Field Survey of Heat Recovery Ventilation Systems

Final Report

Prepared for:

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CMHC and BLP are indebted to the homeowners who opened their door to the investigators and let them string plastic tubing throughout their houses. The contracting firm of Pinkney and Gardiner Construction Inc. was also instrumental to this effort.

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ABSTRACT

This research study was undertaken to assess the effectiveness of ventilation in dwellings in relation to:

- mechanical ventilation system design,
- installation practices, and
- occupant use and maintenance of ventilation systems.

The project involved the inspection of 60 homes with heat recovery ventilator (HRV) ventilation systems, a survey of the occupants to determine their understanding and usage of their ventilation system, telephone surveys of a further 15 households and intensive performance testing of 20 conventional and four experimental ventilation systems.

The methodology for the testing involved the use of a trace of concentration of gas (Sulphur Hexafluoride) to assess air change rates. A tracer gas decay methodology was used to calculate the natural, combined apparent natural and mechanical, and mechanical air change rates in representative areas of each house. Based on an assessment of the air change rates, evaluations were made of the fresh air distribution in the homes with and without the operation of the mechanical systems.

The common types of HRV installations investigated under this study (fully ducted, simplified and extended) were capable of performing well. The majority of the HRV ventilation systems were operating and the occupants believed the use of their HRV was beneficial. Potential existed for far greater benefits, however, and considerable improvements were possible in installation practice, system performance, occupant understanding and occupant interaction with their system.

Key Words:
ventilation, air distribution, indoor air quality, heat recovery ventilators, HRVs, mechanical design, performance testing, tracer gas testing, air movement

EXECUTIVE SUMMARY

Ventilation is one of the most important design issues of the '90s in the Canadian Construction industry. Building Codes promote thc comfort and safety of occupants by ensuring fresh air is provided to new homes, and stale, contaminated air is exhausted outdoors. Increasingly, these code requirements are being satisfied by the use of packaged heat recovery ventilators (HRVs).

Given the increased reliance on HRVs for ventilation, several authorities expressed a desire to explore and assess the relationships between home design, mechanical ventilation system design, installation practices and occupant use of ventilation systems as they relate to the effectiveness of ventilation of the dwelling. In response to such concerns, Canada Mortgage and Housing Corporation engaged Buchan, Lawton, Parent Ltd to study the field performance of HRV ventilation systems.

The conclusions drawn from these results will make it possible to improve installation practices, HRV system performance, and occupant understanding of and interaction with their HRV system.

The project involved four phases: 1) inspections of 60 homes with HRV ventilation systems, 2) survey of the occupants of the 60 households to determine their understanding and usage of their HRV ventilation systems and a telephone survey of a further 15 households, 3) intensive performance testing of existing HRV ventilation systems, and 4) intensive performance testing of experimental HRV ventilation systems.

Under Phases I and II of the study, the field inspections, occupant surveys and telephone surveys reviewing existing HRV installations provided an understanding of how HRV ventilation systems were perceived and how they were used in Canadian housing. The assessed parameters included whether the installation met acceptable standards, the performance of the system, and the occupant's understanding of and interaction with the system.

Fifteen homes were inspected on the West Coast, fifteen homes on the East Coast, and thirty homes in the Central Region. All installations were at least one year old and ranged in age up to fourteen years. Four categories of systems were investigated: fully ducted, extended, simplified standard installation and simplified cross furnace. To gain a broader range of information, a further fifteen homes were surveyed by phone in the Central Region.

Under Phase III, detailed measurements were made of the effectiveness of typical HRV installations to provide ventilation. The apparent air change rates and the mean age of air in the rooms of the test homes was determined with

and without the ventilation and circulation systems running. Mechanical air supply and exhaust rates were also measured. Conclusions were drawn on the effective installation and operating practice for HRV ventilation systems in terms of distribution of ventilation air, propensity for short-circuiting and the effects of closing doors.

Under Phase IV of the study, the effectiveness of a variety of alternative HRV ventilation strategies was tested. Not installed as common practice at the time of the study, the low-cost HRV ventilation systems were tested as an addendum to this project using the same protocol as the Phase III testing.

The methodology for Phases III and IV involved the use of a trace concentration of gas to assess air change rates. Sulphur Hexafluoride, an innocuous gas not found in household environments, was released at predetermined points throughout the house and mixed by mechanical means until similar concentrations were achieved throughout the house. By measuring the decay in the concentration of the gas, the apparent air change rates were derived. The operating conditions of the ventilation system and the locations of the sampling points had an impact on the extent to which the measurements reflected whole house ventilation rates, room-by-room ventilation rates, natural air change rates caused by forces other than mechanical ventilation systems, or other factors related to ventilation, such as short circuiting within rooms, and cross contamination.

The common types of HRV installations investigated under this study (fully ducted, simplified and extended) were capable of performing well. The majority of the HRV ventilation systems were operating and were perceived to be providing a benefit to the occupants of the houses. Far greater benefits were possible, however, and considerable improvements could be made in installation practice, system performance, occupant understanding and occupant interaction with their system.

Simplified systems have a large share of the market in tract-built housing in the Central Region. When these simplified systems were compared with other types, the quality of the installations and the occupant use and understanding of the systems were notably lower.

These trends must be reversed as the use of the HRVs becomes common in most new homes across the country. Standard installation practice must be improved – this study found that simple and inexpensive measures can dramatically improve the ability of HRV ventilation systems to perform adequately. Information transfer must be improved to encourage the average occupant to use their HRV optimally, maintain it properly, and believe it to be of positive value.

RÉSUMÉ

Dans les années 1990, la ventilation a constitué l'une des plus importantes questions en matière de conception que l'industrie de la construction canadienne ait eu à aborder. Les codes du bâtiment contribuent au confort et à la sécurité des occupants en exigeant l'amenée d'air frais à l'intérieur des maisons neuves et l'évacuation de l'air vicié et contaminé à l'extérieur. De plus en plus, on répond aux exigences des codes en installant des ventilateurs-récupérateurs de chaleur monoblocs.

Comme l'usage des ventilateurs-récupérateurs de chaleur se répand pour la ventilation, plusieurs autorités ont exprimé le désir d'examiner et d'évaluer les liens entre la conception des maisons, la conception des installations de ventilation mécanique, les pratiques de pose et l'utilisation des installations de ventilation par les occupants, dans le contexte de l'efficacité de la ventilation des habitations. Afin d'aborder ces préoccupations, la Société canadienne d'hypothèques et de logement a retenu les services de la firme Buchan, Lawton, Parent Ltd, et elle lui a demandé d'étudier le rendement des ventilateurs-récupérateurs de chaleur.

Les conclusions qui seront tirées des résultats de cette étude permettront d'améliorer les pratiques de pose, le rendement des ventilateurs-récupérateurs de chaleur, les connaissances des occupants sur leur ventilateur-récupérateur de chaleur ainsi que leur interaction avec cette installation.

Le projet comprenait quatre étapes : 1) l'inspection de 60 maisons dotées de ventilateurs-récupérateurs de chaleur, 2) une enquête auprès des ménages qui occupaient ces 60 maisons afin de déterminer leurs connaissances sur les ventilateurs-récupérateurs de chaleur et l'usage qu'ils en font, de même qu'une enquête téléphonique auprès de 15 ménages additionnels, 3) la vérification intensive du rendement des ventilateurs-récupérateurs de chaleur existants, 4) la vérification intensive du rendement des ventilateurs-récupérateurs de chaleur expérimentaux.

Les inspections sur place, les enquêtes auprès des occupants et les enquêtes téléphoniques visant les installations existantes de ventilateurs-récupérateurs de chaleur qui ont été effectuées dans le cadre des étapes I et II nous ont permis d'en apprendre sur les perceptions relatives aux ventilateurs-récupérateurs de chaleur et sur les utilisations qu'on en fait dans les habitations canadiennes. Les paramètres étudiés ont permis de déterminer si l'installation répondait à des normes acceptables, son rendement, les connaissances de l'occupant sur le sujet et l'interaction de ce dernier avec l'installation.

Quinze maisons ont été inspectées sur la côte ouest, quinze sur la côte est, et trente dans le centre du pays. Toutes les installations avaient au moins un an et au plus quatorze ans. Quatre catégories d'installations ont été inspectées : les installations reliées par conduits à toute l'habitation, les installations étendues, les installations simplifiées et les installations montées sur un générateur d'air chaud. Pour élargir davantage la gamme d'informations obtenues, quinze maisons situées dans le centre du pays ont fait l'objet d'une enquête téléphonique.

Dans le cadre de l'étape III, la capacité des ventilateurs-récupérateurs de chaleur de fournir une ventilation efficace a fait l'objet de mesures détaillées. Le taux de renouvellement d'air apparent et

l'âge médian de l'air des pièces des maisons d'essai ont été établis avec les installations de ventilation et de circulation en marche et à l'arrêt. Les taux d'approvisionnement mécanique en air et d'évacuation ont aussi été mesurés. Des conclusions ont été tirées sur l'efficacité de la pose et de l'utilisation des ventilateurs-récupérateurs de chaleur en termes de distribution de l'air de ventilation, de la tendance au court-circuitage et des effets de la fermeture des portes.

Dans le cadre de l'étape IV de l'étude, on a vérifié l'efficacité d'une variété de stratégies de remplacement en matière de ventilateurs-récupérateurs de chaleur. Bien que leur installation n'ait pas fait partie des pratiques courantes au moment de l'étude, les ventilateurs-récupérateurs de chaleur bon marché ont été mis à l'essai à titre d'addenda au projet, sous réserve du même protocole que les essais de l'étape III.

La méthode employée pour les étapes III et IV nécessitait l'utilisation d'un gaz à l'état de traces afin d'évaluer les taux de renouvellement d'air. De l'hexafluorure de soufre, un gaz inoffensif absent de l'environnement intérieur des habitations, a été libéré à des points prédéterminés des maisons et mélangé à l'aide de moyens mécaniques jusqu'à ce que les concentrations soient semblables dans tout le bâtiment. En mesurant la diminution de la concentration de gaz, il a été possible de calculer le taux de renouvellement d'air apparent. Les conditions de fonctionnement de l'installation de ventilation et l'emplacement des points d'échantillonnage ont eu des répercussions sur la mesure dans laquelle les données reflétaient les taux de ventilation de la maison au complet, les taux de ventilation pièce par pièce, les taux de renouvellement d'air naturels causés par des forces autres que les installations de ventilation mécanique, ou d'autres facteurs reliés à la ventilation comme le court-circuitage à l'intérieur des pièces et la contamination croisée.

Les types courants de ventilateurs-récupérateurs de chaleur examinés dans le cadre de la présente étude (les installations reliées par conduits à toute l'habitation, les installations simplifiées et les installations étendues) pouvaient fournir un bon rendement. Dans la majorité des cas, les ventilateurs-récupérateurs de chaleur étaient fonctionnels et perçus comme bénéfiques pour les occupants des maisons. Toutefois, il est possible d'en tirer de bien plus grands avantages. En outre, des améliorations considérables peuvent être apportées au niveau des pratiques de pose, du rendement des installations, des connaissances des occupants et de leur interaction avec les installations.

Les installations simplifiées enlèvent une large part du marché des maisons en série du centre du pays. Comparativement aux autres types, la qualité de pose de ces installations, les connaissances des occupants à leur sujet ainsi que leur niveau d'utilisation sont beaucoup plus faibles.

