 ft	furnace
Guelph 11	61500	50	1118	8	750	260	-2	53.3	average	1st 10 ft	furnace
Guelph 12	61500	45	1242	8	700	243	-2	55.9	more rusty	1st 8 ft	furnace
Guelph 13	49000	50	891	5	390	57	-2	65.4	average	no	furnace
B.C. 1	84000	84	909	6	150	29	19	68.4	average	no	furnace/manual
B.C. 2	80000	80	909	4	400	35	19	68.0	average	bare	furnace/manual
B.C. 3	72000	90	727	3	450	22	19	68.5	average	bare	continuous 2 spd
B.C. 4	79800	87	834	4	300	26	19	68.4	average	bare	furnace
B.C. 5	68000	95	651	7	500	173.6	19	56.4	average	bare	continuous
B.C. 6	68000	44	1405	4	225	19.5	19	69.3	average	bare	furnace/manual
B.C. 7	104000	110	860	4	250	22.5	19	68.7	average	bare	furnace/manual
B.C. 8	84000	105	727	4	470	41	19	67.1	average	bare	furnace/manual
ALBERTA 1	79680	55	1317	6	380	75	-26	64.5	much more rusty	?	furnace
ALBERTA 2	121260	70	1575	4	400	34.7	-26	67.9	average	yes	furnace/manual
ALBERTA 3	109572	56	1779	6	650	126.4	-26	63.2	average	yes	furnace/manual
ALBERTA 4	80685	40	1834	6	700	136.1	-26	62.9	less rusty	yes	furnace/manual
ALBERTA 5	79712	90	805	6	800	150	-26	52.1	less rusty	yes	furnace/manual
ALBERTA 6	87035	60	1319	5	575	79.9	-26	64.2	much more rusty	yes	furnace/manual
ALBERTA 7	56832	62	833	5	350	48.6	-26	64.4	less rusty	bare	furnace/manual
ALBERTA 8	84975	56	1379	5	475	66	-26	65.4	average	yes	furnace/manual
ALBERTA 9	91124	94	881	5	350	48.6	-26	64.7	average	yes	furnace/manual
ALBERTA 10	85696	85	917	4 ?		75	-26	62.1	less rusty	yes	furnace/manual
ALBERTA 11	98400	90	994	4	350	30.4	-26	67.1	average	yes	furnace/manual

Test House

The Edmonton test house provided a great deal of valuable information. The house was a relatively air-tight R2000 house with an air change rate of 1.11 at 50 pa. A mid-efficiency gas furnace was installed, therefore, to simulate a chimney when required, an upstairs window was opened 13 mm (1/2 inch) to provide the free area of a typical gas furnace vent (125 mm or 5 inch). An HRV was used to simulate the operation of exhaust devices in the house through the operation of only the exhaust side fan. A maximum exhaust flow rate of 65 l/s (130 cfm) could be achieved by the HRV. A combustion air duct of 125 mm (5") was installed in the house, the same diameter of the fresh air duct connecting the furnace return air to the outdoors. Since both the ventilation duct and the combustion air duct were considered to be inlet ducts, they were located only 330 mm (12 ") apart. Because of the design of the house, the rim joist area used to measure the house pressure as it was located close to the natural neutral pressure plane position when all exhaust and supply devices were inoperative.

Though tests were run with no exhaust fan running and then when exhausting at 25 l/s, 35 l/s, 45 l/s, 55 l/s and 65 l/s, only the results of the exhaust fan off and the 65 l/s test will be discussed here because they most dramatically show the operation of the house systems. See Table 3 for the complete test results.

Operation With the Exhaust Fan Off

This test shows what will happen in a tight house with a supply only system operating and all exhaust devices shut down. Before operation of the furnace, the air flow rate in the ventilation and combustion air ducts were 3.4 l/s and 4.9 l/s respectively, the likely due to the natural stack effect in the house. With the furnace operating at high speed, 499 l/s (1000 cfm), the pressure at the rim joist increased from 0.0 to 3.3 pa. The air flow rate in the ventilation duct increased to 48.7 l/s and the combustion air duct, acting as a pressure relief opening, began to exhaust air at the rate of 8.6 l/s. Since both the ventilation duct and combustion air duct inlets were located relatively close together, 300 mm (1 ft), the air exiting from the combustion air duct was partially short circuiting and entering the ventilation air duct. Opening a window to simulate a chimney had little effect on the ventilation air flow but did reduce the exhaust rate from the combustion air duct to 4.9 l/s. With both the window (chimney) and combustion air inlet open, the pressure at the rim joist, with the furnace blower at maximum speed and ventilation flow rate at its maximum, was only 1.5 pa. When the combustion air duct was sealed closed, the window closed (chimney) and the furnace blower was operated at high speed, the house was pressurized to 2.5 pa at the rim joist by the fresh air supply, however, if a window was opened to simulate the presence of a chimney, the pressurization was reduced to .5 pa. For some undetermined reason, pressure at the rim joist was greater (3.3 pa) when the window was closed and the combustion air inlet open, than when both the window and combustion air inlet were closed (2.5 pa), with the furnace blower operating at high speed. The opposite should have been true. Perhaps the wind conditions were such that neutral pressure point that was usually at the level of the rim joist pressure measurement, when all supply and exhaust devices were off, had shifted at the point of measurement because of local internal pressure effects.

This test showed that in a tight house, a supply only system providing 1/3 ach may not cause excessive internal positive pressure changes even though there is no pressure relief device such as a chimney or combustion air inlet. In a house that was not so tight, or where a conventional furnace and or a combustion air inlet was installed, the positive pressure caused by the supply-only ventilation system should be even less. For more details, see Table 3 in Appendix C. Table 3a has been reproduced with an explanation of the test results on the following page.

Operation With Exhaust Fan Exhausting 65 l/s (130 cfm)

When operated at 65 l/s (130 cfm), with no fresh air supply being mechanically provided, house pressure at the rim joist decreased to -6.3 pa, enough to cause spillage from a naturally aspirated furnace. The negative pressure induced a flow of 14.9 l/s through the combustion air duct and 15.9 through the ventilation air duct. These two ducts provided a total of 30.8 l/s, almost half that being exhausted, when no chimney was present (the balance being provided through envelope leakage). When a window was opened to simulate a typical chimney, the total air flow through the two ducts decreased to 19.9 l/s, indicating that a 125 mm (5") chimney would supply approximately the same amount of air as either the 125 mm combustion air duct or the 125 mm ventilation air duct, approximately 10 l/s. During high speed operation of the furnace blower, the ventilation air flow rate was 51.2 l/s and the combustion air duct flow rate was 8.6 l/s, for a total of 59.8 l/s, almost equal to the 65 l/s exhaust rate. The negative pressure at the rim joist reduced to 3.3 pa. Opening the window to simulate the presence of a chimney had little effect on flow rate but did reduce the negative pressure at the rim joist to only .8 pa.

This test indicates that in a tight house, an exhaust device removing only 65 l/s of air, could de-pressure the house sufficiently to cause combustion spillage even when both a fresh air duct connected to the furnace return air system and a combustion air supply is present. It appears that when the furnace blower comes on, even at medium speed (the low speed setting), sufficient air is introduced to the house to reduce the negative pressure to an acceptable level. This means that a conventional furnace may spill until the blower comes on and then establish a draft. A conventional gas water heater would also spill unless the furnace blower came on. If the furnace blower was left on continuously, neither water heater nor furnace spillage would likely occur in a tight house with an exhaust device operating at less than 65 l/s. (An even higher exhaust rate may have also caused no problem providing the furnace blower was left on continuous run, however, we did not measure the upper limit of safe exhaust rate.) For more information see Table 3 in Appendix C. Table 3c has been reproduced with an explanation of the test results on page 19.

VENTILATION SYSTEM USING A HARD DUCT CONNECTION BETWEEN THE FURNACE RETURN AIR SYSTEM AND THE OUTDOORS

Table 3a: ONE–TIME MEASURMENTS OF AIRFLOWS, TEMPERATURE AND PRESSURE

Test Measurements With Exhaust Fan Off

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Furnace Fan	L/s	OFF	340	499	OFF	346	489	OFF	325	473	OFF	342	482	OFF	345	503	OFF	346	499	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	0.9	13.8	17.7	1.3	12.0	15.0	1.8	1.1	1.0	0.7	0.5	0.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	0.9	3.5	3.2	1.3	2.4	1.7	n/a	n/a	n/a	n/a	n/a	n/a	0.6	0.6	0.3	0.7	0.5	0.7	−0.6	−0.6
Rim Joist Pressure	Pa	0.0	1.8	3.3	0.0	0.3	1.5	0.0	0.0	0.0	−1.0	−1.0	−1.0	−0.5	1.3	2.5	−0.8	0.0	0.5	0.0	−1.0
Ventilation Air Flow	L/s	3.4	32.5	48.4	5.6	33.9	48.7	0.0	0.0	0.0	0.0	0.0	0.0	6.9	34.0	49.3	7.3	33.9	49.3	0.0	0.0
Combustion Air Flow	L/s	4.9	−5.7	−8.6	6.2	−2.4	−4.9	4.0	4.0	4.8	6.9	7.2	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		705	715	720	725	730	735	805	809	812	815	820	822	827	830	833	836	839	842	612	625

Combustion-air inlet is exhausting instead of supplying air.

Air exhausting from combustion air inlet is short circuiting to ventilation air inlet.

Chimney is partially relieving positive pressure created in the house by the ventilation system.

The additional stack effect created by the presence of a chimney, causes increased air flow in the ventilation duct when the furnace blower is off.

Shows chimney creates a stack effect of −1.0 pa in this house.

VENTILATION SYSTEM USING A HARD DUCT CONNECTION BETWEEN THE FURNACE RETURN AIR SYSTEM AND THE OUTDOORS

Table 3c: ONE–TIME MEASURMENTS OF AIRFLOWS, TEMPERATURE AND PRESSURE

Test Measurements With Exhaust Fan @ 65 L/S

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Furnace Fan	L/s	OFF	363	498	OFF	361	500	OFF	339	482	OFF	352	480	OFF	357	495	OFF	365	500	OFF	OFF
Fresh/Makeup Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	9.3	9.4	9.9	10.3	10.7	9.2	8.7	8.6	8.3	7.8	8.4	7.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fresh/Makeup Air Hood Temp.	°C	9.5	9.4	10.2	10.4	9.3	9.2	n/a	n/a	n/a	n/a	n/a	n/a	9.0	9.1	9.0	10.2	9.3	8.4	−0.6	−0.6
Rim Joist Pressure	Pa	−6.3	−3.5	−3.0	−1.0	−1.0	−0.8	−8.	−8.5	−8.5	−3.8	−3.8	−3.0	−8.3	−5.5	−2.0	−2.8	−1.3	−0.8	−14.0	−6.0
Fresh/Makeup Air Flow	L/s	15.9	37.5	51.2	10.2	36.5	51.9	0.0	0.0	0.0	0.0	0.0	0.0	18.0	38.5	51.6	12.9	37.0	50.6	0.0	0.0
Combustion Air Flow	L/s	14.9	11.9	8.6	9.7	7.5	8.4	17.6	17.6	17.8	14.4	14.2	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		1352	1355	1358	1401	1404	1407	1413	1416	1419	1423	1427	1430	1436	1439	1442	1445	1448	1451	622	635

Exceeds acceptable limits for naturally aspirated furnaces.

Chimney supplying about 5 l/s.

Unacceptable levels of depressurization for a naturally aspirated appliance.

Indicates ventilation duct is an effective make–up air source.

Chimney supplying about 10 l/s.

Chimney is providing about 5 l/s of air.

Fresh Air Migration in the Heating/Ventilating System When the Furnace Blower is Off

The above tests indicated that the ventilation air duct will operate as a make-up air duct when the furnace blower is off, if a negative pressure is present.

The tests showed that very little air flows upstream through the cold air return ducts. The cold outdoor air tended to migrate towards the furnace, collect in the furnace which acted as a large "P" trap after the warm air present in the furnace had been replaced by much colder outdoor air. Eventually, if the furnace off cycle was sufficiently long, the furnace "P" trap completely filled with cool air which then spilled out into the supply system, flowing only a short distance in the trunk duct (after a furnace off period of approximately 45 minutes). With an outdoor air temperature of 1.8 °C, the air temperature in the furnace, after four hours, decreased to 11.2 °C. This may be sufficiently cool to cause condensation under some circumstances. A subsequent test when the outdoor temperature reached - .2 °C resulted in the temperature of the air in the furnace reaching 10. 4 °C after only one hour. The temperatures measured in the return air duct and the furnace reflect tempering that has incurred caused by heat gain through the duct from the warmer basement air.

The results of this monitoring are displayed in Table 4. The following points should be noted with regards to the data:

1. The measurements were taken during periods when the thermostat did not call for heat. In colder weather, the furnace will fire more frequently and it is suspected, although not confirmed, that the cooling effect of the ventilation air may not be dramatically different than displayed in Table 4.

2. Each data set represents a furnace off cycle.

3. The fresh air enters the return air plenum approximately 2 m (7 feet) above the point where the mixed air into the furnace is measured.

4. The furnace supply temperature is measured 76 cm (2.5 feet) above the furnace. The supply duct to the lower floor room branches off the supply plenum 46 cm (1.5 feet) higher than the supply temperature measurement point.

This test indicates that fresh air introduced though a 125 mm (5") duct hard connected to the return air system may cause furnace heat exchanger condensation problems under cold weather conditions, especially if a standing pilot light is present, during the furnace off cycle, if the off cycles are prolonged (such as after a thermostat set-back) and/or if significant exhaust devices/appliances are utilized. Usually thermostat set-back periods occur during periods of inactivity or occupant absence, lessening the likelihood of prolonged exhaust device activation. In most parts of the country, normal automatic thermostat operation would probably cause the furnace to come on before the temperature of the air around the heat exchanger cooled sufficiently to reach the dew point. The exception may be an oversized furnace installed in a well insulated house where the outdoor winter temperature is very low. In such a case, the off times may be sufficiently long, and the outdoor air sufficiently cool, to cause the temperature of the heat exchanger to go below the dew point. For more detailed information see Table 4.

FRESH AIR MIGRATION IN DUCT SYSTEM DURING FURNACE OFF-CYCLE

Table 4: CONTINUOUS AIRFLOW AND TEMPERATURE MONITORING

	Data Set 1										Data Set 2						
Flow Measurements (L/s)																	
Flow of Fresh/Makeup Air (L/s)	18.6	18.0	16.6	16.4	15.4	17.1	16.6	16.8	17.1	17.8	13.4	13.6	13.5	13.5	13.4	18.0	16.6
Flow of Exhaust Air Makeup Air (L/s)	65.7	65.7	65.9	65.9	65.8	65.9	66.0	66.0	66.0	65.9	66.8	67.1	66.8	66.8	66.8	66.6	66.6
Furnace Fan	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Temperature Measurements (°C)																	
Fresh/Makeup Air Entering Intake Hood	7.1	5.2	4.9	4.5	3.9	3.1	2.4	2.3	2.0	1.8	0.3	−0.8	−0.5	−1.0	−0.9	−0.6	−0.2
Fresh/Makeup Air Entering Return Air Plenum	9.1	8.7	8.4	8.2	7.8	7.0	6.4	6.3	5.8	5.6	11.3	6.5	5.3	4.7	4.6	3.9	4.1
Return Air Entering Main Floor Register	21.1	20.5	20.1	19.9	19.7	19.6	19.4	19.0	18.5	18.2	21.3	21.0	20.6	20.6	20.2	19.7	19.1
Mixed Air Entering Furnace	19.6	14.7	13.6	13.3	13.0	12.7	12.1	11.9	11.3	11.2	18.0	16.1	13.8	12.6	12.0	11.1	10.4
Supply Air Leaving Furnace	20.6	18.6	17.1	16.3	15.9	15.7	15.1	14.9	14.3	14.3	21.1	20.2	19.2	17.6	16.5	15.5	14.2
Air To Main Floor Room Close to Furnace	21.1	20.1	19.5	19.3	19.1	18.9	18.6	18.4	18.1	18.5	21.5	21.1	20.6	19.9	19.5	18.7	18.1
Air To Main Floor Room Far From Furnace	21.2	21.0	20.7	20.5	20.3	20.2	20.0	19.8	19.4	19.2	22.0	21.7	21.4	21.0	20.8	20.3	19.9
Air To Lower Floor Room	18.9	18.9	18.6	18.5	18.4	18.3	18.0	17.9	17.4	17.5	20.2	20.1	19.8	19.4	1.0	18.8	18.1
Time of Measurement	2021	2036	2051	2106	2121	2151	2221	2251	2351	20	647	652	657	707	717	727	747
Elapsed Time (hrs)		0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.50	4.00		0.08	0.17	0.33	0.50	0.66	1.00

Cost of High-Wall Supply Outlet Installation

A heating contractor in both Toronto (Dearie Contracting) and Edmonton (Accent Heating) provided cost estimates of the additional cost, per run, to install the high inside wall outlets that would allow cooler air to be delivered to occupied rooms without causing comfort problems. Accent heating estimated the additional cost to be \$50 to \$52 per run and Dearie estimated \$40 to \$65. In addition, Dearie Contracting advised that the duct system design procedure could be more complex and therefore costly, and the increased logistics necessary, in the form of trade coordination and an extra site visit, would also add cost. They also said that if the grille selected was not sealed air tight to the duct, air leaking around the perimeter could leave dirt stains on the wall, as commonly found in commercial applications. See Appendix B for more information.

Since high inside wall supply outlets could introduce air as cool as 13°C into a space without causing comfort problems, compared to 18°C for normal floor diffusers, less tempering of the fresh air would be required during cold weather. Though high inside wall outlets would have a higher initial cost, they would reduce the operating cost of the ventilating system.

A typical 187 ft^2 house would require approximately 10 high inside wall outlets for a total additional cost (over floor outlets) of \$500. Calculations show that if the ventilation air for that same house located in Toronto had to be tempered electrically, so that the mixed air temperature in the return air system was above 18°C, the tempering cost would be \$218 annually, at today's rates. The cost to temper that same air by natural gas would be \$97, \$121 less. The cost to electrically temper (duct heater) the air sufficiently to 13°C for high inside wall outlets would be only \$26 annually. That is only about \$14 more than the cost to temper the air with natural gas. These costs assume a continuous ventilation rate of 1/3 ach. The use of high wall outlets would save \$192 in electrical energy annually. Since this cooler supply air would still have to be heated, the approximate cost to do so with natural gas would be about \$84. Therefore, the total savings for the home owner, if high wall outlets were used, would be \$194-\$84 = \$110 annually. This would provide a six year payback for the additional cost of the ten high wall outlets. Of course an HRV could be used to temper the fresh air to 13°C, rather than an electric duct heater, for an even greater annual operating saving, however, the payback period would be much longer because of the high initial HRV cost (approximately \$1300 installed) compared to that of a duct heater (\$400 installed). (See the "Operating Cost of a Duct Heater Used to Temper Ventilation Air" table in Appendix B.)

Best Place to Connect Fresh Air Duct to Return Air Duct

The issue of where to connect the fresh air duct to the return air system has been a concern that can be resolved through the process of elimination.

Though there would seem to be some advantage in having this connection as far upstream from the furnace as possible to allow duct heat gain to temper the air before it reaches the furnace heat exchanger, this option is impractical for two reasons. It would be very difficult to calculate the tempering that may occur and the resulting mixed air temperature at the furnace and portion of the return air duct that could be exposed to temperatures lower than 13 °C, the dew point, would have to be insulated and sealed with a vapour barrier. Therefore, the connection location must be downstream of all other return air branch connections.

This leaves the question of "how close to the furnace can this connection be made". Again the answer is simple. The further from the furnace, the more mixing of cold and warm air that will occur, reducing the likelihood of pockets of very cool air passing over a part of the heat exchanger. Therefore, the ideal location is immediately downstream of the last branch connection to the return air trunk duct. Ideally this distance should be within one foot downstream to take advantage of the substantial turbulence caused by the upstream connection. This turbulence will enhance the mixing of cold fresh air with the recirculating indoor air.

Other Work Conducted

Review of Hudac Mark III and IV Test House Monitoring

Scanada consulting was to review the results of monitoring conducted in the early 1980's at the HUDAC Mark III and IV test houses in Ottawa, for any information on their ventilating systems that might be useful.

Scanada could find little new data in the HUDAC Mark house studies. They did confirm that use of an insect screen instead of a rodent screen on the supply inlet could quickly result in a plugged inlet.

Review of University of Illinois Air Flow Tests

If they could be located, test reports that emanated from the University of Illinois duct and air flow testing done in the 1950's were to be reviewed by Scanada for relevant information.

Scanada was unable to find the University of Illinois information. The project manager attempted to get this information from his original source, James Healy, of the North American Heating and Air Conditioning Wholesalers Association (NHAW), in Columbus Ohio. Though we were seeking information on return air duct connections, all that could be found was information on the supply side. Mr. Healy advised that the Sheet Metal Association of America (SMACNA) had produced a video of air flow in ducts. This video was ordered and reviewed. It was excellent, but again, unfortunately, only addressed supply side air flow and branch duct fittings. SMACNA was contacted by phone to determine if any subsequent research and recording of return air systems was in process or being considered. They advised that there was no research being conducted or anticipated at this time. They did indicate that they could duplicate the kind of testing done on supply systems, on return air systems, for a cost of approximately $50,000.

CONCLUSIONS

Hard ventilation-duct connections to the return air trunk duct of a forced air furnace distribution system do not appear to cause premature rusting of the furnace heat exchanger. It must be kept in mind however, that most of the systems examined only operated when the furnace was operating and those that did operate continuously were located in British Columbia, where the climate is milder.

The air flow in the ventilation ducts examined was approximately what would be anticipated in a designed system where the available static pressure in the return air system would be approximately 15 pa at the normal connection location. There were some exceptions (system design likely by rule-of-thumb) and some systems had dampers purposely closed or partially closed to restrict flow.

None of the ventilation air ducts located in the Ontario sample were insulated for their full length and those with partial insulation had no vapour barrier over the insulation. The lack of continuous insulation and vapour barrier in these homes is an indication that the installing contractors had little or no understanding of basic principles and ventilation systems. This is reinforced by the fact that the ventilation rate in the small Ontario townhouses examined often exceeded two ach. The ducts in the British Columbia homes were not insulated but were not experiencing any condensation problems - likely because of the mild climate. All of the Alberta homes inspected, except one, had insulated ventilation ducts. The one that had no insulation experienced condensation on the ventilation duct in cold weather.

Most of the homeowners interviewed knew that they had a fresh air ventilation system. Those in Ontario knew because they either consciously had the system added to eliminate a moisture problem, or in the case of the townhouses with the high ventilation rate, were experiencing very high utility bills. Most of those in Alberta and British Columbia may have known because they were heating business. Few of the systems examined had a manual control (other than the fan switch on the furnace) so it is difficult to determine owner understanding of the ventilation system operation. Nearly all of those surveyed complained that the house was too dry in winter and several had added humidifiers as a result. This may be an indication that the ventilation rates may be too high, based upon the natural infiltration level of the houses examined, or in the case of the Alberta homes, that the outdoor air is extremely dry.

The Edmonton test house indicated that when a supply only ventilation system is combined with a combustion air supply and or an open chimney, the chimney and or combustion air supply will act as a pressure relief, and exhaust air. It would appear that when a supply-only system is installed, that it may not be necessary to provide an additional combustion air supply because the supply becomes an exhaust as a result of house pressurization. When the furnace blower comes on, the house pressurizes and any spillage occurring should stop. The tests also showed that when the furnace blower is off, that the fresh air duct acts as a make-up air supply when the house is under negative pressure. The ventilation duct and combustion air duct, both coincidently similar in size and equivalent length, provided an almost equal amount of make-up air. When the ventilation air inlet provides make-up air during the furnace blower off cycles, the air moves into the return air system and flows slowly towards the furnace. It then settles in the furnace, which acts as large "P" trap, until after a considerable length of time (longer than normal furnace off-cycles), when cool air will enter the beginning of the supply trunk duct. This cool air sitting in the furnace should be of concern on furnaces with standing pilots, as condensation of the pilot gases could occur on the heat exchanger and cause premature corrosion. B.C. Gas provided a short video of such an occurrence. All gas furnaces now being installed have an electronic ignition systems so the potential problem may be solved. It is unlikely that in most houses, except where a large temperature set-back is made, that the furnace would remain off for a sufficiently long period of time for enough cold air to enter the furnace and cause a problem, especially if there is no standing pilot. The test house was an R2000 house with a low heat loss and could therefore sustain long off-periods after a thermostat set-back, without furnace activation.

Since the use of high inside wall supply outlets has the potential to reduce the need to temper ventilation air being supplied on a continuous basis, the extra cost of such installations was examined. Both the Edmonton and Toronto contractors calculations indicate a premium of approximately $50 per supply run. In a typical Ontario house of approximately 195 m^2 (2100 ft^2), approximately 10 such outlets may be required for an additional total cost of $500 per house. One Ontario contractor interviewed on such an approach was somewhat negative because of the increased complexity of design and logistics required, in addition to the increased costs. Another saw the increased cost as an increase in the installation charge to a builder and therefore an increase in profit. He favoured the approach.

A review of the HUDAC test house studies did not provide any useful information, except that they also found that insect screening on air inlets soon clog with grass and other debris. Unfortunately, the University of Illinois studies on return air systems and branch duct connections could not be located. This information originally came into Canada from a participant in the original research, now working for NHAW in the U.S. This person was contacted, however, he also could not find his records of this research on return air systems. Somehow this valuable information needs to be regenerated. He did provide data on supply systems and take-offs and recommended a review of a SMACNA video on air flow in ducts. This video was reviewed and was found to document the first major supply duct air flow research conducted since the 1950's University of Illinois studies, again however, it only addressed supply air.

RECOMMENDATIONS

None of the systems examined were both designed in accordance with the new NBC 1990 requirements and the HRAI design procedures. A number of houses through-out Ontario (the first province to implement the new requirements) should be examined to determine the actual flow rates in ventilation systems being installed in accordance to the new Code requirements. Since most of the homeowners reported that their house was too dry in winter, it is likely that either the ventilation rates are too high or the natural infiltration rates are higher than expected. A number of new homes built in accordance with the 1990 Code should be airtightness tested and after the coming winter, the occupants should be surveyed, and or the humidity recorded in a number of these houses, to determine if current ventilation rates are higher than required.

Despite the extensive training sessions provided to contractors, by HRAI, a visit to many houses being built in accordance with the new Ontario Building Code indicates that some designers and installers have little or no understanding of basic physics, air movement or ventilation. Better and more practical training courses delivered by knowledgeable trainers may help.

Consideration should be given, by those responsible for the Gas Code, of the need for a combustion air supply when a supply-only ventilation system, providing at least 1/3 ach, is present, because rather than supplying air it would be exhausting air whenever the furnace blower is operating. Installers should be cautioned to not use insect screening on ventilation or combustion air inlets as they soon clog and reduce air flow, as was verified at one of the Alberta homes inspected. Only rodent mesh should be used. Caution should be taken when installing one or more inlets through the envelope because under certain circumstances, a given inlet may become an outlet, and short circuiting of air could take place if the inlets are located too close together.