Or, ces tendances doivent être inversés car la présence des ventilateurs-récupérateurs de chaleur devient monnaie courante dans la plupart des maisons neuves du pays. Il importe d'améliorer les pratiques courantes de pose -- l'étude a permis de déterminer que des mesures à la fois simples et peu coûteuses pourraient améliorer grandement le rendement des ventilateurs-récupérateurs de chaleur. La diffusion d'information doit être encouragée afin d'inciter les occupants à faire une utilisation optimale de leur ventilateur-récupérateur de chaleur, à entretenir ce dernier correctement et à croire en ses avantages.

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1.0 INTRODUCTION

With the increasing concern for the quality of indoor environment, ventilation has become one of the most important design issues in the Canadian construction industry. Building codes have been revised to promote the comfort, health and safety of occupants by ensuring fresh air is provided to new homes, and stale, contaminated air is exhausted outdoors. Increasingly, these code requirements are being satisfied by the use of packaged heat recovery ventilators (HRVs).

Over the past ten years, the use of HRVs has grown steadily. Once found primarily in R-2000 homes and other energy-efficient housing, HRVs are more and more frequently being installed in conventional Canadian homes. HRVs have evolved into durable, relatively energy-efficient devices.

Concurrent with the increased use of HRVs, the information transfer tools promoting HRV systems have been developed and refined to educate ventilation system designers, installers, builders, and homeowners. Despite the advances, questions remain about the impact of the various conventional HRV installation practices and the occupant and system interactions on the ability of HRV systems to provide effective, energy-efficient and safe ventilation.

Concerns have been raised that the inherent shortcomings of design, installation, commissioning, maintenance, and other factors related to tract-built housing may be contributing to deviations from the predicted performance of HRVs. Even in the context of R-2000 houses, where much of the research on ventilation has been carried out, little is known with respect to air movement and the effectiveness of ventilation within rooms. Given the increased reliance on HRVs for ventilation, several authorities have expressed a desire to explore and assess the relationships between home design, mechanical ventilation system design, installation practices and occupant use of ventilation systems as it relates to the effectiveness of the ventilation of the dwelling.

In response to such concerns, Canada Mortgage and Housing Corporation issued a contract to Buchan, Lawton, Parent Ltd to study the field performance of HRV ventilation systems. The project was divided into four phases:

Phase I	HRV Ventilation System Inspections
Phase II	HRV Occupant Survey and Telephone Survey
Phase III	Intensive Performance Testing of Existing Ventilation Systems
Phase IV	Intensive Performance Testing of Experimental Ventilation Systems

1.1 Phases I and II

A review of existing HRV installations was accomplished through the use of field inspections, occupant surveys and telephone surveys. The objective was to gain an understanding of how HRV ventilation systems were perceived and how they were used in Canadian housing in terms of:

- installation – meeting acceptable standards;
- performance – air flow and durability;
- occupant understanding – perceived value, knowledge, operation and maintenance; and
- occupant interaction – actual usage, maintenance and subsequent condition of the system.

From a systematic review of the existing installations, it was possible to determine the types of problems associated with the various HRV systems and the common deficiencies in installation practices, and to identify the gaps in occupant knowledge that could lead to less than optimal usage of the HRV systems.

Many of the ventilation systems included in this study were installed during the period when building codes provided limited regulation on the installation and performance of HRV systems. Although recent building code changes have indicated a shift towards increased regulation, the majority of the installations inspected during the course of this study were believed to be typical examples of current industry practice.

1.2 Phase III

The objective of this third phase was to develop a detailed measurement technique to determine the effectiveness of typical HRV installations in providing ventilation. Of particular concern was the characterization of the effective ventilation of houses on a room-by-room basis.

The ventilation systems in the test homes included under the Phase III evaluation met the requirements of Canada's most comprehensive ventilation standard, CAN/CSA-F326-M91. Designing and installing ventilation systems in accordance with this standard was referenced in the 1995 National Building Code as an alternative to the prescriptive requirements contained within the code.

Utilizing the methodology outlined in Section 3 of this report, attempts were made to establish the apparent air change rates and the mean age of air in the rooms of the test homes with and without the ventilation and circulation systems running. Mechanical air supply and exhaust rates were also investigated.

Analyzing these rates in conjunction with a review of the idiosyncrasies of each house made it possible to draw conclusions on the effective installation and operating practice for HRV ventilation systems in terms such as:

- distribution of ventilation air;
- propensity for short-circuiting within rooms and between rooms;
- effects of closing doors.

1.3 Phase IV

The fourth phase of the study was undertaken to test effectiveness of a variety of alternative conceptual ventilation strategies not currently installed as common practice.

The Efficiency and Alternative Energy Technology Branch (CANMET) of Natural Resources Canada (NRCan) had earlier commissioned a study to identify and evaluate various alternative, low-cost ventilation systems intended to meet CAN/CSA-F326-M91, *Residential Mechanical Ventilation Systems*. The systems developed were evaluated in terms of initial cost and operating cost using HOT2000 but were not evaluated in terms of ventilation effectiveness. The report on this work was titled *Energy Impact of Ventilation Air Distribution.*

The most promising of these alternative systems were installed and tested as an addendum to this project. This Phase IV work was sponsored by NRCan, Residential Programs.

The testing of the Phase IV systems was carried out using the same methodology followed in Phase III. This permitted the comparison of all the results from the ventilation system testing.

2.0 HOUSE AND SYSTEM CHARACTERISTICS

2.1 Phases I and II – Houses and HRV Systems

Fifteen Homes were inspected on the West Coast, fifteen homes on the East Coast, and thirty homes in the Central Region. All installations were at least one year old and ranged up to fourteen years of age.

The HRV installation types fell into the following four categories.

2.1.1 Fully Ducted

Fully ducted HRV installations are completely independent of any other air circulating devices. Air is exhausted from areas of high contamination and humidity (kitchens and bathrooms) and supplied directly to other rooms throughout the house.

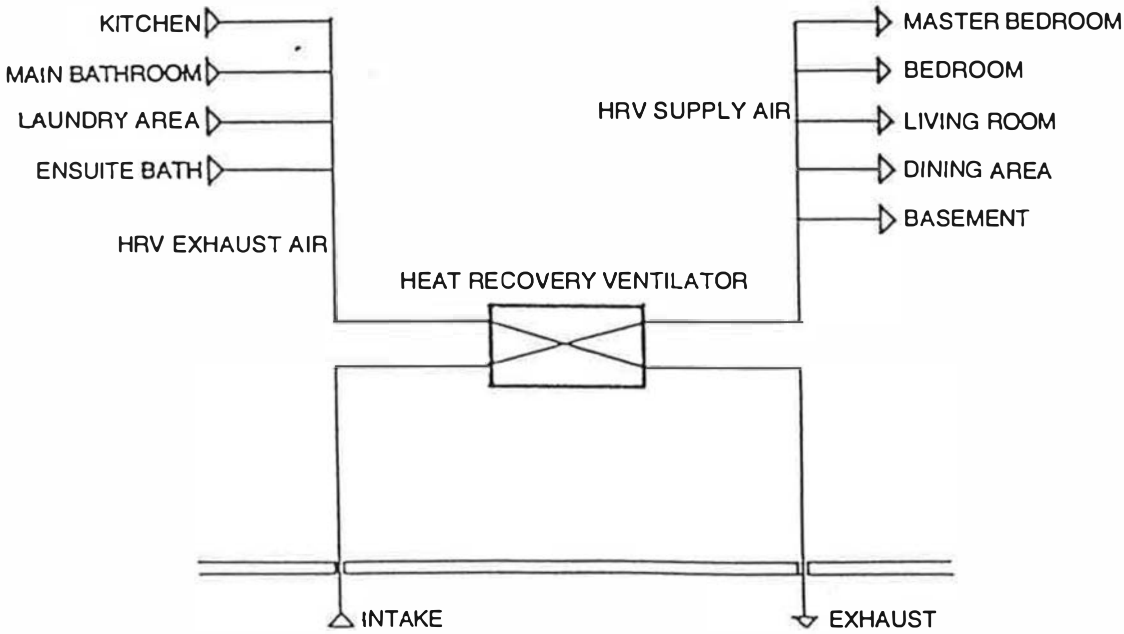


Figure 2.1: Schematic Drawing of Fully Ducted HRV System

2.1.2 Extended

Extended HRV installations exhaust air from the kitchen and bathrooms and supply air into the furnace return. The furnace fan circulates the ventilation air throughout the house.

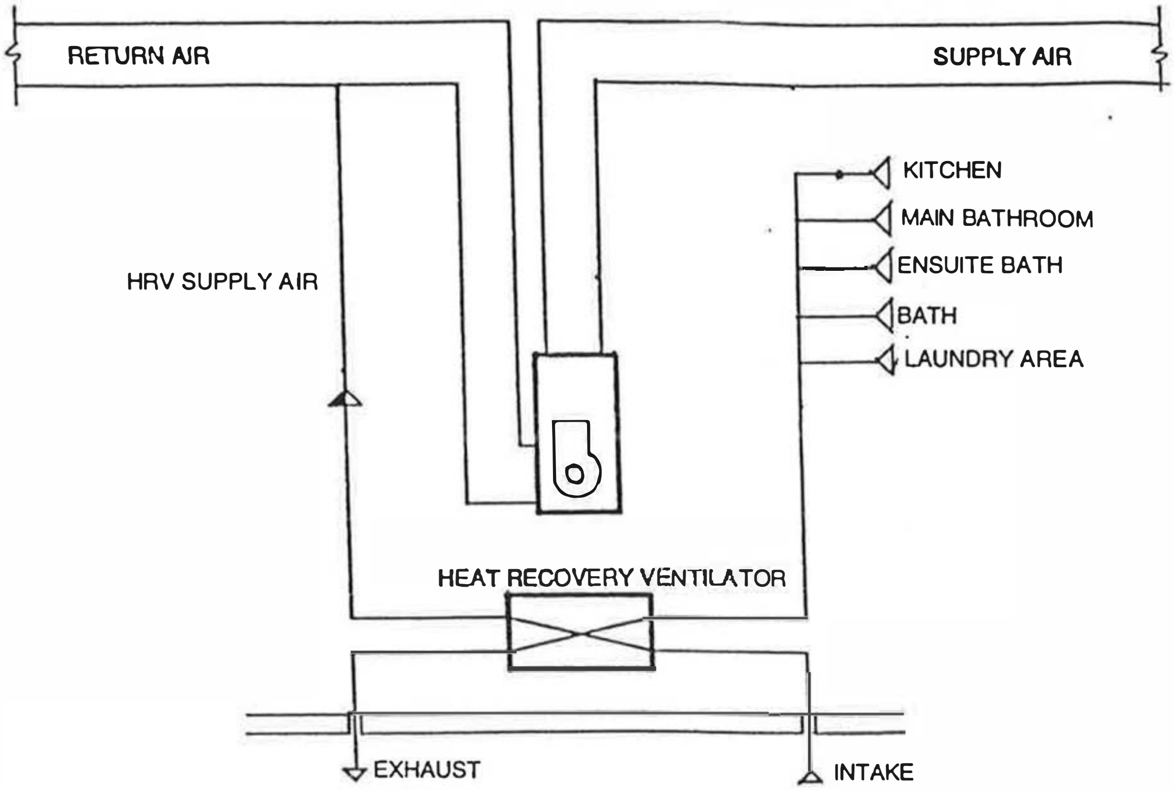


Figure 2.2: Schematic Drawing of Extended HRV System

2.1.3 Simplified Standard

Simplified standard HRV installations exhaust air from the furnace return air plenum and supply air to the furnace return air plenum (downstream of where air is exhausted). Ventilation air is circulated by the furnace fan.