The duct system configurations and designs used since the early 1950's have reached the point where they should be reviewed with consideration being given to making them more efficient, that is, less blower energy should be required to move air. A review of the SMACNA video shows that some branch take-offs are much more efficient than others. Round elbows are much more efficient than right angle elbows. There is no prescriptive requirement for efficient duct fittings.

Canada should investigate opportunities with SMACNA to conduct research on return air fittings, turning vanes and configurations. Return air systems are the weak link in most forced air systems, being affected to a much greater effect by turbulence caused by branch connections. On the other hand, such turbulence may be a useful tool in some situations to ensure adequate mixing of cold outdoor air with indoor air in a return air duct. SMACNA was contacted and after considerable discussion they indicated that they would reactivate their test apparatus to study return air flows in cooperation with a Canadian project, at a cost of approximately $50,000. This is very good value considering the complexity of the set-up. Such research results, when combined with work already done on the supply-side, could provide the information required to produce a new duct system design procedure that would result in a system that would require much less energy to move the air.

Investigation should be made of the duct design and installation procedure used south of the Mason/Dixon Line in the U.S., where high, inside-wall, supply outlets are the norm. There must be better products and cheaper ways of providing air this way. Especially important is to find a source of low cost high-wall diffusers. We would suggest a Canadian consultant working with John Tooley, an air movement researcher and trainer operating out of Florida - he is excellent.

Since supply-only ventilation systems offer considerable advantages, such as preventing combustion spillage and reducing infiltration of soil gasses, they should be given higher consideration when designing ventilation systems. Such systems also help compensate for the many exhaust devices found in most homes today. The major concern over such systems appears to be moisture problems from exfiltration of air, however, it may be possible to compensate for some of the pressurization through the use of one or more passive ABS plastic pipes leading from bathrooms in the upper level of a house, to the plumbing stack. This was a common ventilation method for bathrooms many years ago. It would also reduce the need for electricity consuming exhaust fans in such rooms and would ensure quick removal of moisture at the source, automatically, without the need for occupant activation of a fan. Such a pressure relief device should be investigated prior to the adoption of CSA Standard F326.

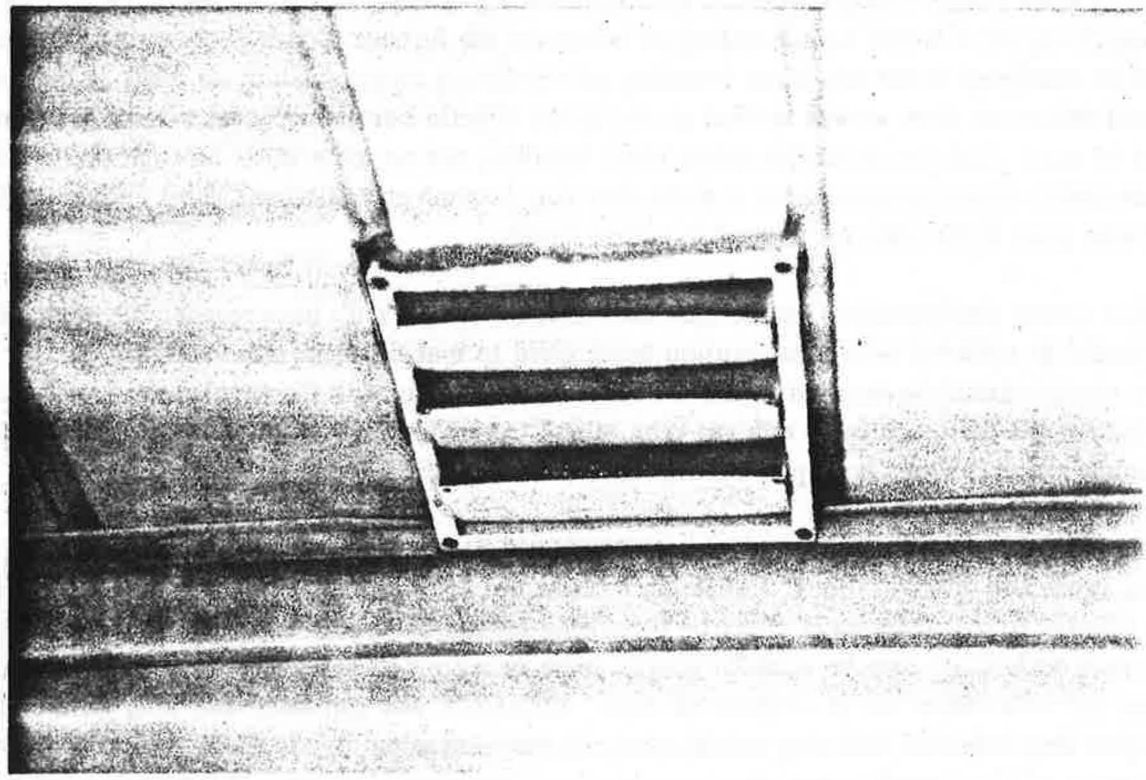


Photo 5 - Example of a Fresh-Air Inlet Vent - Guelph

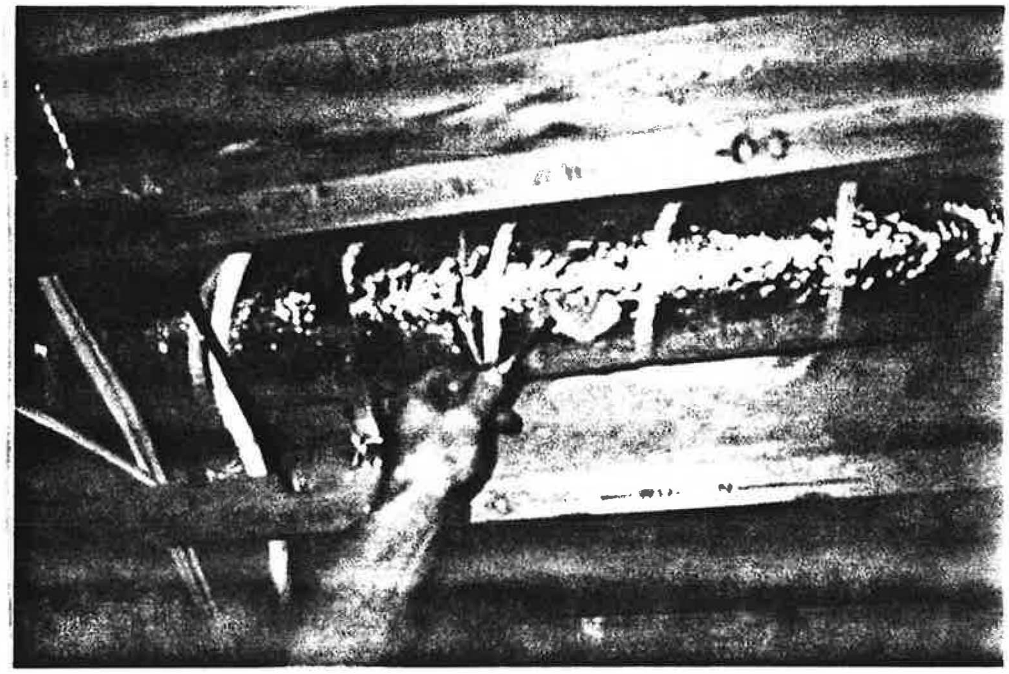


Photo 6 - Puncturing Air Duct to Make Air-Flow Measurement

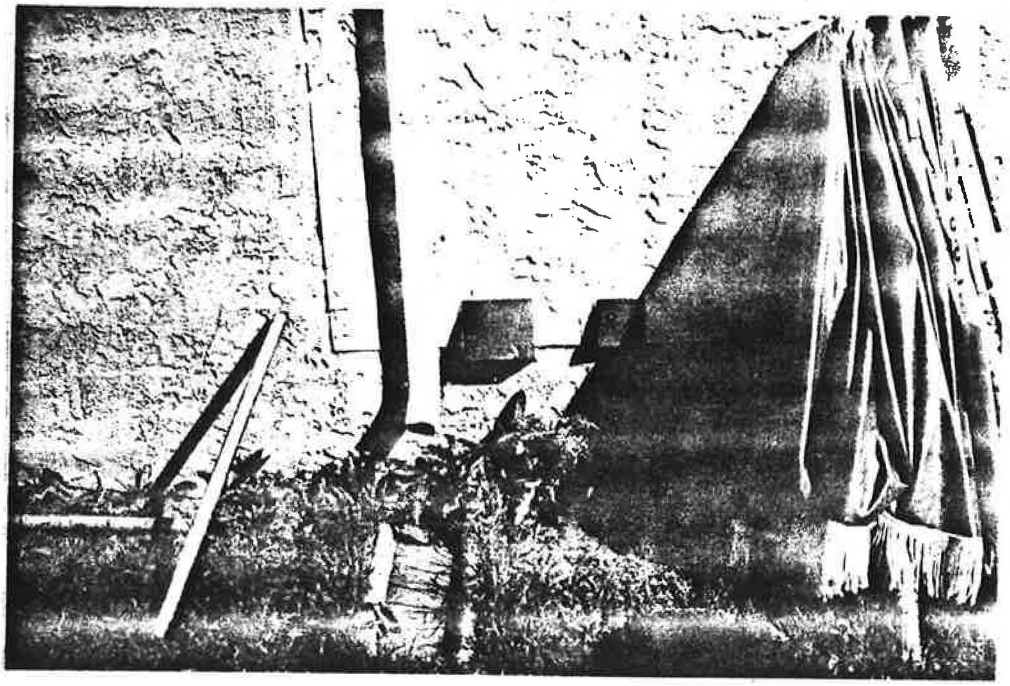


Photo 8 - An Example of the Competition for Wall Space that is Occurring

APPENDIX A

HEAT EXCHANGER INSPECTIONS

AND

HOMEOWNER SURVEYS

HEAT EXCHANGER INSPECTION RECORD FORM

House

House Address ____

Size (including basement) __________ sq. ft.   No. of Storeys _____   House Age _____

Furnace

Make ______________   Model ____________   Output _________ Btuh   Age _____

CFM ______   High Efficiency ___   Medium Efficiency ___   Standard Efficiency ___

Blower operation: Continuously _____   Humidistat Control _____   Manual Control _____

Ventilation System

Type ____________________   Vent Duct Size ____ "   Air Velocity _____ FPM   CFM __

Return Air/ Furnace Total FPM ____ / Trunk duct size ____ or T.R. Calculated CFM* ____

Return Air Mixed Temp. (downstream of fresh-air duct) ____°C   Return Air Static Pressure ____

Heat Exchanger Condition

No Rust _____   Slightly Rusted _____   Moderately Rusted _____   Very Rusted _____

How does the amount of rust compare to a similar furnace of the same age that is used to only circulate air for heating, not heating and ventilating air?

Less Rusty ___   About the same ___   Slightly More Rusty ___   Much more Rusty ___

Air Conditioning

Does this house have central air conditioning? ______________________________

What method and instrument(s) were used to measure air flow? ____________________

____

*** Calculating Total Air Flow Through Furnace**

If measuring the air flow is impractical, it can be calculated by dividing the Btuh output by 1.1 times the temperature rise in °F.

Date _______________   Outdoor Temperature ______ °C

VENTILATION SYSTEM HOMEOWNER/OCCUPANT SURVEY

Name ______________________ Address ____

____ Phone # _________________________

1. Are you aware that your house has a fresh air ventilation system? ______________________

2. Do you control this system manual or is it automatically controlled through continuous operation or a dehumidistat? ____

3. If you answered manual, do you use the system often? ________ If yes, when? ____________

4. If the system is controlled by a humidistat, how often would it come on in a week? _________

5. When operating, does the ventilation system cause any discomfort from cold drafts? Yes No

6. If the system causes discomfort, in which room(s) ___________________________________

and under what circumstances (eg. sitting watching TV) _________________________________

7. In Winter, is your house: Too dry (static & shocks)____ Just humid enough for comfort ___

Very Humid (mould growth or condensation on window frames or inside window pane) _____

8. Is there condensation on the ventilation air duct or any heating system duct, in the winter?

____

9. Do you have central air conditioning? ____

10. Do you have a wood burning fireplace?____ Do you use it often?___ Is it hard to establish a draft at start-up ?____ Is it easier or harder to start when the ventilation system is operating? ___

11. Please add any comments that you would like to make about your ventilation system.

____

____

Date: ____________________ Thank you very much for completing and returning this survey.