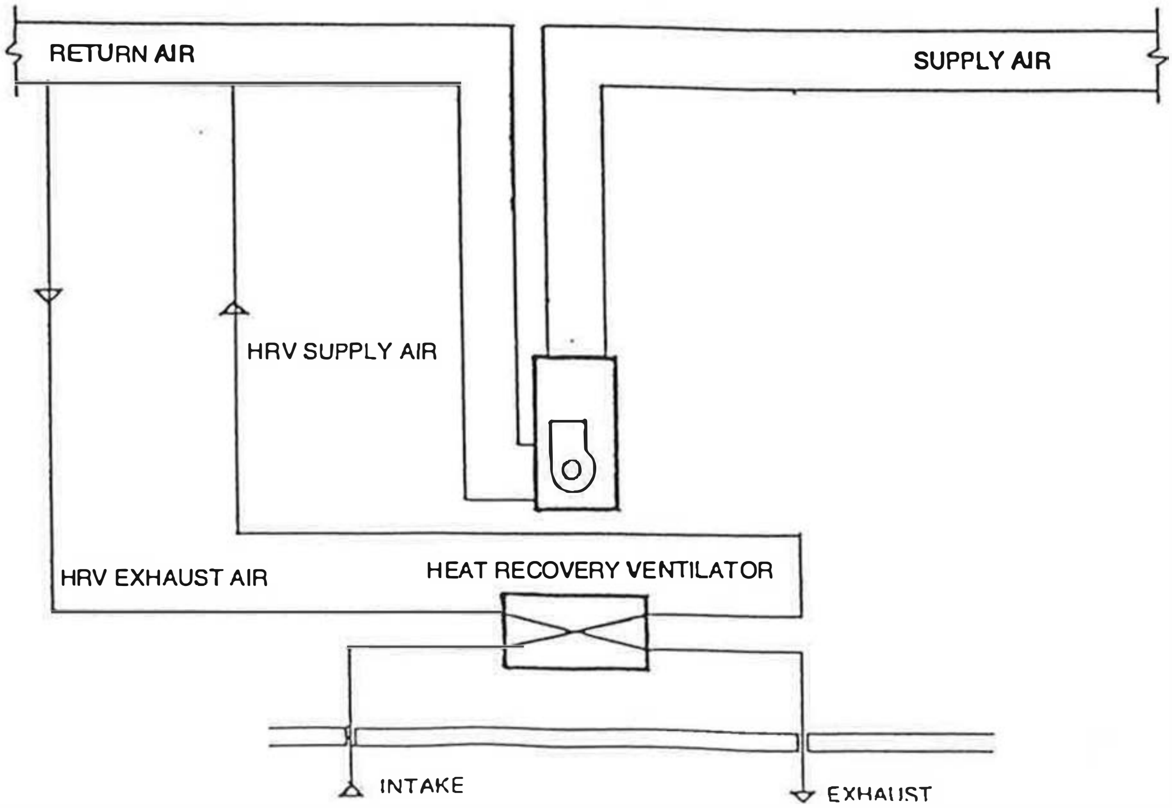


Figure 2.3: Schematic Drawing of Simplified Standard HRV System

2.1.4 Simplified Cross Furnace

Simplified cross furnace HRV installations are a modification of the Simplified Standard Installation. Again, air is exhausted from and supplied to the furnace ductwork and circulated via the furnace fan. These installations fall into two categories; those that exhaust from the return air plenum and supply into the supply air plenum, and those that exhaust from the furnace supply air plenum and supply to the furnace return air plenum.

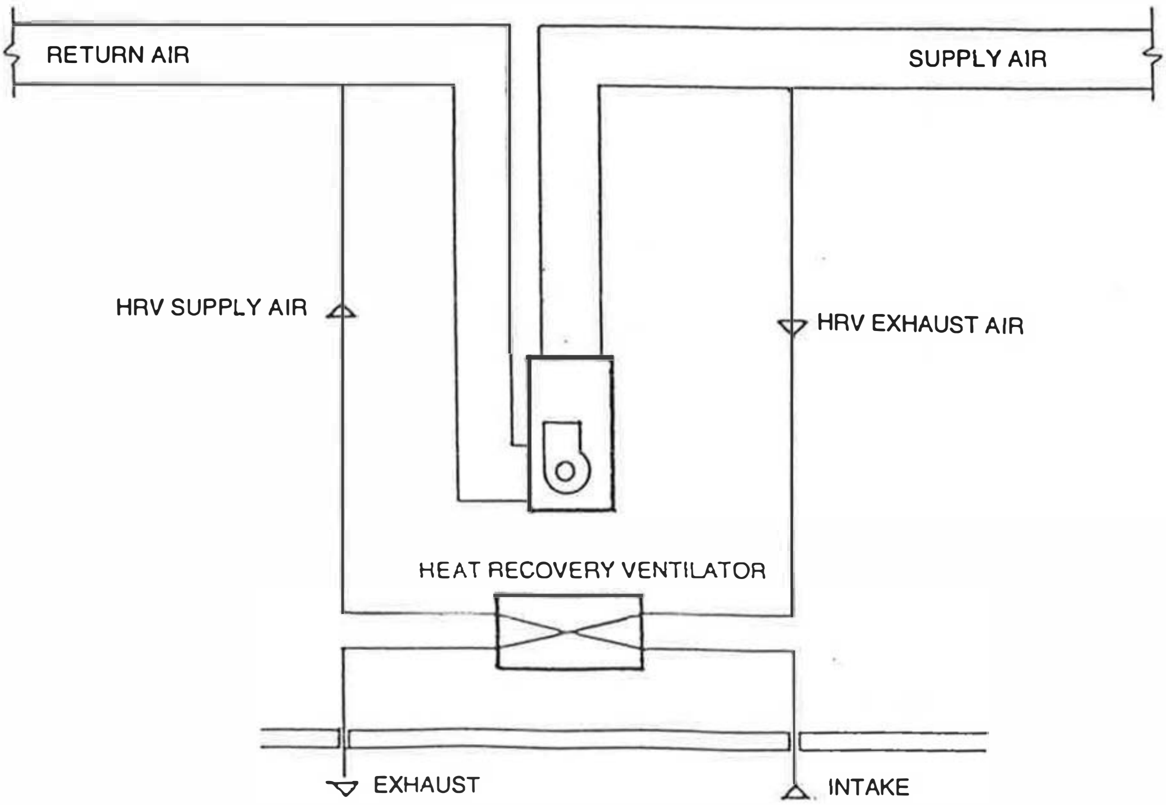


Figure 2.4: Schematic Drawing of Simplified Cross Furnace HRV System

2.1.5 Phase I House Data

Table 2.1 provides a breakdown of the houses included in Phase I of the study by age, type, and location.

Table 2.1: House Type and Age Distribution

Type	Region	Age			Subtotal
		2 – 4 years	5 – 7 years	8 years plus	
Fully Ducted	Western Region	3	4	2	9
	Central Region	4	2	1	7
	Eastern Region	3	2	4	9
Subtotal					25
Extended	Western Region	3	3		6
	Central Region	7	1	4	12
	Eastern Region	4	1	1	6
Subtotal					24
Simplified Standard	Central	6			6
Simplified Cross	Central	5			5
Subtotal					11
Total		**35**	**13**	**12**	**60**

All of the inspected installations had HRVs with cross-flow heat recovery cores. None of the inspected installations had HRVs with thermal wheels for heat and moisture recovery.

The simplified standard and cross furnace systems were only prevalent in the Central Region. It should be noted that a large percentage of the simplified systems inspected were installed by a single large mechanical contracting firm. This was unavoidable since this contractor does the majority of installations for tract builders in the Ottawa area.

2.2 Coding System Used in Report

Because many houses were inspected and tested as part of this project, a means of tracking results and findings had to be developed, which was, at once, accurate and comprehensive, as well as easy to use. The following four-part, alpha/numeric code system was established and used in the preparation of this report.

CODE CONFIGURATION

1. character: House Location (region)
2. character: HRV Installation Type
3. number: HRV Installation Age
4. number: Order in Which Houses Were Found Within Category

1. HOUSE LOCATION (1ST character)

"W"	=	Western region
"C"	=	Central region
"E"	=	Eastern region

2. HRV INSTALLATION TYPE (2nd character)

"F"	=	Fully Ducted system
"E"	=	Extended system
"S"	=	Simplified 1 system
"C"	=	Cross-Furnace (Simplified 2) system

3. HRV INSTALLATION AGE (3rd character)

"0"	=	New House (Phase III Ventilation System testing only)
"2"	=	2 to 4 years old
"5"	=	5 to 7 years old
"8"	=	8 years old or older

EXAMPLE

CE2-3	=	*Central region; Extended system; 2-4 years old; House No. 3*

2.3 Phase III – Homes and Systems for Phase III Testing

Twenty homes were selected for the Phase III testing in the study. Since all system types were represented in the Central Region and to maintain consistency in testing and to reduce costs, the homes were all drawn from the eastern Ontario area.

It was crucial that the group of test houses be somewhat representative of common HRV installation systems used in Canada. The following list breaks down the 20 test homes based on installation type:

Fully Ducted Systems	5
Extended Systems	8
Simplified Standard Systems	5
Simplified Cross-Furnace Systems	2

2.4 Phase IV – Alternative HRV System Installations for Testing

An agreement was made with a builder for the use of a bungalow that was almost ready for occupancy, but had not yet had the HRV component of the ventilation system installed. Alternative ventilation systems, based upon NRCan's conceptual systems, were designed and installed. The HRV warm-side ductwork was configured in such a way that, with minimal effort, the ventilation system could be rearranged from one alternative ventilation strategy to another. Conventional fully ducted, extended, and simplified systems were also configured and tested in this house.

A discussion of the test house is included in Appendix E.

2.4.1 System 1 – Simplified System with Backdraft Damper

This simplified system was installed with the HRV drawing exhaust air from the furnace return and supplying fresh air to the supply plenum. A backdraft damper was located in the vertical section of the furnace supply air plenum between the furnace and the point where the HRV fresh-air supply was connected. It opened due to air pressure when the furnace fan was operating and closed due to gravity when the fan was not operating.

The damper, therefore, prevented the fresh air delivered by the HRV from flowing through the furnace and return air system when the furnace was not operating. Dampers were installed to simulate low system air flow rates provided by an electronically commutated (ECM) DC motor.

This system was designed to test two configurations that could become common installation practice. The first was the use of an ECM motor with a simplified system. Particularly with the electronically commutated (ECM)

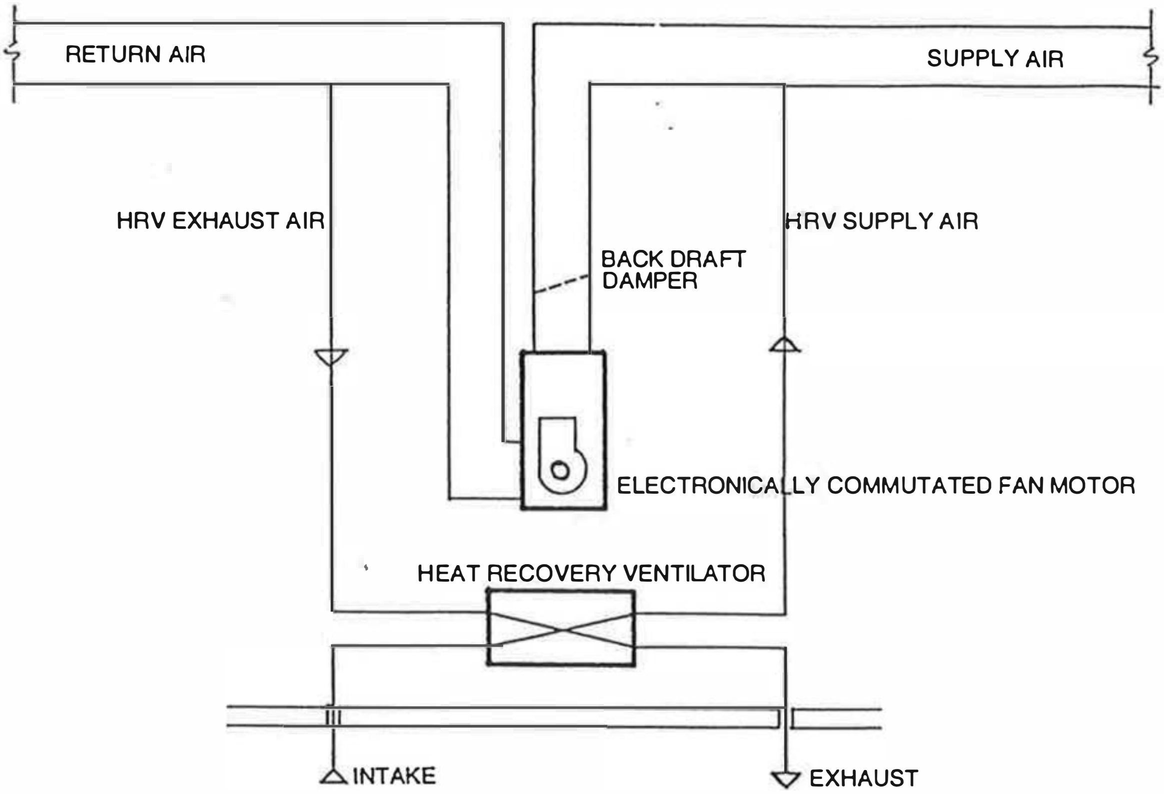


Figure 2.5: Schematic Drawing of System 1

motors now available for furnace fans, the low speed continuous air flow rate can be a much smaller fraction of the higher speed settings for heating and cooling. The intention was to determine whether the advantages of low-speed operation, low-noise generation, and low-energy use, were offset by reductions in distribution effectiveness. Testing was carried out to determine the effect of low-speed operation on the distribution of ventilation air via a ductwork system designed for a higher operating air flow rate.

The system was also designed to test the distribution of ventilation air when the furnace fan was not operating. During the earlier phases of the study, it was found that many of the surveyed occupants were not operating their furnace fan when their HRV was operating. The reasons for this included: they were unaware that they should; they found it noisy; or they were concerned about operating costs.

The concern with a typical simplified ventilation system when the furnace fan is not operating is that the air supplied by the HRV could either flow through the furnace and supply ductwork or through the return ductwork. Resistance is usually far less on the return side and it would be expected that most of the air would flow out of the closest return air registers and leak in the return air ductwork. Much of the fresh air would likely be exhausted outside again due to suction from the HRV exhaust pickup that is also connected to the furnace return.

To distribute the fresh air without the furnace fan operating, the HRV supply was connected to the most airtight side of the distribution ductwork with smaller registers. This increased the air flow within the supply ductwork, and ultimately caused more air to move further through the system than it would in a return system with leaky ductwork and large registers. Also, the supply system typically had a register in all rooms whereas the return system did not. For these reasons, the fresh air from the HRV was provided to the supply plenum instead of the return plenum.

2.4.2 System 2 – Extended System with Backdraft Damper

This system was identical to System 1 with the exception that the exhaust air for the HRV was taken from the kitchen and bathrooms instead of the return air plenum. The purposes of testing this alternative system installation were the same as those for System 1. The intent was to compare the effect of drawing stale air from the bathrooms and kitchen on the apparent net mechanical AC/H rates in living areas when the circulation system was not operating.

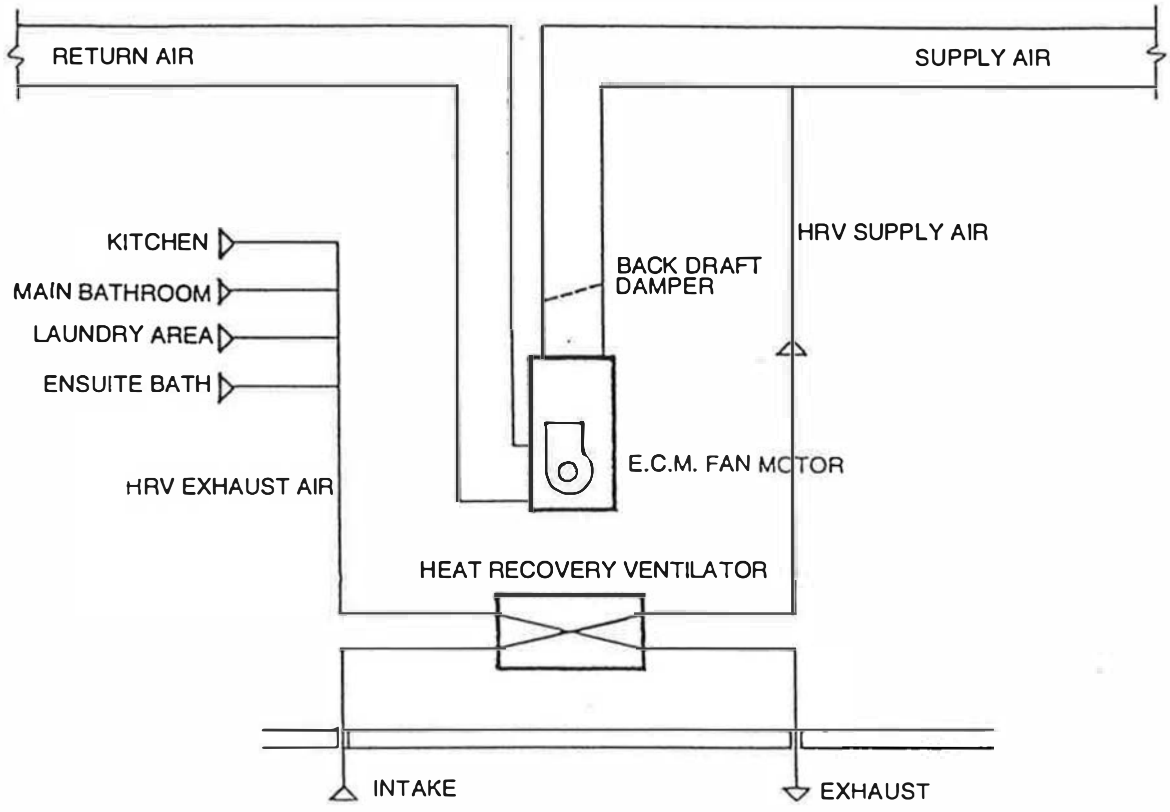


Figure 2.6: Schematic Drawing of System 2

2.4.3 System 3 – Supply to Central Location, Exhaust Fans in Bedroom Doors

The installation of fans in or above bedroom doors was perceived, in the *Energy Impact of Ventilation Air Distribution* report, to be a ventilation option with low installation and operating costs. The premise was that supply-side HRV ductwork in houses without forced-air heating systems could be reduced through the use of small fans above bedroom doorways to aid in distribution and circulation. The air drawn from bedrooms was to induce air circulation with adjacent ventilated spaces. During the testing, small, efficient, axial fan motor sets were installed and operated at the rates required by CAN/CSA-F326-M91 for rooms not directly supplied by ventilation air. The exhaust air rates from the master bedroom and the other bedroom were 20 L/s and 10 L/s respectively.

The HRV exhausted from the kitchen and bathrooms during all testing. An ensuite bath for the master bedroom also exhausted air during testing.

During one test, the HRV central air supply location was in the living room of the first storey. In the other test, the central supply was placed in the

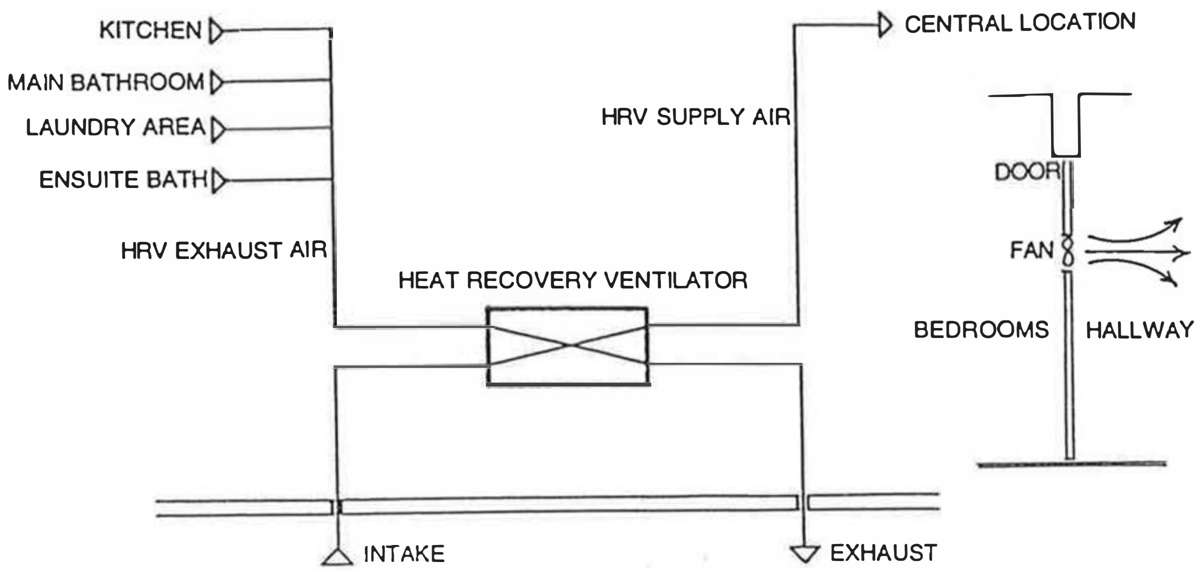


Figure 2.7: Schematic Drawing of System 3

basement to simulate a typical, two-storey house with a ventilation air supply in the first storey living area only and bedrooms located on the second storey.

2.4.4 System 4 – Supply to Central Location, Exhaust Fans in Bedroom Closets

System 4 was based on the same premise as System 3. The difference was in the location of the small exhaust fan. In System 4 the small fans exhausted stale air from bedroom closets to the floor below instead of exhausting air from the bedrooms into the hallway on the same floor as they did in System 3.