APPENDIX B

ADDITIONAL COST OF HIGH INSIDE WALL SUPPLY OUTLETS

OPERATING COST OF A DUCT HEATER USED TO TEMPER VENTILATION AIR TO 65 DEG. F. IN TORONTO FOR A 2000 SQUARE FOOT HOUSE

DUCT HEATER OPERATED WITH CONTINUOUSLY OPERATING FURNACE BLOWER

MONTH	J	F	M	A	M	J	S	O	N	D	YEARLY
AVG OUTDOOR TEMP. C.	–5	–4	1	8	14	19	17	11	5	–2	
AVG OUTDOOR TEMP. F.	23	25	34	46.5	57	66	62.5	52	41	28.5	
MIXED AIR TEMP. F.	58.25	58.75	61.00	64.13	66.75	69.00	68.13	65.50	62.75	59.63	
kW TO RAISE TO 65 DEG. F	1.31	1.21	0.77	0.17					0.44	1.04	
kW/24 HOURS	31.33	29.01	18.56	4.06					10.44	24.95	
kW FOR THE MONTH	939.82	870.20	556.93	121.83					313.27	748.37	3550.42
% OF TIME UNHEATED MAT(3) ABOVE 55 DEG. F.	80%	82%	97%	100%	100%	100%	100%	100%	100%	92%	
EL.COST/24 HRS @ $.0613/kW	$1.92	$1.78	$1.14	$0.25					$0.64	$1.53	
COST PER MONTH	$57.61	$53.34	$34.14	$7.47					$19.20	$45.88	$217.64
COST IF HEATING TO A MAT(3) OF 55 DEG. F	**$11.52**	**$9.60**	**$1.02**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$3.67**	**$25.82**
GAS COST/24 HRS *	$0.85	$0.79	$0.51	$0.11					$0.28	$0.68	
COST/MONTH FOR NATURAL GAS	$25.59	$23.70	$15.17	$3.32					$8.53	$20.38	$96.68
ADDIT. COST FOR DUCT HTR	$32.02	$29.65	$18.97	$4.15	$0.00	$0.00	$0.00	$0.00	$10.67	$25.50	$120.96

DUCT HEATER OPERATED ONLY DURING FURNACE OPERATION (1)

	J	F	M	A	M	J	S	O	N	D	YEARLY
% FURNACE ON TIME (2)	42.74%	40.99%	33.14%	22.24%	13.08%		8.29%	17.44%	27.04%	37.94%	
Kw REQ'D DURING ON–TIME	401.68	356.70	184.57	27.09	0.00	0.00	0.00	0.00	84.71	283.93	1338.68
EL COST PER MONTH	$24.62	$21.87	$11.31	$1.66	$0.00	$0.00	$0.00	$0.00	$5.19	$17.41	$82.06
N. GAS COST PER MONTH	$7.11	$6.31	$3.27	$0.48	$0.00	$0.00	$0.00	$0.00	$1.50	$5.03	$23.69
ADDITIONAL COST FOR DUCT HTR	$17.51	$15.55	$8.05	$1.18	$0.00	$0.00	$0.00	$0.00	$3.69	$12.38	$58.37

* BASED ON $.185425 PER M3 OR $.0177/KWH AND A 65% SEASONAL EFFICIENCY ($.027231 PER KwH)
(1) BASED UPON A 40,000 BTUH HEAT LOSS AT 0 DEG DESIGN TEMP. AND A 63,750 BTUH OUTPUT GAS FURNACE
(2) BASED UPON SEPARATE FURNACE ON–TIME CALCULATION SPREADSHEET.
(3) MAT = MIXED AIR TEMPERATURE IN RETURN SYSTEM DOWNSTREAM OF OUTDOOR AIR SUPPLY CONNECTION

Accent HEATING LTD.

April 17, 1991

Howell Mayhew Engineering
15004 - 103 Avenue
Edmonton, ALberta
T5P 0N8

ATTENTION: WILL MAYHEW

Dear Sir:

RE: High sidewall outlets

The following represents the increase in price for high sidewall outlets using flat double deflection grills and round whisper grills as opposed to floor registers:

4" dougle deflection
10 x 6 grill
2 x 4 wall required

Labor:	$14.00
Material:	$31.00
TOTAL:	$45.00

4" whisper grill

2 x 6 wall required

Labor:	$ 8.00
Material:	$29.00
TOTAL:	$37.00

5" double deflection
2 x 4 wall required
10 x 6 grill

Labor:	$15.00
Material:	$35.00
TOTAL:	$50.00

5" whisper grill
2 x 8 wall required

Labor:	$10.00
Material:	$37.00
TOTAL:	$47.00

6" double deflection
10 x 6 grill
2 x 4 wall required

Labor:	$15.00
Material:	$35.00
TOTAL:	$50.00

6" whisper grill

2 x 8 wall required

Labor:	$11.00
Material:	$41.00
TOTAL:	$52.00

10 x 6 double deflection grills:

Advantages:

1. Can be put in 2 x 4 wall
2. adjustable blades for diffusion adjustment

Disadvantages:

1. more difficult installation

continued.....

HEATING • AIRCONDITIONING
4918 - 72 Avenue, Edmonton
Alberta T6B 2K2
(403) 465-9111

Round whisper grills:

Advantages:

1. Easy installation
2. Attractive grill

Disadvantages:

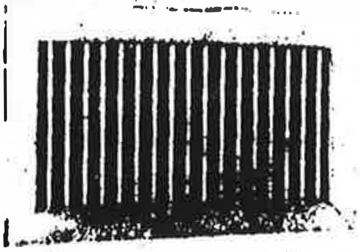
1. Requires 2 x 6 or 2 x 8 walls

Yours truly,

Otto Beutler

OB/pb

HART & COOLEY



T64, T647

Double Deflection

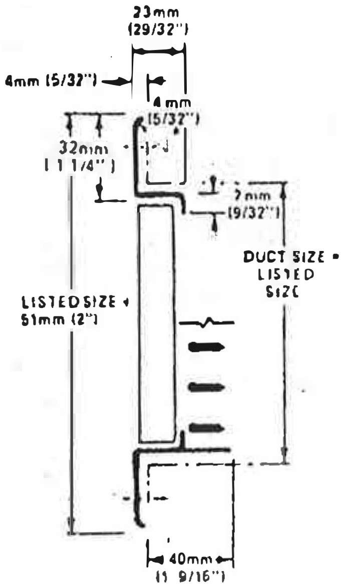
Series T64 and T54 double-deflection supply grilles and registers are recommended for application in systems requiring optimum flexibility of pattern change to accommodate changing job conditions. They perform efficiently with temperature differentials of 11-12°C (20-22°F) cooling, 11-28°C (20-50°F) heating and for ventilating while handling .47 to .94 / s (1.0 to 2.0 cfm) per square metre (foot) with draftless distribution.

PRODUCT #	SIZE
T64-64	6x4
T64-66	6x6
T64-84	8x4
T64-86	8x6
T64-88	8x8
T64-104	10x4
T64-106	10x6
T64-108	10x8
T64-1010	10x10
T64-124	12x4
T64-126	12x6
T64-128	12x8
T64-1210	12x10
T64-1212	12x12
T64-144	14x4
T64-146	14x6
T64-148	14x8
T64-1410	14x10
T64-1412	14x12
T64-1414	14x14
T64-164	16x4
T64-166	16x6
T64-168	16x8
T64-1610	16x10
T64-1612	16x12
T64-1614	16x14
T64-1616	16x16
T64-184	18x4
T64-186	18x6
T64-188	18x8
T64-1810	18x10
T64-1812	18x12
T64-1814	18x14
T64-1818	18x18
T64-206	20x6
T64-208	20x8
T64-2010	20x10
T64-2012	20x12
T64-2014	20x14
T64-2016	20x16
T64-2018	20x18
T64-2020	20x20
T64-244	24x4
T64-246	24x6
T64-248	24x8
T64-2410	24x10
T64-2412	24x12
T64-2414	24x14
T64-2416	24x16
T64-2418	24x18
T64-2420	24x20
T64-2424	24x24
T64-304	30x4
T64-306	30x6
T64-308	30x8
T64-3010	30x10
T64-3012	30x12
T64-3014	30x14
T64-3016	30x16
T64-3018	30x18
T64-3020	30x20
T64-3024	30x24
T64-3030	30x30

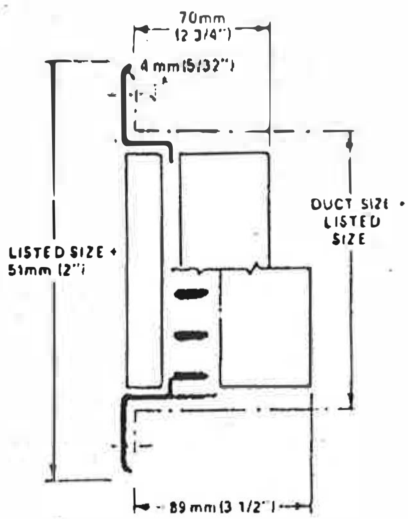
TO ORDER

Double Deflection grilles with damper use prefex T647.

Example:
30x10 Double Deflection grille with damper
T647-3010



T64 Grille



T647 Register

EXTRA COST OF INSTALLING HIGH-WALL SUPPLY OUTLETS

IN THE TORONTO AREA

AS SUPPLIED BY

DEARIE CONTRACTING

Extra material cost		$25-35
Grille		$5-10
Direct labour	-stack	$15
	-other	$5
TOTAL		$$40-$65

In addition, there would be an increase in cost for the duct system designer because of the added complexity and an additional cost arising from the increased logistics and need for trade coordination.

July 25, 1991

APPENDIX C

SUMMARY OF MEASUREMENTS

IN ALBERTA TEST HOUSE

VENTILATION SYSTEM USING A HARD DUCT CONNECTION BETWEEN THE FURNACE RETURN AIR SYSTEM AND THE OUTDOORS

Table 3a: ONE–TIME MEASURMENTS OF AIRFLOWS, TEMPERATURE AND PRESSURE

Test Measurements With Exhaust Fan Off

Parameter		Condition																			
		No Chimney				Chimney		No Chimney				Chimney			No Chimney			Chimney		N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Furnace Fan	L/s	OFF	340	499	OFF	346	489	OFF	325	473	OFF	342	482	OFF	345	503	OFF	346	499	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	0.9	13.8	17.7	1.3	12.0	15.0	1.8	1.1	1.0	0.7	0.5	0.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	0.9	3.5	3.2	1.3	2.4	1.7	n/a	n/a	n/a	n/a	n/a	n/a	0.6	0.6	0.3	0.7	0.5	0.7	−0.6	−0.6
Rim Joist Pressure	Pa	0.0	1.8	3.3	0.0	0.3	1.5	0.0	0.0	0.0	−1.0	−1.0	−1.0	−0.5	1.3	2.5	−0.8	0.0	0.5	0.0	−1.0
Ventilation Air Flow	L/s	3.4	32.5	48.4	5.6	33.9	48.7	0.0	0.0	0.0	0.0	0.0	0.0	6.9	34.0	49.3	7.3	33.9	49.3	0.0	0.0
Combustion Air Flow	L/s	4.9	−5.7	−8.6	6.2	−2.4	−4.9	4.0	4.0	4.8	6.9	7.2	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		705	715	720	725	730	735	805	809	812	815	820	822	827	830	833	838	839	842	612	625

Test Measurements With Exhaust Fan @ 25 L/S

Parameter		Condition																			
		No Chimney				Chimney		No Chimney				Chimney			No Chimney			Chimney		N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Furnace Fan	L/s	OFF	349	495	OFF	346	499	OFF	326	486	OFF	342	489	OFF	349	504	OFF	360	504	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	1.7	1.4	10.6	1.6	1.5	1.7	1.6	1.9	1.8	2.2	2.2	2.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	1.7	1.0	1.9	1.7	1.2	1.4	n/a	n/a	n/a	n/a	n/a	n/a	3.2	3.2	2.9	3.9	3.1	3.2	−0.6	−0.6
Rim Joist Pressure	Pa	−5.0	0.0	0.5	0.0	−0.8	0.0	−3.8	−3.3	−3.5	−2.3	−2.0	−2.0	−3.3	−0.5	0.8	−2.0	−1.5	−0.8	−5.0	−2.0
Ventilation Air Flow	L/s	10.4	35.8	50.1	8.3	35.4	50.3	0.0	0.0	0.0	0.0	0.0	0.0	11.5	35.7	49.7	8.4	36.0	49.7	0.0	0.0
Combustion Air Flow	L/s	11.0	6.4	−3.5	−1.3	8.4	5.2	11.4	11.1	10.8	9.5	9.2	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		905	909	915	921	924	927	930	933	936	939	942	944	949	952	955	959	1002	1005	614	627

VENTILATION SYSTEM USING A HARD DUCT CONNECTION BETWEEN THE FURNACE RETURN AIR SYSTEM AND THE OUTDOORS

Table 3b: ONE–TIME MEASUREMENTS OF AIRFLOWS, TEMPERATURE AND PRESSURE

Test Measurements With Exhaust Fan @ 35 L/S

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Furnace Fan	L/s	OFF	347	513	OFF	370	501	OFF	338	481	OFF	343	491	OFF	350	505	OFF	348	512	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	S UT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	3.8	3.9	4.5	3.9	4.2	4.2	3.9	4.6	4.1	4.1	4.4	0.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	4.0	3.9	4.2	4.2	4.6	4.3	n/a	n/a	n/a	n/a	n/a	n/a	5.2	5.1	4.7	5.5	5.4	5.1	−0.6	−0.6
Rim Joist Pressure	Pa	−2.8	−0.3	3.3	−2.0	−1.0	0.0	−4.0	−4.0	−4.0	−1.5	−2.0	−2.5	−4.0	−1.3	0.0	−2.5	−1.0	0.5	−6.3	−2.8
Ventilation Air Flow	L/s	10.6	35.0	50.3	9.3	36.3	51.1	0.0	0.0	0.0	0.0	0.0	0.0	12.8	35.1	49.5	8.7	36.0	50.6	0.0	0.0
Combustion Air Flow	L/s	11.2	7.8	0.0	9.7	8.5	6.0	12.9	12.0	13.2	11.8	9.1	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		1014	1017	1021	1024	1027	1030	1035	1038	1040	1044	1047	1050	1055	1059	1102	1104	1107	1109	616	629

Test Measurements With Exhaust Fan @ 45 L/S

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Furnace Fan	L/s	OFF	349	498	OFF	346	509	OFF	339	493	OFF	344	481	OFF	356	498	OFF	351	501	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	5.2	5.5	4.9	5.0	5.3	5.2	5.2	4.8	5.6	5.1	5.5	5.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	5.2	5.8	5.0	5.4	5.6	5.1	n/a	n/a	n/a	n/a	n/a	n/a	6.3	6.5	6.5	7.2	7.1	7.1	−0.6	−0.6
Rim Joist Pressure	Pa	−3.5	−0.3	−0.3	−1.0	−1.3	−0.5	−5.0	−4.5	−4.5	−2.0	−2.0	−2.5	−5.0	−2.0	0.0	−2.8	−1.3	−0.8	−8.0	−3.5
Ventilation Air Flow	L/s	11.3	35.4	50.1	9.1	35.1	50.1	0.0	0.0	0.0	0.0	0.0	0.0	11.9	36.2	50.1	9.5	35.9	50.5	0.0	0.0
Combustion Air Flow	L/s	11.1	9.4	6.1	9.7	7.2	6.2	14.1	15.1	12.4	12.9	11.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		1114	1117	1120	1123	1125	1128	1132	1134	1137	1141	1144	1147	1204	1207	1209	1212	1215	1218	618	631