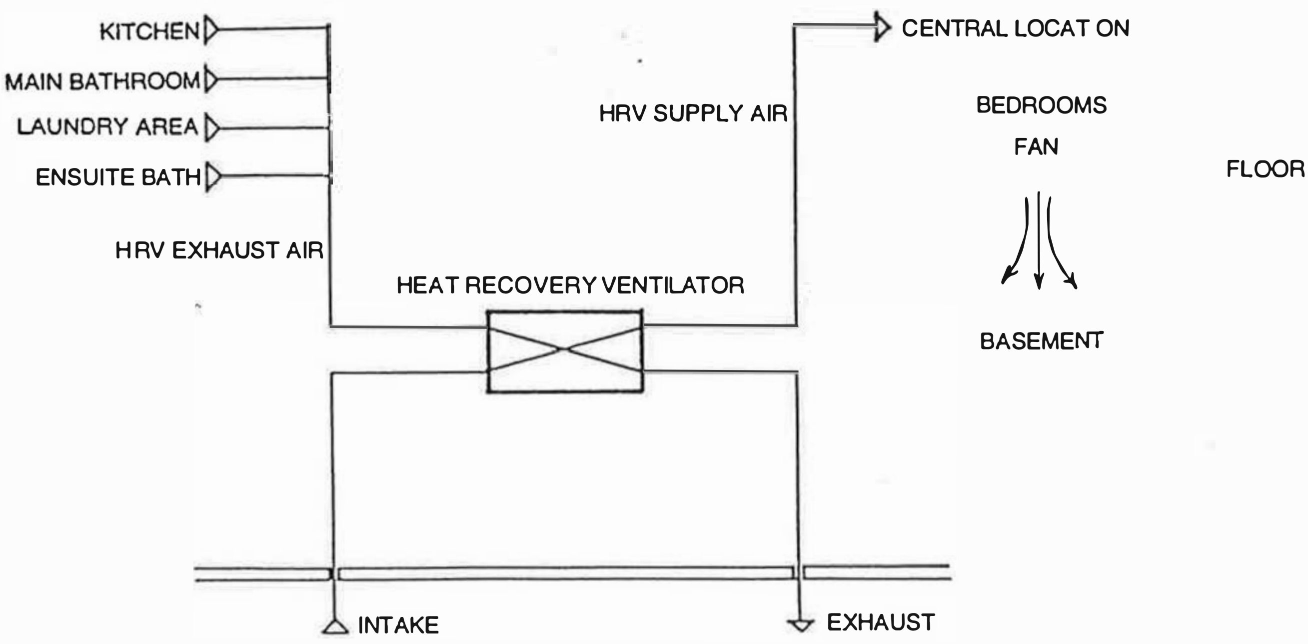


Figure 2.8: Schematic Drawing of System 4

3.0 METHODOLOGY

3.1 Phases I and II - HRV System Inspections, Occupant and Telephone Survey

The HRV system inspections and occupant surveys were completed for 60 homes. Chosen to be as representative as possible of the Canadian housing stock, the selection criteria for the homes included:

- geographic region;
- HRV installation type; and
- age of installation.

An *HRV System Inspection Form* was prepared and used to investigate and document the status of the ventilation system. A copy of the inspection form is included in Appendix F.

During the inspection, the investigator documented the way in which the HRV was originally installed, surveyed the existing condition of the components of the system, and measured the air flow capabilities of the system at the time of the inspection. Major deficiencies and occupant-related adjustments and modifications were also noted.

The *Occupant Survey* was designed to gain information in the following three areas:

1. the occupants' understanding of the operation of their ventilation system,
2. The occupants' understanding of how their ventilation system interacted with other systems in their home, and
3. The way in which the occupants used and maintained their ventilation system.

A copy of the *Occupant Survey* form is included with this report as Appendix G.

The inspection and survey findings were statistically analyzed to quantify the results. This made it possible to determine where deficiencies were most likely to occur. Further analyses related the results of the occupancy and telephone surveys with the HRV inspection results. Table 3.1 lists the subgroups chosen for the statistical analysis.

Table 3.1: Subgroups Used in Analyzing Responses to Inspection and Survey Questionnaires

ALL SYSTEMS

GROUPED BY SYSTEM
Fully Ducted
Extended Ducting
Simplified Ducting

GROUPED BY REGION
Central
Central without simplified
East
West

GROUPED BY AGE OF HRV
2 to 4 years old
2 to 4 years old without simplified
5 to 7 years old
8 years plus

GROUPED BY REGION & SYSTEM
Central Fully Ducted
Central Extended Ducting
Central Simplified Standard
Central Cross-Furnace
East Fully Ducted
East Extended Ducting
West Fully Ducted
West Extended Ducting

Appendices A and B contain the questions and responses for both the inspection results and survey findings respectively. The results are expressed as a percentage of houses to which a particular question was applicable within each group. Not applicable (NA) was used for groupings where the question was not applicable to all houses within the grouping.

The *Telephone Survey* was conducted with 15 Ottawa homeowners of tract-built housing. Each reportedly had a simplified system. The questionnaire used in the telephone survey was a simplified version of the questionnaire used for the *Occupant Survey.*

A copy of the *Telephone Survey* form is included in Appendix G. This survey provided additional perspective on occupant understanding and usage of their ventilation system and, thus, increased the breadth of the study.

3.2 Phases III and IV – Ventilation Effectiveness Testing

3.2.1 Definitions

The following terms are used to discuss the ventilation effectiveness testing in the methodology, the test results, conclusions and recommendations.

Air Change Rate: The rate at which air changes within a room or house; usually expressed in terms of air changes per hour (AC/H).

Note that an air change rate of 1 per hour means that the volume of fresh air brought into the room is equal to the volume of the room. Assuming perfect mixing prior to air leaving the room at all times, this would lead to the air originally in the room being diluted to 37 per cent of the total room air at the end of the hour.

Natural Ventilation Air Change Rate: The rate at which outdoor air enters the building envelope due to natural causes, such as wind and stack effect.

Total Ventilation Air Change Rate: The rate at which outdoor air enters the building due to natural causes, such as wind and stack effect, and mechanical causes, such as HRV operation.

Mechanical Ventilation Air Change Rate: The rate at which outdoor air enters the building envelope due to mechanical causes only, such as HRV operation.

The *Mechanical Ventilation Air Change Rate* is equal to the *Total Ventilation Air Change Rate* minus the *Natural Ventilation Air Change Rate.*

From the tracer gas testing, it was possible to calculate the following:

- *Apparent Natural Ventilation Air Change Rate*
- *Apparent Total Ventilation Air Change Rate*
- *Apparent Mechanical Ventilation Air Change Rate*

These terms correspond to those previously discussed with the addition of the word *apparent* in the term because they do not differentiate between:

- fresh air supplied to a room directly from outside via the ventilation/circulation system, or
- interzonal movement of air brought into the house after testing began.

By including the air not directly supplied from outside to the rooms in the air change rates, the calculated air change rates become more similar throughout the house than they would be if all fresh air either remained in the room to which it entered or was exhausted from this room without entering another. This tends to make the air change rates appear to be greater in rooms where the direct delivery of fresh air is relatively low, and appear to be lower in rooms where the direct delivery of fresh air is relatively low, and appear to be lower in rooms where the direct delivery of fresh air is relatively high.

Throughout the text, the previously defined *apparent* terms are defined in respect to air changes per hour by the following abbreviated names:

- *Apparent Natural AC / H*
- *Apparent Total AC / H*
- *Apparent Mechanical AC /H*

Mean Age of Air is the average time that air in a particular space has been within the building (average time since air came from outside). Mathematically, it is the reciprocal of the *air change rate* in a given location. *Mean age of air* has been used to refer to the reciprocal of the calculated *Apparent Mechanical AC/H* values.

Ventilation Effectiveness is defined as the portion of the fresh air that reaches the living space. Ventilation effectiveness does not provide a measure of the removal of stale air.

3.2.2 General

The testing under Phases III and IV was fundamentally aimed at assessing the effectiveness of ventilation systems that, by normal industry measures (i.e. through the measurement of HRV air flows), were thought to comply with Canadian Codes and/or *CAN / CSA-F326-M91 Residential Mechanical Ventilation* – the key ventilation standard used today.

Three factors were considered important. These included:

- the overall house air change rate,
- the distribution of air to various rooms in the house, and
- the mixing of air within the individual rooms.

The test methods used were experimental in nature.

Mechanical ventilation systems provide one aspect of air change in houses. Air change at any location in the home is affected by:

- mechanical ventilation rates;
- natural air change;
- air diffusion to/from other spaces;
- stratification and mixing; and
- cross contamination of supply and exhaust air stream.

Where possible, attempts were made to try to determine the impact of these factors on the measured ventilation rates.

At the basic level, it was necessary to measure air change rates with and without the ventilation system running. In this way, it was possible to "net out" the natural ventilation from the mechanical ventilation air flows.

Closely related to the ventilation ducting scheme was the operation of the furnace fan and its impact on air distribution. Because systems with simplified ductwork or extended ductwork employ the furnace ductwork to distribute ventilation air, the impact of "furnace on" versus "furnace off" was of obvious interest. Forced-air heating systems recirculate a considerable amount of air throughout the building; in most cases, air flows through a forced-air furnace will be five to ten times the flow through the HRV. This could have a significant impact on the stratification of air and distribution of ventilation air between rooms and could also result in the short-circuiting of ventilation air within the forced-air heating system.

Doors, partitions, floors, furnishings and other interior features can act to limit air distribution and circulation in the home and in individual rooms. As well, the proximity of a given room to the distribution fans may affect the amount of ventilation air it receives. Further away from the ventilation fan, the combined impacts of duct leakage and pressure losses may limit flows.

The testing carried out under Phase III was aimed at attempting to quantify these effects.

A tracer gas decay test method was used to assess air change rates. The tracer gas (Sulphur Hexafluoride) was distributed as evenly as possible throughout each house prior to testing. Air was drawn from each monitoring location three times over the time frame of each test. (Monitoring locations are discussed in the following section). Outside air did not contain the tracer gas and, once testing began, the concentration of the tracer gas decreased as the outside air entered the room by natural and mechanical means. By measuring the decay in the concentration of the gas over the time frame of the test, the air change rate was derived. The operating conditions of the ventilation system and the locations of sampling points will have an impact on the extent to which the measurements reflect whole house ventilation rates, room-by-room ventilation rates, natural air change rates, or other factors related to ventilation, such as short-circuiting within rooms and cross contamination.

Because so many factors can affect ventilation in individual zones, a test procedure was required to facilitate the on-site analysis of results in order to identify and account for anomalous results. To this end, the direct measurement of tracer gas concentrations on site was undertaken using a Lagus Technologies, multi-port Sulphur Hexafluoride (SF_6) portable gas chromatograph. The equipment was capable of taking gas samples from eight different locations during each test.

Three configurations of the various parameters affecting ventilation within the house were chosen for the study. The three chosen were considered to be the most significant although many different operating parameters affect the ventilation rate. These were:

- ventilation system on/off – to determine the portion of air change that was related to the mechanical ventilation system;
- interior doors open/closed – to assess the impact of closed doors on ventilation flows within individual rooms; and
- forced-air heating system on/off (if applicable – to assess the effect of furnace fan operation on air distribution.

Table 3.2 outlines the configurations of the test house and their systems as they were used for the testing. Test Type A for a simplified system, for example, involved tracer gas testing of the house with the HRV turned off, the furnace fan on and the interior door were open. Test Type E for all installations included intensive sampling in one room. Air was sampled to determine tracer gas concentration from different elevations and floor plan locations within the room.

Table 3.2: House Configuration by Test Type

For Simplified and Extended Installations:

Test Type	HRV	Furnace Fan	Interior Doors
A	OFF	ON	OPEN
B	ON	ON	OPEN
C	ON	ON	CLOSED
D	ON	OFF	OPEN
E	ON	ON	OPEN (intensive)

For Fully Ducted Installations:

Test Type	HRV	Furnace Fan	Interior Doors
A	OFF	N/A	OPEN
B	ON	N/A	OPEN
C	ON	N/A	CLOSED
E	ON	N/A	OPEN (intensive)

Note: Intensive tests were carried out with four or more probes in the same room to determine the variation in apparent ventilation rates within rooms.

3.2.3 Tracer Gas Testing Procedure

The following summarizes the experimental tracer gas testing procedure used in the study.

House Conditions

Prior to releasing the tracer gas, all exterior windows and doors were shut and all exhaust equipment was turned off. Fireplace doors were shut. All intentional openings, such as combustion air inlets and HRV outside ports, were left unsealed. This configuration was considered to best represent a minimum ventilation condition.

Monitoring Locations

The monitoring locations were established at the sites for which the apparent air change rates were to be calculated. Locations were chosen to permit the calculation of the apparent air change rates for distinct zones throughout the house with a bias towards living areas. Typically, the monitored locations included two bedrooms, the living room, kitchen and basement.

The most appropriate locations for sampling points within the rooms were determined on the basis of preliminary testing carried out in the first three house configurations (See Appendix C, Section 1.0: Mixing Within Rooms). Unless otherwise noted, the room-by-room air change rates were arrived at using sampling points located in the centre of the room at mid-height (1.2 m above floor level).

Sampling was also carried out at the return air grilles and HRV exhaust air grilles in fully ducted houses to determine if the air was fresher at this location than in the middle of the room. This would indicate the short-circuiting of ventilation air in the rooms.

Distribution of Tracer Gas

The tracer gas was distributed as evenly as possible throughout the house prior to testing in order to reduce the effect of air change between the rooms.

In houses with furnace fans, the tracer gas was released into the return air plenum and the furnace fan was run until the tracer gas concentration was relatively even throughout the house. In houses with fully ducted systems, tracer gas was injected into each room and distributed using hand held fans.

Equipment Operation

The equipment was operated at the settings given for each one of the tests in Table 3.2. Where the HRV was in operation, it was running and balanced at a rate close to the CAN/CSA-F326-M91 MVC rate. When a furnace fan was in operation, it was running at the low speed continuous rate. Since the heating and cooling mode rates were higher or equal to these rates on all tested systems, these were the worst case conditions for air distribution in the house.

Testing

An air sample from each location was analyzed every two minutes from the start of each test to determine the concentration of the tracer gas.

The greater the amount of fresh air brought into a room, the faster the decline in the tracer gas concentration. A sample plot of a decay curve is illustrated in Figure 3.1. This plot shows the tracer gas concentration curves for each of the eight sampling port locations. The sampling time was selected to allow for a minimum of three readings at each sample location.

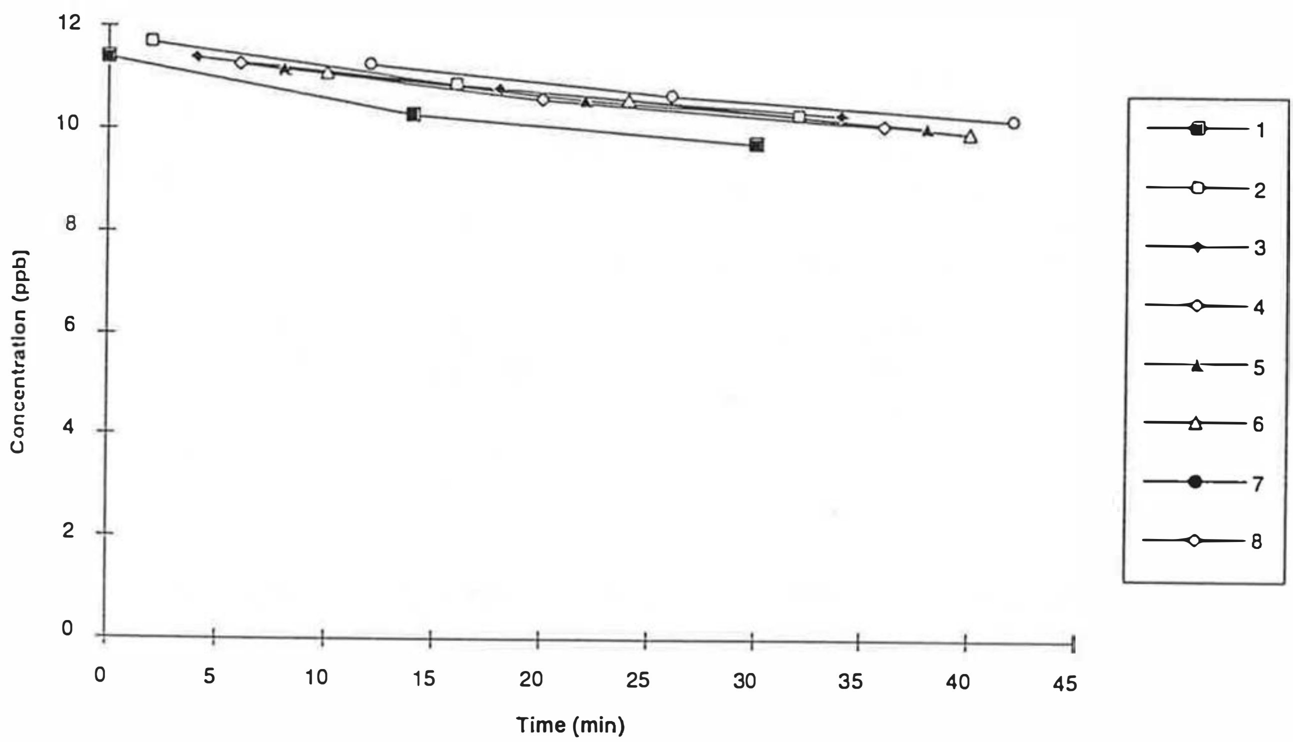


Figure 3.1: Sample Tracer Gas Decay Curve
(House CE2-3, Test C, Numbers reference sampling locations)

Resetting

After the test, the ventilation equipment was turned off. Prior to running the next sequence of tests described in Table 3.2, steps were taken to reestablish an even distribution of the tracer gas at an appropriate concentration.

Calculation of Apparent Ventilation Rate
The apparent ventilation rates were calculated from each series of three data points for a given location based upon the following formula.

$$I = 1/t*\ln(Co/Ct)$$

where I is the apparent ventilation rate,
t is the time, and
C is the concentration of tracer gas over time.

The apparent ventilation rates were determined based upon a line estimate of the natural logarithms of the tracer gas concentrations over time.

The coefficient of determination, a measure of the strength of the fit of the line to the individual data points, was used to determine the validity of the recorded data. Only test data with a coefficient of determination of greater than 0.75 were used in the analyses.

3.3 Air Flow Measurements

The HRV air flow rates were measured prior to testing to determine the amount of fresh air entering the house mechanically. The air flow through the HRV supply and exhaust grilles within each home was measured. Similarly, the air flows through the furnace supply and return air grilles were also measured.

The intent was to investigate the expected distribution of ventilation air based on these flow measurements, and to compare them with the distribution of ventilation air found using tracer gas testing.

The CMHC duct test rig was used for all flow measurements at HRV and furnace grilles. Unfortunately, it proved to be inaccurate at low flow rates. Air flows on high wall registers were also estimated based on the time it took to inflate or deflate a bag of known volume. The bag method was chosen because of the sum of the exhaust and supply flows using this method were found to be relatively close to those measured using flow measuring stations in the ductwork. This was an improvisational measure required because of the problems experienced with the CMHC duct test rig. No calibration was done to determine the effect of bag inflation resistance.

For comparison purposes, the bag method of air flow measurement and the duct test rig air flow measurements were taken on the same furnace circulation system registers at some houses.

For fresh air delivered by the HRV to the furnace, it was assumed that the same proportion of fresh air to supply air was delivered to each room.

Direct supply air rates were determined by taking the fraction of the supply air rate at a given register to that of all registers and multiplying it by the measured HRV supply flow rate. No attempt was made to account for air leakage from the furnace supply air system or from the HRV to furnace return air connection.

3.4 HRV Cross Contamination

During the latter half of the study, four single point tracer gas concentration measurements were taken in the warm and cold side ductwork of the HRV for both the supply and exhaust air streams. This was carried out in order to determine the extent of cross contamination within thc HRV corc and thc extent of contamination outside the building envelope from the exhaust port to the supply port.

4.0 TRENDS

4.1 HRV Installation Type

The percentage of homes built without forced-air heating systems on the East and West Coasts is far greater than it is in the Central Region. Fully ducted HRV installations were far more prevalent on the two coasts.

In Ontario until the early 1990s, the majority of HRV installations were the extended type. As HRV installations have become standard practice for many tract home builders, however, simplified systems have become more prevalent.

4.2 Guidelines, Standards and Building Codes

Over the time frame of the installations of the HRV systems included in this study, guidelines, standards and building code provisions were introduced and revised to define good practice in HRV installation and to regulate the installation of the HRVs.

In 1981, when the first HRV system included in this study was installed, standards of good practice had not been defined.

In 1982, the R-2000 Program was established. HRV installations in R-2000 homes were required to meet the requirements set out by the R-2000 Program.

Soon thereafter, the Heating, Refrigeration and Air-Conditioning Institute of Canada (HRAI) produced an *Installers' Manual for Heat Recovery Ventilators.* This manual was designed for those installing HRVs in R-2000 housing. It defined the standard of good practice required in R-2000 housing and was a reference point for other installations. It continues to be used in installer training sessions today. The manual has been revised and broadened, and is now titled *Installation Manual for Mechanical Ventilation Systems.*

In 1985, the Canadian Standards Association (CSA) published CAN/CSA-C439, *Standard Methods of Test Rating the Performance of Heat-Recovery Ventilators.* This standard was updated in 1988. All models of HRVs used in R-2000 houses are required to have been independently tested in accordance with this standard to ensure that they meet performance requirements.

In 1985, CSA also published CAN/CSA-C444, *Installation Requirements for Heat Recovery Ventilators.* In 1991, the CSA withdrew this standard and replaced it with CAN/CSA-F326, *Residential Mechanical Ventilation Systems.* HRV installations in R-2000 houses have been required to meet this standard since September 1, 1991.

During the 1990s, residential ventilation requirements in building codes have changed rapidly. Mechanical ventilation requirements in the 1990 National Building Code (NBC) became more stringent. Part 9 of the 1995 NBC makes CAN/CSA-F326-M91 one of the options available for the design and installation of HRV ventilation systems.

The revisions to the Ontario Building Code (OBC) in 1993 required the installation of HRVs in all electrically heated homes.