VENTILATION SYSTEM USING A HARD DUCT CONNECTION BETWEEN THE FURNACE RETURN AIR SYSTEM AND THE OUTDOORS

Table 3c: ONE-TIME MEASURMENTS OF AIRFLOWS, TEMPERATURE AND PRESSURE

Test Measurements With Exhaust Fan @ 55 L/S

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Furnace Fan	L/s	OFF	347	507	OFF	348	506	OFF	345	481	OFF	356	470	OFF	360	505	OFF	348	505	OFF	OFF
Ventilation Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	7.4	6.8	7.3	7.6	8.4	7.9	7.9	7.4	8.3	8.5	8.2	8.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation Air Hood Temp.	°C	7.9	7.0	7.6	8.1	8.8	7.9	n/a	n/a	n/a	n/a	n/a	n/a	9.7	9.3	9.5	9.6	9.5	9.2	−0.6	−0.6
Rim Joist Pressure	Pa	−5.0	−2.0	−0.5	−2.5	−1.0	−1.0	−6.0	−6.3	−6.3	−3.3	−3.5	3.3	−7.0	−2.8	−1.8	−3.5	−1.8	−1.0	−10.3	−4.3
Ventilation Air Flow	L/s	9.7	36.5	50.5	10.0	36.1	50.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	36.9	50.8	10.7	36.0	50.8	0.0	0.0
Combustion Air Flow	L/s	9.7	9.5	6.0	10.1	9.9	5.8	15.1	14.9	14.2	10.9	11.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		1245	1250	1253	1255	1258	1300	1303	1307	1309	1324	1326	1327	1330	1332	1335	1338	1341	1344	620	633

Test Measurements With Exhaust Fan @ 65 L/S

Parameter		Condition																			
		No Chimney			Chimney			No Chimney			Chimney			No Chimney			Chimney			N C	Ch
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Exhaust Fan	L/s	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Furnace Fan	L/s	OFF	363	498	OFF	361	500	OFF	339	482	OFF	352	480	OFF	357	495	OFF	365	500	OFF	OFF
Fresh/Makeup Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT
Combustion Air Duct		OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT	SHUT
Window (Simulates chimney)		SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	SHUT	SHUT	OPEN	OPEN	OPEN	SHUT	OPEN
Combustion Air Hood Temp.	°C	9.3	9.4	9.9	10.3	10.7	9.2	8.7	8.6	8.3	7.8	8.4	7.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fresh/Makeup Air Hood Temp.	°C	9.5	9.4	10.2	10.4	9.3	9.2	n/a	n/a	n/a	n/a	n/a	n/a	9.0	9.1	9.0	10.2	9.3	8.4	−0.6	−0.6
Rim Joist Pressure	Pa	−6.3	−3.5	−3.0	−1.0	−1.0	−0.8	−8.5	−8.5	−8.5	−3.8	−3.8	−3.0	−8.3	−5.5	−2.0	−2.8	−1.3	−0.8	−14.0	−6.0
Fresh/Makeup Air Flow	L/s	15.9	37.5	51.2	10.2	36.5	51.9	0.0	0.0	0.0	0.0	0.0	0.0	18.0	38.5	51.6	12.9	37.0	50.6	0.0	0.0
Combustion Air Flow	L/s	14.9	11.9	8.6	9.7	7.5	8.4	17.6	17.8	17.8	14.4	14.2	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Time of Measurement		1352	1355	1358	1401	1404	1407	1413	1416	1419	1423	1427	1430	1436	1439	1442	1445	1448	1451	622	635

APPENDIX

D

TEST HOUSE DESCRIPTION

AIR LEAKAGE TEST REPORT

Nov 11, 1987

Name: GORDON HOWELL Address: 15006 - 103 Avenue

Technician: W. Mayhew Project Name: CCDH

Volume = 505 m^3

House pressure:
Initial = 0 Pa
Final = 0 Pa
Backgrnd = 0 Pa

Comments on the wind speed: 13 km/h
Barometric pressure = 94 kPa
Indoor air temperature = 22 °C
Outdoor air temperature = 10 °C

Reading #	Measured house pressure (Pa)	Corrected house pressure (Pa)	Fan pressure (Pa)	# holes plugged (-1=open)	Corrected Flow (cfm)	Maximum Error (must be < 6%) (%)
1.	60	60.0	39	4	378	.6
2.	53	53.0	32	4	346	.0
3.	44	44.0	23	4	298	.6
4.	32	32.0	15	4	245	4.4
5.	20	20.0	55	7	157	3.6
6.	14	14.0	31	7	120	2.7
7.						

Air Leakage Test Results

C = 16.1 r = .997 (must be > 0.990)

n = .772 (between 0.5 and 1.0) RSE_{10} = 4.2% (must be < 7%)

Q_{50} = 330 cfm Air $change_{50}$ = 1.11 per hour
Q_{20} = 163 cfm
Q_{10} = 95 cfm Equivalent leakage area = 28 in^2 at 10 Pa
Q_5 = 56 cfm

Comments: (Major leakage sites, recommendations...)

APPENDIX E

ALBERTA AND BRITISH COLUMBIA

BUILDING CODE

VENTILATION REQUIREMENTS

VENTILATION AND COMBUSTION AIR

I. Ventilation

The Alberta Building Code (Article 9.33.3.1.) requires that systems capable of at least ½ air change per hour mechanical ventilation be provided in all dwelling units.

This can be calculated as per the following examples.

Home with a floor area of 2,000 square feet (including basement) and that has 8 foot high ceilings.

Volume of home = 2,000 square feet *8 foot ceiling height
= 16,000 cubic feet

One air change would mean that we exhaust 16,000 cubic feet of air per hour and supply an equal amount of heated air.

Since we are interested in ½ air change per hour, we would only have to exhaust 8,000 cubic feet of air per hour and, of course, supply an equal amount of heated air.

Normally, exhaust fans and ductwork calculations are performed using valves given in cubic feet of air moved per minute (C.F.M.), rather than cubic feet per hour.

Therefore, if we convert our 8,000 cubic feet per hour to cubic feet per minute, we would have to divide it by 60.

$$\text{C.F.M.} = \frac{\text{8,000 cubic feet per hour}}{\text{60 minutes per hour}}$$

$$= \text{133 C.F.M.}$$

To determine if this house would meet the requirement, it would be necessary to check the sizing of the:

- exhaust fans located in the washrooms and kitchen. (Fans must exhaust air directly to the outside of the building.)
- heated make-up air requirements.

I. Ventilation(continued)

A. Heat Recovery Ventilator

In some buildings "heat recovery ventilators" are used. These systems exhaust air and heat incoming air using heat that is in the exhaust air. In air to air type heat recovery ventilators, the supply and exhaust air streams never combine, however, are channelled through small passageways that are side by side so that the heat can be transferred across the material used to separate the air streams.

As long as the heat recovery ventilator was sized to supply at least 133 C.F.M. and exhaust the same amount, the minimum ventilation required by Article 9.33.3.1 would be met.

B. Forced Air Furnace System

Another method that can be used, where forced air furnaces are present, is as follows:

1. The exhaust fans located in the washroom(s) and kitchen can be sized to provide at least 133 C.F.M. exhaust.

2. The fresh air duct (make up air) that leads from outside of the building to the return air of the furnace can be sized to handle 133 C.F.M. of outdoor air. (The furnace sizing will have to be checked to ensure it can handle this additional load - also the furnace manufacturer should be consulted regarding the type of material the heat exchanger must be made of in order to avoid rapid corrosion.)

It will be necessary to actually calculate out the size of the fresh air duct since it depends on the friction losses and the effective length of the duct. (Normally a 6 inch or 7 inch diameter duct would be sufficient for this amount of air.)

II. Combustion Air

A. Furnace and Hot Water Heater

Combustion air is not provided through the fresh air duct that leads to a return air system of a furnace. This is due to the fact that hot water heaters are also normally present in homes and are required to have combustion air as well as the furnace. Also, the quantities of air (in addition to ventilation air requirements) would be too large a load on most furnaces (not a practical solution to combustion air in today's tight homes).

Therefore, combustion air must be provided separately to the room in which the furnace and hot water heater are located. (Refer to Standata D.I.-017R "Combustion Air in Dwelling Units). Other methods such as the use of the A.C.A.P.A.C. Combustion Air Damper are also acceptable.

B. Fireplaces

The method that would be most acceptable in today's energy efficient atmosphere would be to provide combustion air directly to the fire chamber. For factory built fireplaces, the units must be tested and listed with this feature and be complete with glass doors. The combustion air sizing will be provided in the installation instructions. If the unit does not come with this feature, it would be necessary to provide combustion air directly from the outside to the room in which the fireplace is located. The minimum size required would be calculated in relation to the inside cross-sectioned area of the chimney. As long as the fresh air duct has an area at least equal to the area of the inside of the chimney, it can be accepted. (Normally a 8 inch diameter duct or two 6 inch diameter ducts would be acceptable for factory built fireplaces.) The duct should be as straight and short as possible. A manual dampering mechanism is required to shut off the flow when the fireplace is not in use.

When site built masonry fireplaces (w/o tight-fitting glass doors and combustion air directly to the firebox) are installed in a home the combustion air duct(s) must be sized in relation to the cross-sectioned area of the inside of the chimney flue. As long as the combustion air duct(s) has the same total cross-sectional area it would be accepted (normally a 9 inch or two 7 inch diameter ducts are required).

DIRECTOR'S INTERPRETATIONS STANDATA

COMBUSTION AIR FOR DWELLING UNITS

This bulletin has been developed jointly by the Building Standards Branch and the Plumbing and Gas Safety Services Branch to clarify the requirements for combustion air for gas, oil and solid fuel (wood/coal) burning appliances that are installed within dwelling units.

The information provided relates only to the quantities and methods of providing combustion air for appliances and does not cover the quantities of air removed by mechanical ventilation systems that are also required to be provided for all dwelling units.

Other methods may be accepted - contact your local gas (for gas fired appliances) or building (for oil and solid fuel fired appliances) inspector for further information.

Fireplaces, Stoves, Space Heaters and Ranges Burning Solid Fuel

Combustion air must be supplied by one of the two following methods:

1. Directly to the fire chamber (for factory built appliances the units must be tested and listed with this feature and complete installation instructions are required). For fireplaces, glass doors are normally required in order for this method to be workable.

2. Directly to the room in which the appliance is located. This can be accomplished by installing a duct leading directly from outside the building into the room where the appliance is located. The duct should be as straight and short as possible and should have the same cross sectional area as the inside of the stovepipe (or chimney) that serves the appliance. A dampering mechanism is also required so that the duct may be closed when the appliance is not in operation.

Furnaces and Boilers

Appliance (fuel burned)	Area of Combustion Air Duct (based on input of all appliances in space)
Gas	CAN/CGA B149.1 CAN/CGA B149.2
Oil	CSA B139
Solid Fuel	3300 mm^2/kW

(example: wood and coal)

All combustion air ducts should be as straight and short as possible. Normally no more than two elbows may be used unless the duct size is increased.

ISSUE OF THIS INTERPRETATION IS AUTHORIZED UNDER SENTENCE 1.5.4.2.(15) OF THE ALBERTA BUILDING CODE 1985 BY THE DIRECTOR OF BUILDING STANDARDS

D. O. MONSEN, M.R.A.I.C.

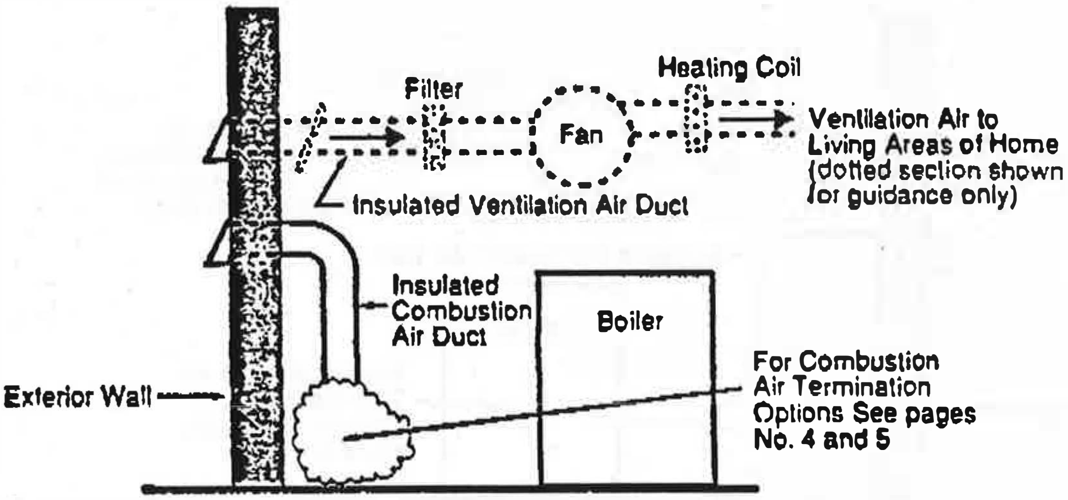
Alberta LABOUR

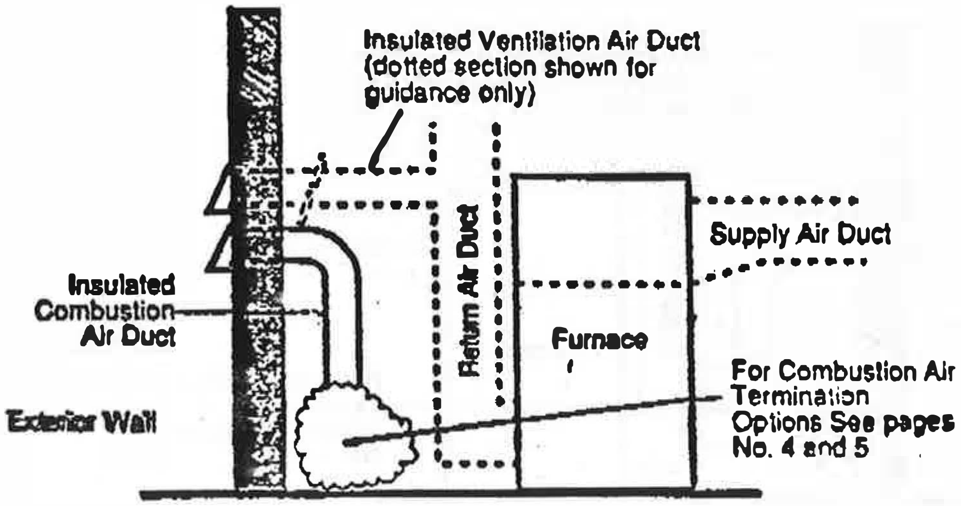
OIL AND SOLID FUEL FIRED FURNACES AND BOILERS

NOTE

The combustion air termination options shown on pages #4 and 5 will assist in the prevention of cold draughts on the floor within the general vicinity of the combustion air duct (in the past open ended combustion air ducts were often blocked off). It will also lessen the chance of water pipes (in the area below the combustion air duct) failing due to freezing temperatures (at least one option must be used).