For the purposes of this study, comments and noted deficiencies have been discussed in relation to the following guidelines, standards and codes:

- 1992 HRAI Installation Manual for Residential Mechanical Ventilation Systems
- CAN/CSA-F326-M91 Residential Mechanical Ventilation Systems (October 1993 Edition)
- 1990 NBC
- 1990 OBC with 1993 amendments

5.0 PHASE 1 – HRV SYSTEM INSPECTION RESULTS

In this section, the inspection results for each item are reviewed individually. The organization of the section is based on the organization of the survey used in the field and highlights the results of the relevant questions from the survey. The requirements for the installation of the component as outlined in the related guidelines, standards, and building codes are identified first. The statistical results from the survey are then documented. This is followed, where applicable, by comments on the deficiencies as they relate to the guidelines, standards, and building code requirements.

Appendix also contains a summary of the HRV air flow measurements at each house.

5.1 HRV Installation

Warm-Side Ductwork

Appendix A Inspection Results, Question 13

The assessment of the ductwork requirements was based upon the guidelines and performance requirements of the HRAI Installation Manual, CAN/CSA-F326-M91 and building codes.

The ductwork for more than four in five of the non-simplified HRV installations appeared to be reasonable sized according to standards of good practice.

In most of the simplified installations inspected, flexible ductwork was used. Very little consideration appeared to have been given to the design and installation of this ductwork. Often inappropriate connection and transition sections were used, such as taping a flexible duct supply from the HRV to the furnace return.

Cold-Side Ductwork

Appendix A Inspection Results, Question 15

The HRAI Manual and CAN/CSA-F326-M91 detail how insulation and vapour barriers are to be installed on the cold side ductwork. The HRAI Manual also discusses preventing the compression of cold side insulation. The current OBC requires insulation on cold-side ductwork, but does not state that a vapor barrier is required.

Only half the HRV installations inspected had adequately installed cold-side ductwork. The most common problems included poor sealing of vapour barrier at connections and the compressions of the insulation by support straps or surrounding material. In many simplified system installations, ductwork was substantially compressed between the joist and top plate of the framed basement wall.

The insulation was either partly or altogether missing in five of the installations noted to have deficiencies related to the installation of cold-side ductwork.

Vibration Isolation

Appendix A Inspection Results, Question 14

The HRAI Installation Manual provides details on the vibration isolation of the HRV unit and the ductwork. CAN/CSA-F326-M91 states that vibration isolation is to be installed as per manufacturers' instructions and details the vibration isolation of the HRV from the building structure. Vibration isolation is not discussed in the NBC. It is required to be installed as per manufacturers' recommendations in the OBC.

HRVs were generally suspended properly and had flexible duct vibration isolation on the cold and warm side ductwork in over 80 per cent of the installations inspected.

HRV Condensate

Appendix A Inspection Results, Question 9

The HRAI Manual and the OBC both require condensate tubes to be trapped.

Two thirds of the homes in the Central Region had condensate tubes containing traps. This was a relatively uncommon practice on the East and West Coasts, where 20 per cent or less of the inspected HRV installations had condensate tubes containing traps.

Kitchen Grease Filters

Appendix A Inspection Results, Question 7

CAN/CSA-F326-M91 requires a grease filter to be installed in the kitchen exhaust port. It must be possible to remove the filter without tools. The NBC and OBC do not require a grease filter, if the exhaust duct is accessible for cleaning. A definition is not given for "accessible" in the Codes.

Kitchen grease filters were installed in 50 per cent of the homes inspected in the Central Region. However, on the east and west coasts, less than 20 per cent of the homes had kitchen grease filters.

Exterior Ports

Appendix A Inspection Results, Question 16 & 17

The HRAI Manual recommends a minimum clearance of 6 feet from contaminant sources to the HRV supply port. CAN/CSA-F326-M91 and the OBC both require a minimum clearance of 3 feet (900 mm). It should be noted that the Ontario Gas Utilization Code requires that the minimum clearance for a fresh air intake from the exhaust port of a gas appliance be 6 feet. The clearance for a gas regulator is 10 feet (3 metres).

Twenty-two per cent of the inspected HRV installations had a pollutant source within six feet of the supply port. The most commonly noted pollutant sources were HRV and clothes dryer exhaust ports. Other potential pollutant sources noted within six feet of the HRV supply port included: a gas regulator, central vacuum exhaust ports, and a bathroom fan exhaust port.

A few of the inspected hood assemblies were installed at elevations below those recommended by the guidelines and the codes. Some of the hood assemblies were installed in inaccessible locations, such as under decks or against deck header plates. Bird screens were missing in two of the hood assemblies inspected.

Typically, the HRV intake and exhaust ports of installations four years old or older were equipped with galvanized steel or aluminum hoods coupled with hinged screens. Many of the newer installations had plastic port assemblies with snap-in-place grilles in front of the bird screens. Often these snap-in-place grilles had already been broken or were missing.

5.2 Controls

Appendix A Inspection Results, Questions 1 to 4

The HRAI Manual recommends the use of dehumidistats in living areas and high-speed timers in kitchens and bathrooms to control HRVs. CAN/CSA-F326-M91 requires a controller to be installed to allow the occupant to reduce the HRV air flow rates. The OBC requires a switch for the HRV in the living area to allow the occupant to turn the HRV on and off.

Eighty-three per cent of the inspected installations had operable dehumidistats which properly controlled the HRV.

None of the HRVs installed in simplified systems had any remote controls to vary HRV speeds, although some had living area switches to turn on the HRV.

Only 23 per cent of the installations had operable dehumidistats for the HRV in the living area. Older installations were more likely to have remote controls in the living area. Even after excluding tract-built homes with simplified systems, the percentage of HRV installations in the two- to four-year old category with living area remote controls was less than half the percentage of older installations with living area remote controls.

As air is not directly exhausted from bathrooms by the HRV in homes with simplified systems, these systems do not have high speed remote controls in bathrooms. For houses with fully ducted and extended systems, 75 per cent of the homes had remote speed timers in bathrooms to initiate high-speed operation of the HRV.

Ventilation systems that use forced-air systems to circulate ventilation air are required to have switches to run the furnace fans continuously in the HRAI guidelines and CAN/CSA-F326-M91. The 1993 OBC revisions also brought in this requirement. Of the homes with simplified systems, three of the eleven did not have a switch to allow the furnace fan to operate continuously. All houses with extended systems had these switches.

5.3 Defrost Mode

Appendix A Inspection results, Questions 10 to 12

Due to the mild West Coast climate, none of the HRVs inspected in the west had defrost modes. A hundred per cent of the non-simplified, two- to four-year old HRV installations in the Central and Eastern Regions had damper-type defrost modes. Two-thirds of the simplified HRV installations had electric resistance-type defrost modes while the remainder had damper defrost mechanisms.

Overall, the defrost mechanisms worked properly in 90 per cent of the HRV installations with a defrost mode. Of the four defrost mechanisms malfunctioning at the time of inspection, three were equipped with an electric coil on the supply intake of the HRV. A failed electric resistance defrost mechanism in one of the inspected units had caused the core to freeze. In two simplified cross-furnace HRV installations, the electric coil defrost mechanism could not be activated. However, the homeowner was not aware of any problem because the warm exhaust air coming directly from the supply plenum defrosted the core.

One mechanical damper did not close completely. As a result, the majority of air drawn in from the supply side was coming from the basement rather than outside.

5.4 Filters and Cores

Appendix A Inspection Results, Questions 5 & 6

In eighty per cent of the homes inspected, the filters and core were installed correctly in the HRV unit.

Poorly fitted filters were a relatively common problem in the remaining HRV installations inspected. Some of the original filters had been poorly fabricated to begin with, and other HRVs were provided with filters not intended for use in that particular unit. As a result of ill fitting filters, large airborne particles and insects were able to enter the cores of the HRVs.

The filters and cores of the HRV units appeared to be clean in just under 50 per cent of the homes inspected. This figure dropped to under ten per cent for all HRV systems five years or older.

5.5 Bird Screens

Appendix A Inspection Results, Question 8

The minimum bird screen mesh size referenced by guidelines, codes and standards is ¼ inch (6 mm).

Overall, 74 per cent of the HRV installations had appropriate unblocked bird screens (either partially or completely unblocked). Of the 17 houses where this was not the case, 7 had screens blocked with debris, and 5 had inappropriate screens that, to a large degree, restricted air flow. These fine mesh screens had apparently been installed by occupants who were concerned about insects being drawn into the unit. In two cases, the bird screens could not be cleaned because they had been installed in inaccessible locations. Bird screens were missing altogether in two cases.

5.6 Non-Operational HRV Installations

Appendix A Inspection Results, Questions 20

Non operational HRV installations were defined as those systems in which a component of the HRV system had failed, such that it prevented the ventilation system from operating as intended.

Seven per cent of the inspected HRV installations were not operational. The supply air fan motors in two of these units had ceased to function. However, since both units also contained operational exhaust air fan motors, the homeowners could still hear their HRVs running and were not aware of the problem. In one instance, one of the cold-side ducts had been poorly connected to the HRV and had become detached from the unit. In the fourth installation, the electric coil had failed, allowing the core to freeze.

5.7 Occupant Adjustment

Appendix A Inspection Results, Question 27

The two most common adjustments made by occupants to their HRV ventilation systems were:

- installed a fine mesh screen on exterior ports to prevent debris from reaching the HRV (five cases); and
- blocked or installed a damper on an HRV exhaust port within a room because they felt it was not required (three cases).

Two of the fully ducted HRV ventilation systems inspected for the project were installed by the same mechanical contractor for environmentally hypersensitive people. Dampers had been installed in these systems to permit the occupant to divert HRV supply air into the furnace return during the winter.

Other occupant adjustments included:

- Addition of vibration isolation to an older HRV installation.
- Addition of extra filters on the HRV supply side.
- Adjustment of main trunk balancing dampers.
- Removal of HRV fresh-air supply duct from the furnace return of a cross-furnace HRV system installation.

5.8 HRV Balancing

Appendix A Inspection Results, Questions 18 & 19, 21 to 26

The supply and exhaust flow rates in HRVs are required to be within 10 per cent of each other according to the HRAI Installation Manual, CAN/CSA-F326-M91 and the OBC. The HRAI guidelines detail procedures for measuring air flows. CAN/CSA-F326-M91 requires the measurement technique used to be accurate within 15 per cent. The OBC makes no mention of measurement technique and performance.

Appendix A contains a listing of the CAN/CSA-F326-M91 required flow rates and the measured rates on high speed for each house with no other adjustment.

Twenty-seven per cent of the inspected HRV installations had permanently installed flow measuring stations. The Ontario R-2000 Program requires flow measuring stations to be permanently installed. Therefore, seven per cent of the homes included in the study (four homes in Ontario) have an impact on the above figure. These all had permanently installed flow measuring stations.

Fifty per cent of all HRV installations had balancing dampers installed in both the main supply and exhaust runs.

Forty seven per cent of the installations were found to be balanced within 10 per cent on the high speed. Twenty-nine per cent of the installations were out of balance by more than 40 per cent. Of these, the simplified, cross-furnace installations were the least likely to be balanced within 40 per cent. Furnace operation caused a net change in the HRV balance of more than 10 L/s (20 cfm) in 18 per cent of the simplified systems and in 6 per cent of the extended systems. Furnace fan operation was found to have more of an effect on simplified cross furnace installations than standard simplified installations.

It was not possible to achieve CAN/CSA-F326-M91 Minimum Ventilation Capacity (MVC) flow rates for many of the rebalanced simplified systems. The HRVs were adequately sized. However, the excessive use of flexible ducting often reduced air flow by 30 to 40 per cent from the expected flow for the given HRV.