* An air to air heat exchanger may be used for ventilation in lieu of fan/coil system shown.





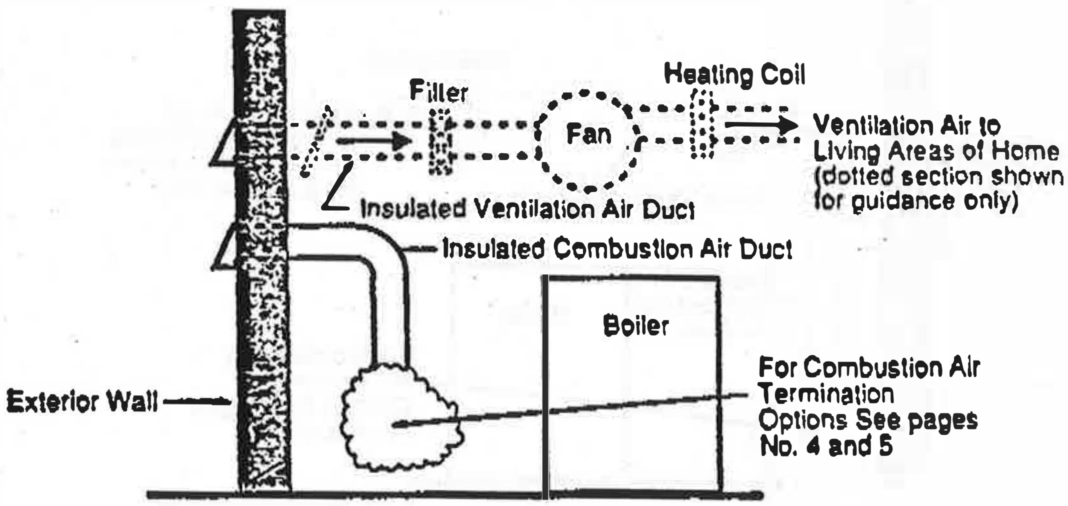
GAS FIRED APPLIANCES

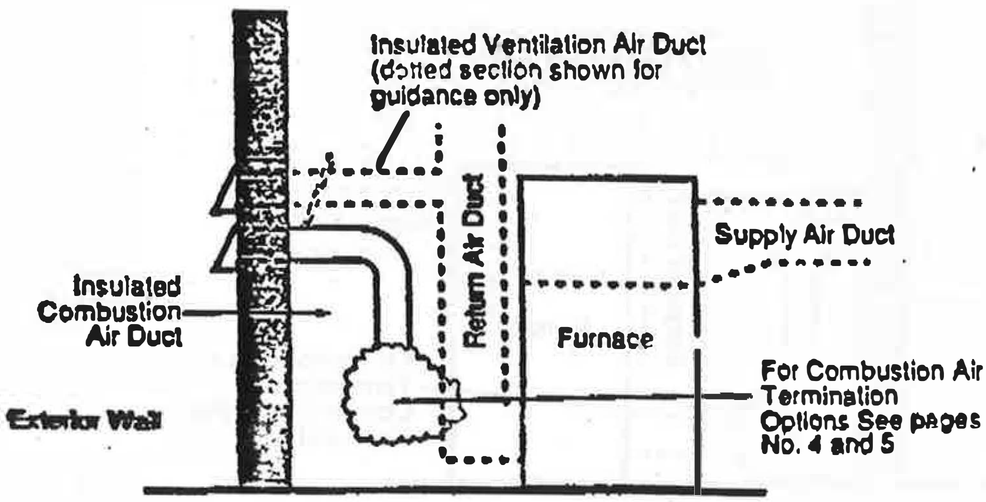
NOTE

The combustion air termination options shown on pages #4 and 5 will assist in the prevention of cold draughts on the floor within the general vicinity of the combustion air duct (in the past open ended combustion air ducts were often blocked off). It will also lessen the chance of water pipes (in the area below the combustion air duct) failing due to freezing temperatures (at least one option must be used).

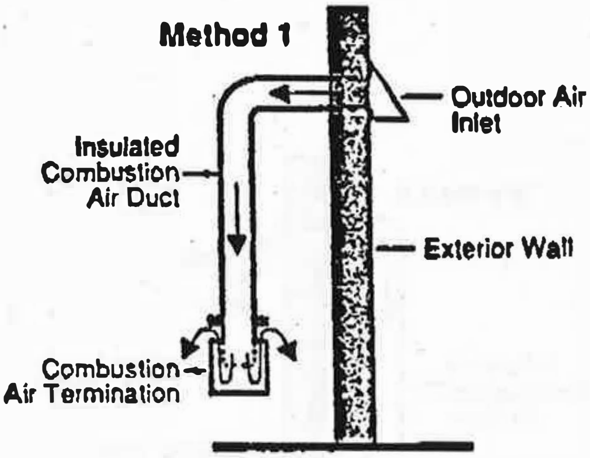
Combustion air must terminate within 300 mm above and within 600 mm horizontally from the burner level of the appliance having the largest input.

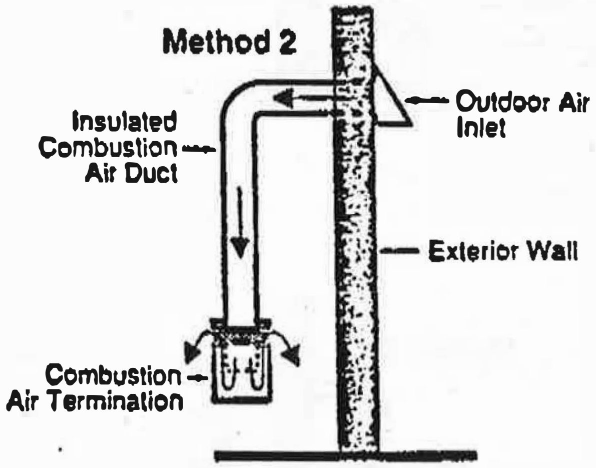
* An air to air heat exchanger may be used for ventilation in lieu of fan/coil system shown.

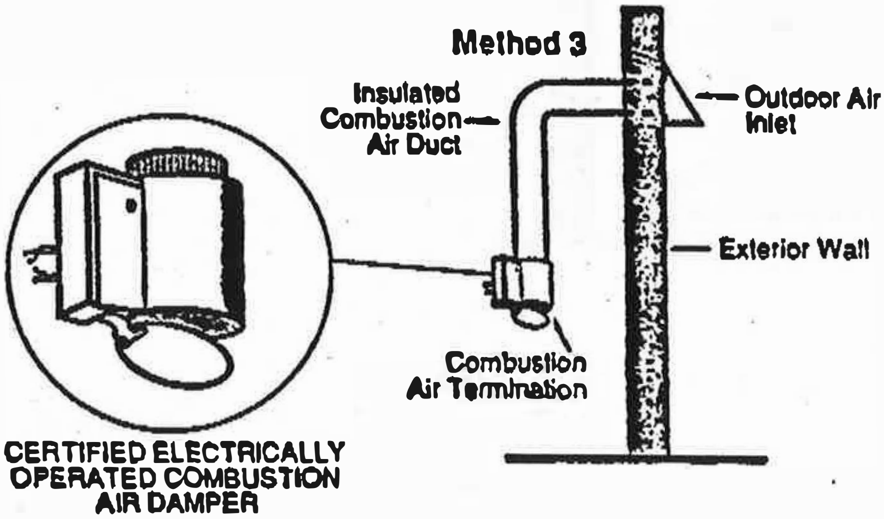




COMBUSTION AIR TERMINATION OPTIONS FOR ALL APPLIANCES



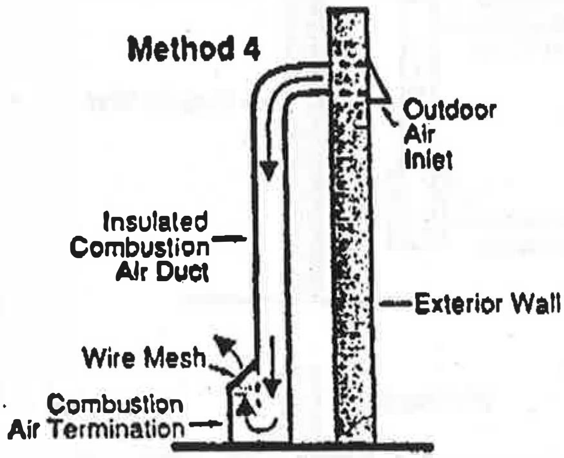




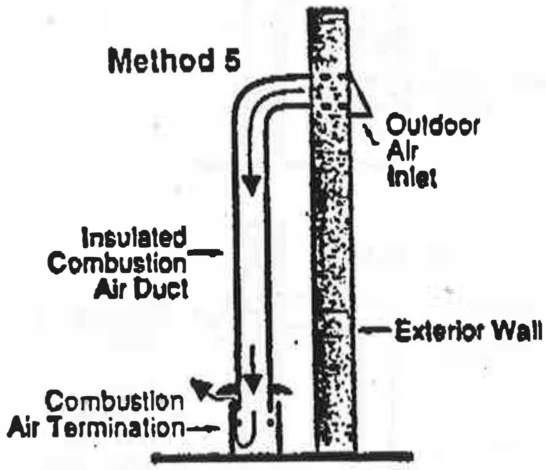
NOTE Other methods may be used provided they are accepted by the local building and gas inspection branches prior to installation.

Following combustion air terminations may be used for solid fuel or oil fired appliances. They may also be used for gas fired appliance[illegible] the termination point meets the B149 Code requirements of within 300 m[illegible] above and within 600 mm horizontally from the burner level of the appliance having the largest input.

Method 4



Method 5



NOTE 15 kW = 50,000 Btu/h (approx.)

BRITISH COLUMBIA BUILDING CODE 1985

FIRST REVISIONS

Issued by

Building Standards Branch
Ministry of Municipal Affairs
Recreation and Culture
Parliament Buildings
Victoria B.C. V8V 1X4
(604) 387-4010

September 1988

• SUBSECTION 9.33.3. MECHANICAL VENTILATION
(See Appendix A.)

Mechanical ventilation requirements

9.33.3.1. Except as required in Article 9.33.3.2., *dwelling units* shall have a mechanical ventilation system capable of providing, during the heating season, at least 0.5 air change per hour or according to Table 9.33.3.A.

9.33.3.2. Mechanical ventilation systems in *dwelling units* designed in accordance to Part 6 to distribute ventilation air to or from all habitable rooms, but excluding such rooms as storage, foyer, laundry or mechanical rooms, shall be capable of providing, during the heating season, not less than 0.3 air change per hour or according to Table 9.33.3.A.

9.33.3.3. The rate of air change in Articles 9.33.3.1. and 9.33.3.2., and Table 9.33.3.A shall be based on the total interior volume of all *storeys* including the *basement* and heated crawl spaces, but excluding any attached or built-in garage.

Table 9.33.3.A.
Forming Part of Articles 9.33.3.1. and 9.33.3.2.

MINIMUM REQUIRED VENTILATION RATE			
Max. Total Interior Volume(1), m^3	Max. Total Floor Area(1) Based On Standard 2.44 m Ceiling Height, m^2	Minimum Ventilation Rate	
		0.5 Air Change per Hour, L/s	0.3 Air Change per Hour, L/s
122	50	17	10
146	60	20	12
171	70	24	14
195	80	27	16
220	90	31	18
244	100	34	20
366	150	51	31
488	200	68	41
610	250	85	51
732	300	102	61
975	400	137	82
1219	500	171	102
1463	600	205	123
Column 1	2	3	4

Notes to Table 9.33.3.A.:

(1) For rooms or spaces to be included or excluded see Article 9.33.3.3.

Rooms or Spaces without Natural Ventilation

9.33.3.4. Where a habitable room or space in a *dwelling unit* is not provided with natural ventilation described in Article 9.33.1.5., mechanical ventilation shall be provided to that room or space that is capable of providing 0.5 air change per hour if the room or space is mechanically cooled in summer, and 1.0 air change per hour if it is not.
(See Appendix A.)

Automatic or Continuous Operation

9.33.3.5. A portion of the ventilation rate required by Articles 9.33.3.1. and 9.33.3.2. shall be controlled automatically by a centrally located dehumidistat, or be provided by a continuously operating fan during the heating season. This portion of ventilation rate shall conform to Table 9.33.3.B. (See Appendix A.)

Table 9.33.3.B.
Forming Part of 9.33.3.5.

MINIMUM REQUIRED VENTILATION RATE CONTROLLED AUTOMATICALLY OR PROVIDED CONTINUOUSLY			
Max. Total Interior Volume[(1)], m^3	Max. Total Floor Area[(1)] Based On Standard 2.44 m Ceiling Height, m^2	Minimum Ventilation Rate, Controlled Automatically, L/s	Minimum Ventilation Rate, Provided Continuously, L/s
244	100	20	10
366	150	30	15
488	200	40	20
732	300	40	30
975 and over	400 and over	40	40
Column 1	2	3	4

Notes to Table 9.33.3.A.:
(1) For rooms or spaces to be included or excluded see Article 9.33.3.3.

9.33.3.6. Except as provided for in Subsection 9.33.4. or as otherwise stated in this Subsection, mechanical ventilation shall conform to the requirements of Part 6.

Make-up Air 9.33.3.7. Except as provided in Articles 9.33.3.8. and 9.33.3.14., mechanical ventilation systems for *dwelling units* shall include provision for introduction of fresh make-up air from the exterior for the ventilation rate controlled automatically or provided continuously as described in Article 9.33.3.5.

Make-up Air not required 9.33.3.8. Make-up air as described in Articles 9.33.3.7. and 9.33.3.13. is not required, if the *dwelling unit* does not contain a naturally-aspirating fuel-fired heating *appliance*, or if all fuel-fired *appliances* are isolated from the *dwelling unit* atmosphere. *Acceptable appliances* include induced draft or sealed *furnaces*, gas fireplaces and hot water tanks, with combustion air directly from outside and with sealed *flues;* or fireplaces and *space heaters* that are equipped with tight-fitting, gasketed doors with all air supply requirements directly from the outside into the firebox.

Make-up Air tempered 9.33.3.9. Make-up air shall be tempered as described in Articles 9.33.3.10. to 9.33.3.12.

9.33.3.10. For locations with winter design temperature not less than -10°C make-up air may be tempered by being supplied by ducting into secondary areas such as utility or storage rooms, by specially designed individual room or space through-wall diffusers, by methods described in Article 9.33.3.11., or by other *acceptable* methods.

9.33.3.11. For locations with winter design temperature less than -10° C make-up air may be tempered by being supplied through a forced air heating system as described in Article 9.33.3.12., by heating/fan unit, by heat recovery ventilator, or by other *acceptable* methods.

Make-up Air tempered by forced-air heating systems 9.33.3.12. Make-up air tempered through forced-air heating systems shall be provided by a duct connected to the return-air *plenum*. The make-up air duct shall be at least 100 mm diam or an equivalent combined duct with the furnace air supply. The make up air duct shall be provided with a motorized damper that is interlocked with the exhaust fan controlled by the dehumidistat so that the exhaust fan only operates when the damper is in the open position. The dehumidistat shall also be interlocked with the furnace air circulating fan so that the furnace fan will operate when the exhaust fan is on and the damper is open.
(See Example (c) in A-9.33.3.)

Make-up air, for other exhaust appliances

9.33.3.13. Except as described in Article 9.33.3.8., additional separate make-up air for the entire capacity shall be provided for other exhaust *appliances* installed in the *dwelling unit* with a rated exhaust capacity exceeding 0.5 air change per hour, or according to Table 9.33.3.A. Non-forced make-up air shall conform to Table 9.33.4.4. for the rates indicated, otherwise the make-up air shall be provided by a fan-forced unit of equivalent capacity interlocked with the exhaust appliance.

Combination forced air/ ventilation system

9.33.3.14. A naturally-aspirating forced air heating system serving a maximum total heated floor area of 460 m^2 is *acceptable* as providing the ventilation requirements, if the system is capable of providing at least 0.3 air changes per hour during its heating operation or has an air supply according to Table 9.33.3.C. The system shall have a ventilation rate controlled automatically or provided continuously by the furnace air circulating fan as required by Article 9.33.3.5., and have the required air supply according to Table 9.33.3.C., provided directly to the return-air *plenum*.
(See Example (b) in A-9.33.3.)

Table 9.33.3.C.
Forming Part of 9.33.3.14.

MINIMUM AIR SUPPLY DUCT(1) DIAMETER FOR A COMBINATION FORCED AIR/VENTILATION SYSTEM		
Max. Total Interior Volume(2), m^3	Max. Total Floor Area(2) Based On Standard 2.44 m Ceiling Height, m^2	Minimum Air Supply Duct(1) Diameter, mm
536 805 1122	220 330 460	100 125 150
Column 1	2	3

Notes to Table 9.33.3.C.:

(1) The air supply duct has been sized for one duct to provide both for the air supply as required by the furnace installation code and for the ventilation air required by this Subsection.

(2) For rooms or spaces to be included or excluded see Article 9.33.3.3.

9.33.3.15. Special purpose air exhausting equipment such as central vacuum cleaning systems, downdraft cook tops and clothes dryers shall not be included in calculating the capacity of the ventilation system.

9.33.3.16. Systems designed to provide combustion and/or dilution air for fuel-burning *appliances* shall not be used to supply make-up air for the ventilation systems unless their capacity is sufficient to serve both functions simultaneously. An *acceptable* combination system includes a forced air heating system as described in Article 9.33.3.14.

Sound rating **9.33.3.17.** Wall and ceiling fans required by Article 9.333.5. to be controlled automatically or operate continuously, shall be rated by the manufacturer not to exceed a sound level of 60 dBA or 2.5 Sones.

Exhaust ducts **9.33.3.18.** *Exhaust ducts* shall discharge directly to the outdoors. Where the *exhaust duct* passes through or is adjacent to unheated space, the duct shall be insulated to prevent moisture condensation in the duct.

Access to ventilation equipment **9.33.3.19.** Ventilation equipment shall be accessible for inspection, maintenance, repair and cleaning. Except where the kitchen exhaust grille is located at least 1.2 m horizontally from the range, kitchen *exhaust ducts* shall be designed and installed so that the entire duct can be cleaned where the duct is not equipped with a filter at the intake end.

Air intake shield **9.33.3.20.** Outdoor air intake and exhaust outlets shall be shielded from weather and insects. Shielding from insects for ventilating equipment may be by an accessible filter at the equipment and by a 6 mm mesh screen at the intake or exhaust hood. Screening if used shall be of rust-proof material.

Duct requirements **9.33.3.21.** Ventilating ducts shall conform to the requirements of Part 6 for *supply ducts*, except *exhaust ducts* that serve only a bathroom or water-closet room may be of *combustible* material provided the duct is reasonably air tight and constructed of a material impervious to water.

Doors undercut **9.33.3.22.** Interior doors for dwelling units shall be undercut a minimum of 12 mm or the rooms shall be provided with a grille of an equivalent area.

SUBSECTION 9.33.4. BASIC MECHANICAL VENTILATION SYSTEM

(See Appendix A and Example (a) in A-9.33.4.)

General

9.33.4.1. A basic mechanical ventilation system shall comply with the requirements in Article 9.33.3.1. and shall consist of one or more exhaust fans, without an air circulating ductwork system. The exhaust fans shall be located in some or all of the kitchens and bathrooms. The ventilation system shall conform to the appropriate requirements of Subsection 9.33.3., except the system need not conform to Part 6.

Exhaust fan

9.33.4.2. The exhaust fans required in Article 9.33.4.1. shall be rated for sound as required in Article 9.33.3.17. and controlled automatically by a dehumidistat as required in Article 9.33.3.5.

System capacity

9.33.4.3. The mechanical ventilation capacity of the exhaust fans in Article 9.33.4.1. shall be assumed as the total of the individual fans, rated by the manufacturer at a differential pressure of at least 50 Pa. The exhaust duct size shall conform to Table 9.33.4.A.

Table 9.33.4.A.
Forming Part of Article 9.33.4.3.

EXHAUST DUCT(1) SIZE FOR A BASIC VENTILATION SYSTEM IN SUBSECTION 9.33.4.		
Maximum Exhaust Fan Ventilation Rate, L/s	Min. Exhaust Duct(1) Dia.	
	Smooth Duct	Flexible Duct
10	75	100
25	100	125
45	125	150
70	150	175
Column 1	2	3

Notes to Table 9.33.4.A.:

(1) The exhaust ducts shall not exceed 15 m in length or have more than two 90° elbows, otherwise the duct shall be increased to the next diameter size.

Make-up air

9.33.4.4. Make-up air shall be provided for the ventilation rate controlled automatically or provided continuously as described in Article 9.33.3.5. and shall conform with Articles 9.33.3.7. to 9.33.3.11. The non-forced air opening size for make-up air for a basic ventilation system as provided for in this Subsection shall conform to Table 9.33.4.B. Forced make-up air equipment shall be rated by the manufacturer to provide for the required air flow rate.

Table 9.33.4.B.
Forming Part of Article 9.33.4.B.

MAKE-UP AIR OPENING SIZE FOR A BASIC VENTILATION SYSTEM IN SUBSECTION 9.33.4.

Maximum Ventilation Rate Controlled Automatically or Provided Continuously, *L/s*	Minimum Make-up Air Duct	
	Vent Area, cm^2	Diam, mm
8	47	80
12	66	90
15	85	100
17	95	110
20	114	120
25	142	130
30	170	150
35	199	160
40	227	170
45	255	180
50	284	190
55	312	200
60	340	210
Column 1	2	3

Page	Reference	Revision
• 501	Appendix A	Delete all existing Appendix Notes to Subsection 9.33.3. and substitute the following:

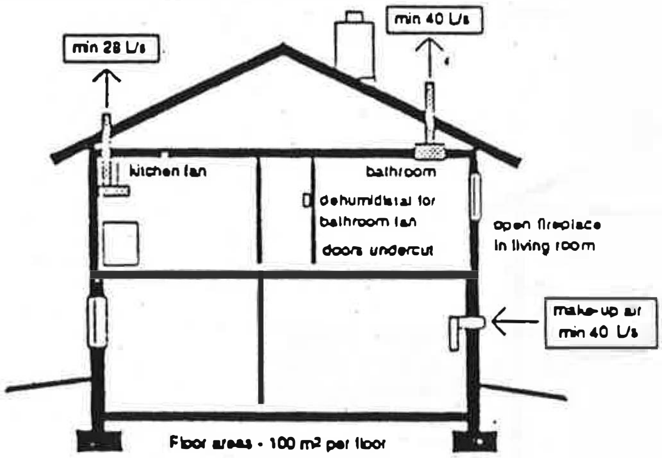
A-9.33.3. & A-9.33.4. Mechanical Ventilation. Subsection 9.33.3. contains the general requirements for mechanical ventilation systems for dwelling units. It also references Part 6 for the design of the ventilation systems, except for the "Basic Mechanical Ventilation System" described in Subsection 9.33.4. Part 6 in turn requires good engineering practice, such as found in ASHRAE handbooks and HRAI Digest for the design of ventilation systems.

Subsection 9.33.4. "Basic Mechanical Ventilation System", contains the specific requirements for the installation and verification of a simple ventilation system, utilizing exhaust fans and make-up air as required.

The following examples illustrate different ventilation systems and how the requirements can be satisfied depending on the heating system used. The house used in these examples has two storeys with 100 m^2 per floor and contains an open fireplace.

Example (a): shows the Basic Mechanical Ventilation System as described in Subsection 9.33.4., this can be used with any heating system. For this example the following would apply:

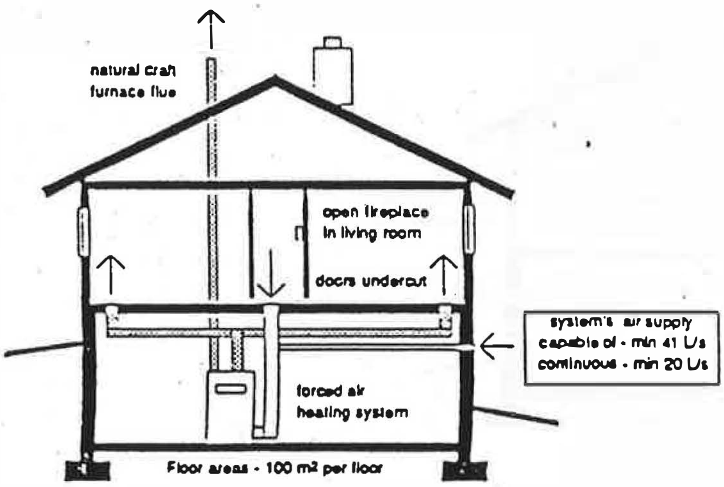
1. 9.33.4.1. - 0.5 air changes per hour or from Table 9.33.3.A. for 200 m^2 a minimum ventilation rate of 68 L/s is required, this is provided by kitchen and bathroom exhaust fans;
2. 9.33.4.2. - the bathroom fan to be rated for a maximum sound rating of 60 dBA (2.5 sones), be controlled by a dehumidistat and from Table 9.33.3.B. a minimum ventilation rate of 40 L/s is required;
3. 9.33.4.3. - fans to be rated at a minimum of 50 Pa, exhaust duct size according to Table 9.33.4.A.;
4. 9.33.4.4. - make-up air is required since there is an open fireplace; from Table 9.33.4.A. a 170 mm diameter duct is required for the 40 L/s bathroom fan and in this case it is provided to a storage room in the basement; and
5. 9.33.3.22. - doors to be undercut a minimum of 12 mm or a grille of an equivalent area provided.



(a) BASIC MECHANICAL VENTILATION SYSTEM - 0.5 A.C./H. WITH ANY HEATING SYSTEM

Example (b): shows a ventilation system utilizing a naturally-aspirating forced air heating system with a two-speed furnace fan as described in Article 9.33.3.14. A permitted alternate arrangement could utilize a dehumidistat which would control the furnace air circulating fan for the ventilation rate as required by Article 9.33.3.5. This is a combination heating/ventilating system where the furnace provides the heating as well as supplying the required house ventilation air. In this example, one air supply duct is provided to the return air plenum to provide both for the air supply as required by the furnace installation code and for the ventilation air required by Subsection 9.33.3. For this example the following would apply:

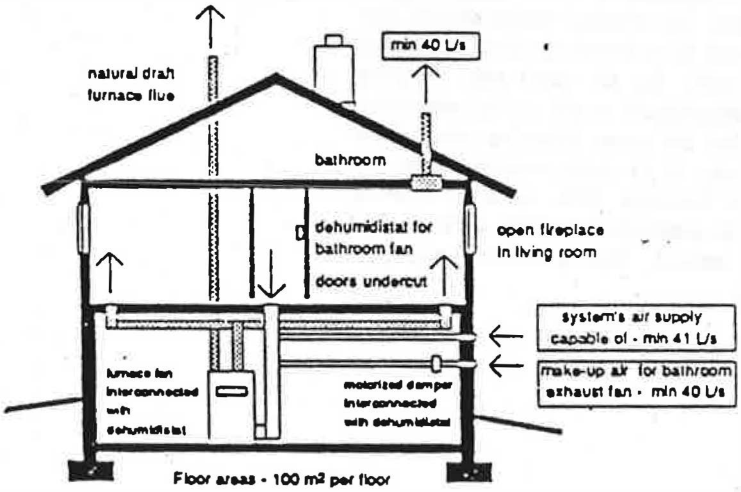
1. 9.33.3.14. - 0.3 air changes per hour or from Table 9.33.3.A. for 200 m^2 total heated floor area a minimum ventilation rate of 41 L/s is required;
2. 9.33.3.14. - minimum continuous ventilation rate of 20 L/s from Table 9.33.3.B. provided by the two-speed furnace fan;
3. 9.33.3.14. - the furnace and ventilation outdoor air supply provided by a 100 mm diameter duct directly to the return-air plenum from Table 9.33.3.C.;
4. 9.33.3.2. - the system design to Part 6, which also refers to ASHRAE handbooks and HRAI Digest for design of ventilation systems; and
5. 9.33.3.22. - doors to be undercut a minimum of 12 mm or a grille of an equivalent area provided.



(b) VENTILATION SYSTEM WITH A FUEL-FIRED FORCED AIR HEATING SYTEM - 0.3 A.C./H. AND CONTINUOUS VENTILATION

Example (c): shows a ventilation system utilizing a naturally-aspirating fuel-fired forced air heating system with a single speed furnace fan and a bathroom exhaust fan. In this example, an additional 100 mm make-up air duct with a motorized damper is provided to the return-air plenum for the make-up air required by the bathroom exhaust fan. This additional make-up air could also be provided by increasing the furnace air supply duct and installing a two-position motorized damper. For this example the following would apply:

1. 9.33.3.2. - 0.3 air changes per hour or from Table 9.33.3.A. for 200 m^2 total heated floor area a minimum ventilation rate of 41 L/s is required;
2. 9.33.3.5. - minimum ventilation rate controlled automatically of 40 L/s from Table 9.33.3.B., provided by bathroom exhaust fan;
3. 9.33.3.12. - make-up air is required since there is an open fireplace, this can be supplied through the forced air heating system by a separate 100 mm duct with a motorized interlocked damper as described in Article 9.33.3.12;
4. 9.33.3.2. - the system design to Part 6, which also refers to ASHRAE handbooks and HRAI Digest for design of ventilation systems; and
5. 9.333.22. - doors to be undercut a minimum of 12 mm or a grille of an equivalent area provided.



(c) VENTILATION SYSTEM WITH A FUEL-FIRED FORCED AIR HEATING SYTEM - 0.3 A.C./H. AND BATHROOM EXHAUST FAN

Page	Reference	Revision
501	Appendix A	Addnew Note: A-9.33.3.4. A mechanical ventilation system capable of operating on a year round basis is required for habitable rooms or spaces which do not have openable windows. The ventilation system for these rooms may be combined with the whole house ventilation system described in Articles 9.33.3.1. and 9.33.3.2. In most cases to comply with this requirement, an exhaust fan controlled by a switch or dehumidistat capable of providing 1 air change per hour (where summer cooling is not provided) based on the room or space volume would be required.
501	Appendix A	Add new Note: A-9.33.3.5. Automatic Control. This Article requires that the fan(s) of a required ventilation rate be controlled automatically by a centrally located dehumidistat. In a typical example, where the bathroom exhaust fan(s) are controlled by this centrally located dehumidistat, the exhaust fan(s) should also be controlled by a switch or timer located in the bathroom. In all cases the centrally located dehumidistat would be the overriding switch. For the most effective use of the dehumidistat, it is recommended that the setting be between 40% to 60% relative humidity to maintain a healthy environment and to control any potential moisture problems.

Page	Reference	Revision
• 501	Appendix A	A-9.33.3.7. Make-up air. Make-up air is not required for the entire ventilation capacity only for the ventilation rate controlled automatically or provided continuously. However, in Article 9.33.3.13. additional separate make-up air is also required for any exhaust appliance with a capacity exceeding 0.5 air change per hour. This acknowledges the fact that although houses are being built tighter there is still enough air leakage through the envelope that can provide the additional air requirements of approximately 50L/s to 100L/s at 5 Pa, depending on the size of the house. This is based on a leakage rate or NLA of 1.08 cm^2/m^2 as established by a BETT/EMR survey of airtightness of housing across Canada. The 5 Pa depressurization has been established as the maximum permitted depressurization to prevent backdrafting of naturally-aspirating appliances.

| - indicates N.R.C. errata (issued January 1988)
•- indicates B.C. errata

Note: N.R.C. issued revisions (or errata) do not automatically become part of the B.C. Building Code, they must be adopted by the Province.

VENTILATION REQUIREMENTS: Changes to B.C. Building Code Ventilation Standards

Richard Kadulski

The ventilation requirements of the B.C. Building Code have been revised, and are now in force. The revisions go a long way to cleaning up the code language, making it more understandable.

A number of tables are provided with the code, to ease calculation. For most standard houses the builder need just follow the steps through a series of tables to calculate what's required.

We're presenting the essential elements of the revised code.

System Capacity

All dwelling units must have a mechanical ventilation system capable of providing at least 0.5 air change per hour (ACH) during the heating season.

Systems designed to distribute ventilation air to or from all rooms, (but excluding rooms such as storage, foyer, laundry or mechanical) must be capable of providing at least 0.3 ACH.

The ventilation rate is to be based on the total heated volume (including basement and heated crawl spaces).

A portion of the required ventilation must be controlled automatically by a centrally located dehumidistat or be provided by a continuously operating fan during the heating season. Table 9.33.3.B spells out the minimum required rates to be controlled automatically or continuously.

In many houses this will mean that bath fans must be run continuously or controlled on a dehumidistat.

Most houses (over 2100 sf) will require that 80 cfm of capacity be controlled by a dehumidistat. Houses with continuous ventilation (e.g. HRV or continuous exhaust fan) will require 40 cfm continuous (80 cfm for houses over 4300 sf).

The alert reader will note that the minimum ventilation rate provided continuously (at 80 cfm for large houses) can be as low as 0.15 ACH. While the system *capacity* must be .3 ACH for distributed and .5 ACH for non-distributed ventilation, it need not run at that rate continuously.

The ventilation standard related to air changes per hour is not a meaningful measure. We began using it when we first seriously looked at ventilation requirements in homes, and had to look at what others do. In Europe, where ventilation has been mandated for much longer, they may use "air changes per hour" - but the volume of the average dwelling unit is much smaller than the average Canadian home.

What has been recognized by the B.C. Building Code (directly or otherwise) is that ventilation is for people. The acknowledged minimum quantity required by a human is around 15 cfm (plus or minus 5 cfm).

Exhaust equipment such as central vacuums, downdraft cook tops and clothes dryers will not be considered in calculating the ventilation system capacity.

Make-up Air

Mechanical ventilation systems must include provision for introduction of fresh make-up air from the exterior to match the ventilation controlled automatically.

Make-up air is not needed if the dwelling has no naturally-aspirating fuel-fired heating appliances, or if all fuel-fired appliances (including fireplaces) are isolated from the interior atmosphere.

In colder climates (design temperature less than -10°C) tempering of the make-up air is required. It can be done by mixing it with forced air heat, by use of an HRV, fan coil unit or other suitable method.

Make-up air need not be tempered in mild climate zones (winter design temperature above -10°C). It can be supplied into areas such as utility or storage rooms.

Make-up air tempered through forced-air heating systems must be provided by a duct connected directly into the return air plenum. The make up air duct must be provided with a motorized damper that is interlocked with the exhaust fan controlled by a dehumidistat so that the exhaust fan only operates when the damper is open. The dehumidistat must also be interlocked with the furnace fan so that the furnace fan will operate when the exhaust fan is on and the damper is open.

Table 9.33.3.B.
Forming Part of 9.33.3.5.

MINIMUM REQUIRED VENTILATION RATE CONTROLLED AUTOMATICALLY OR PROVIDED CONTINUOUSLY

Max. Total Interior Volume(1), m³	Max. Total Floor Area(1) Based On Standard 2.44 m Ceiling Height, m²	Minimum Ventilation Rate, Controlled Automatically, L/s	Minimum Ventilation Rate, Provided Continuously, L/s
244	100	20	10
366	150	30	15
488	200	40	20
732	300	40	30
975 and over	400 and over	40	40
Column 1	2	3	4

1 l/s = 2 cfm

Additional make-up air must be provided for other exhaust appliances installed in the dwelling unit with a rated capacity exceeding 0.5 ACH. This may have to be by a fan-forced unit of equivalent capacity interlocked with the exhaust appliance. This would apply to equipment such as high capacity downdraft cook tops.

Small houses with naturally aspirating appliances require fan forced make-up for 100% of the capacity (tempered if in a cold climate with winter desig temperatures <-10°C).

A naturally-aspirating forced heating system serving a maximum total heated floor area of 460 m^2 is acceptable as providing the ventilation requirements, if the system is capable of providing at least 0.3 air changes per hour during its heating operation or has an air supply (as provided for in a table providing minimum supply duct diameter).

Combination Forced Air-Ventilation

In houses up to 4900 sf, with a naturally drafted furnace, if the supply air is directly connected to the return air plenum, no other ventilation is required if the system can contribute .3 ACH. This type of system requires dehumidistat control of the furnace fan or a continuous running furnace fan.

This system is a minor modification of existing furnace installations that have proven to be acceptable in the general housing stock. It is being accepted for the time being because of its proven track record (and in part because of pressure from the gas industry).

As houses get tighter and more sealed combustion furnaces are used it is likely that this kind of passive system may not be adequate.

Combustion air ducts for fuel burning appliances are not to be used to supply make-up air for the ventilation systems unless their capacity is enough to serve both functions at the same time.

Sound ratings

Wall and ceiling fans that are controlled automatically or meant to operate continuously must be rated by the manufacturer not to exceed a sound level of 60 dBA or 2.5 Sones.

Exhaust Ducts

Exhaust ducts must vent directly to the outdoors. Where the exhaust duct passes through or adjacent to unheated spaces, it must be insulated to prevent moisture condensation in the duct.

Ventilation ducts must be metal, but exhaust ducts that serve only a bathroom or powder room can be made of combustible material that is impervious to water.

Service Access

Ventilation equipment must be accessible for inspection, maintenance, repair and cleaning. Kitchen exhaust ducts must be designed and installed so that the duct can be cleaned if there is no filter at the intake. Kitchen ducts must be metal.

Outdoor air intake and exhaust outlets must be shielded from weather and insects. Screening for insects may be by an accessible filter at the equipment and by a 6mm mesh screen at the intake or exhaust hood. Screening must be made of rust-proof material.

Distribution

To ensure distribution of air through the house, interior doors should be undercut ½", the rooms provided with a grille, or a transfer grill with an equivalent area.

Fan ratings must be rated by the manufacturer at a pressure difference of at least 50 Pascals.

INFORMATION WANTED

A study to evaluate the impact of the draft CSA F326 Standard for Residential Mechanical Ventilation is being done by Allen Associates. (What are the consequences for the building industry if the standard becomes mandatory?)

The study will include a review of available equipment and costs of complete systems.

If you can help, please send your literature to:
Allen Associates
33 Madison Avenue
Toronto, Ontario
M5R 2S2

Attn: Mario Kani, P. Eng.

Allen Associates would like to receive current product literature, preferably with price lists, from manufacturers and suppliers of residential ventilation equipment such as:

* exhaust fans
* make-up air fans and ducts
* recirculation fan systems
* central exhaust systems
* heat recovery ventilators
* exhaust air heat pumps
* passive supply vents
* forced air and low flow high-wall or ceiling supply registers
* exhaust grilles
* intake and exhaust vent hoods (for exterior walls, complete with screens add/or filters)
* ductwork (with an without insulation an for low-flow applications)
* and controls.

Information required is engineering and technical in nature and should specify, among other data, air flows, sound ratings, and applicability.