The HRAI Manual, CAN/CSA-326-M91 and the OBC determine the minimum ventilation capacity based on the room count method so the above comments with respect to CAN/CSA-F326-M91 also apply to capacities with respect to these other codes and standards.

Of the inspected installations, only 36 per cent had low-speed flow rates that were less than 60 per cent of the high-speed flow rates. CAN/CSA-F326-M91 requires a low-speed flow rate of between 40 per cent and 60 per cent of the MVC required rate.

5.9 Equipment and Component Failures

Of the inspected HRVs, seven (12 per cent) had failed components. In two cases, the supply motors had ceased to function. The five remaining failed components were: a variable speed controller, a mechanical damper, and three electric defrost coils. Of the three electric defrost coils, one was within an HRV with a frozen core, while the other two did not begin to operate when required.

A two-year old HRV system, included in the testing but not the inspection phase of this project, had flexible cold side ductwork in which the interior face had completely collapsed. This prevented air flow through the supply side ductwork.

5.10 Potential Health Concerns

In one of the houses where the motor driving the supply side fan was no longer functioning, the operation of the HRV had caused backdrafting of the fireplace.

In 17 per cent (10 out of 60 houses), the HRV exhaust air flow exceeded the supply air flow by more than 35 per cent at the time of inspection. As a result, any spillage-susceptible combustion equipment in these homes would have been susceptible to backdrafting when the HRV was operating.

In one house where the HRV core was completely blocked, the homeowner stated the air quality was poor and they needed to open the windows in winter.

In one case, a gas regulator was noted to be within 6 feet of the HRV exhaust port. It is required to be at least 10 feet from the gas regulator as per the Ontario Gas Utilization Code.

6.0 PHASE II – OCCUPANT AND TELEPHONE SURVEY RESULTS

The *Occupant Survey* was completed in the field at the same time as the inspection of the HRV system. The approach was personal, and the interviewer was on hand to elaborate and explain where necessary.

Based on the results of this initial survey, the *Telephone Survey* was developed by revising the *Occupant Survey* to focus on points of interest and to better accommodate the nature of the type of interview.

Wherever possible, the report outlines the responses to the same or similar important questions from the *Telephone* and *Occupant Surveys.*

From the responses received, it was inferred that 14 of the 15 homes surveyed by telephone had simplified-type installations.

6.1 Information Transfer Mechanisms

Appendix B Occupant Survey Results, Questions 1 to 3

Two thirds of the occupants surveyed said the operation of their HRV had been explained to them. Over 80 per cent said literature had been provided with the unit, and three quarters of these occupants had read the literature provided. When classified by system type, the occupants of the houses with simplified HRV systems were least likely to have had the operation of their HRV explained to them or to have read the literature provided.

Appendix B Telephone Survey Results, Questions 7 to 9

Twenty per cent of the occupants surveyed by telephone reported receiving an explanation on how to operate and maintain their HRV. Eighty per cent of the occupants had been provided with literature on their system, and, of these, 92 per cent had read the literature.

6.2 Maintenance Agreements

Appendix B Occupant Survey Results, Questions 4 to 5

Eighteen per cent of those surveyed had made arrangements with a company to maintain their furnace, and ten per cent had made arrangements with a company to maintain their HRVs.

6.3 Occupant Perception and Understanding

Appendix B Occupant Survey Results, Questions 6 to 8

Overall, 85 per cent of those surveyed demonstrated that they had a basic understanding of the purpose of their HRV. Those with HRV installations 8 years old and older were the most likely to understand the purpose and operation of their HRVs, while those with simplified systems were the least likely.

Over 80 per cent of the surveyed occupants rated air quality in their homes to be good, and a similar percentage of those surveyed believed their HRV system had a positive impact on the air quality in their homes. The people living in homes with simplified HRV systems were the least likely to consider air quality in their home to be good or to believe that the HRV had a positive impact on air quality.

Appendix B Telephone Survey Results, Questions 1 & 2

Sixty seven per cent of the telephone surveyed occupants demonstrated that they understood the purpose of their HRV system. As these occupants had simplified systems, it was reassuring to note that this percentage was similar to the 73 per cent found for occupants with simplified systems in the *Occupant Survey* results. Of the occupants, 27 per cent understood how their HRV worked.

6.4 Occupant Understanding of HRV System and Components

Appendix B Occupant Survey Results, Questions 16 to 18

Overall, only 42 per cent of those surveyed understood the use of their dehumidistat and its effect on humidity in their home. Far fewer (only 16 per cent) understood how their HRV defrost mechanism worked.

Two thirds of the occupants living in homes with extended HRV systems understood the influence of the furnace fan on the effectiveness of their HRV. Unfortunately, only a third of those surveyed in homes with simplified HRV systems understood how the operation of their furnace fan could influence the effectiveness of their HRV.

Only 23 per cent of those surveyed understood that negative effects could occur from running an improperly balanced HRV. Only 9 per cent of the occupants of homes with simplified installations understood this correlation.

6.5 Occupant Usage

Appendix B Occupant Survey Results, Questions 20 to 21, 25 to 34

Eighty per cent of those surveyed used their HRVs continuously in winter, while the remaining 20 per cent used them intermittently. Approximately 75 per cent of those surveyed used their HRVs continuously or intermittently during the spring, summer and fall seasons. It should be noted that, on the West Coast, all occupants ran their HRVs continuously throughout the year.

Seventy-five per cent listed reasons, such as open windows during the summer, for not running their HRV continuously for part of the year. Fifty per cent of the respondents provided reasons, such as "house too dry", for why they might not run their HRVs continuously in the winter.

Sixty-six per cent of the occupants surveyed reported that two or more people interacted with the HRV. Where high-speed timers were provided, most occupants used them.

Appendix B Telephone Survey Results, Questions 12, 17, 23, 38 & 39
Eighty per cent of the telephone surveyed occupants reported they operated the HRV – and the corollary to this was 3 of the 15 respondents did not operate their HRV at all.

Seventy-one per cent of the occupants with HRV systems connected to the furnace ductwork operated their furnace fan in automatic rather than the continuous mode.

During the cold weather months, 67 per cent of the occupants used their HRVs all the time. Twenty per cent of the occupants claimed to operate their units on a periodic basis. During this time period, only 27 per cent of the occupants found the air in their homes to be very fresh, while 67 per cent found the air to be acceptable.

When asked about the humidity in their homes during the cold weather months, 53 per cent of the occupants found the air to be too dry, while 47 per cent found the humidity level to be acceptable.

6.6 Occupant Maintenance

Appendix B Occupant Survey Results, Questions 9 to 15
Over eighty per cent of the surveyed occupants claimed they cleaned some components of their HRV system at least once a year. Eighty-one per cent claimed they cleaned their filters at least once a year. Fifty-one per cent claimed they cleaned their bird screens once a year, and 53 per cent claimed they cleaned their core at least once a year.

Where grease filters had been installed in the kitchen exhaust ports, most of the occupants surveyed claimed they cleaned these filters at least once a year.

Appendix B Telephone Survey Results, Questions 26, 29, 32, &33
Sixty-seven per cent of the occupants surveyed by phone reported someone in the house performed maintenance on the HRV unit.

Seventy-three per cent of the occupants were aware of the need to clean the filters in the HRV. Sixty per cent of all respondents cleaned the filters at least once a year.

Forty per cent of the occupants could confirm the outside ports were equipped with bird screens. Only one of the 15 occupants cleaned the screens at least once a year.

6.7 Humidity and Moisture

Appendix B Occupant Survey Results, Questions 22 to 24

During the winter, very few occupants noted window condensation or basement dampness problems. However, one in three occupants found the air in their home too dry during the winter. Many of those who did not find their homes too dry in winter had installed humidifiers in their furnace ductwork.

6.8 Component Durability

Appendix B Occupant Survey Results, Question 35

Overall, 82 per cent of those surveyed had not replaced any components on their HRV. As the HRV systems aged, the components were far more likely to be replaced. In the two- to four-year old category, none of the occupants had replaced any components. However, for those HRV systems 8 years old or older, 60 per cent of the occupants had replaced components.

Fan motors were reportedly the most frequently replaced components in five year old or older HRVs. A few occupants also reported they had replaced remote control switches and variable speed control switches on their HRVs. In some cases, the filters had been replaced.

7.0 PHASES 1 and II – CROSS-REFERENCED RESULTS

The results of the *Occupant Survey* were cross-referenced with the inspection results to establish to what extent increased understanding and maintenance lead to improved performance.

The most interesting findings were:

Of the occupants who reported they understood their HRV systems (77%):

- 55% had unbalanced HRV systems (unbalanced by more than 10 per cent)
- 60% had substandard ventilation (less than the minimum ventilation capacity specified by CAN/CSA-F326-M91)
- 55% of occupants with partially ducted or simplified HRV systems were not aware of the need to operate the fan of the forced-air heating system

Of the occupants who reported indoor air quality problems (26%):

- 60% had substandard ventilation
- 62% had unbalanced HRV system supply and exhaust air flows
- 56% had HRV systems with dirty filters, heat recovery cores, HRV cabinets

Of the occupants who reported they performed regular maintenance on their systems (81%):

- 42% had systems with dirty filters, cores or cabinets
- 17% had blocked air intakes
- 46% had unbalanced HRV system supply and exhaust air flows

Of the occupants who reported having read the HRV operation and maintenance manuals (32%):

- 34% had dirty filters, cores, cabinets
- 49% had unbalanced HRV supply and exhaust air flows
- 40% operated the HRV systems at recommended ventilation rates

Of the occupants who reported they did not read their HRV manuals (68%):

- 47% had dirty filters, cores, cabinets
- 63% had unbalanced HRV supply and exhaust air flows
- 17% operated the HRV systems at recommended ventilation rates

Of the HRV systems provided with remote controls in the living areas:

- 80% of the occupants understood how to use the controls

Of the HRV systems provided with no remote controls:

- 36% of the occupants understood how to use the controls

8.0 PHASE III – VENTILATION EFFECTIVESS RESULTS

This section contains the results of the tracer gas testing on the HRV ventilation systems in 20 homes. Appendix C contains a description of individual house results and a more detailed discussion of some of the results reported in this section.

The calculated *apparent* air change rate per hour (AC/H) was used in the assessments presented in this section. For the apparent air change rate, the source of the fresh air in a room was not distinguished between:

- air supplied directly from outside via the ventilation/circulation system, or
- air supplied to other rooms after the test began that migrated to the room in question via:
  - the circulation system, and/or
  - open doorways and other unsealed areas between rooms and access ways.

A discussion of terminology is included in Section 3.2.1, Definitions.

By including the fresh air not directly supplied from outside to the room, the calculated AC/H rates were more similar throughout the house than they would have been if all fresh air remained in the room to which it was originally supplied. This would likely make the calculated apparent AC/H rates higher where the actual AC/H were comparatively low, and lower where the actual AC/H were comparatively high.

8.1 Mixing Within Rooms

The middle of each room at a height of 1.2 m above floor level was selected as the sampling location for determining the AC/H rate in the room.

Intensive room testing was carried out to determine how similar AC/H rates were in other locations within rooms to those in the center at 1.2 m above floor level. This testing was carried out for both rooms with the distribution provided by a fully ducted HRV system, and by furnace fan circulation systems. The test method and findings are presented in Appendix C.

The apparent AC/H rates near the floor were very close to those at mid-height. Some variation, however, was found between the apparent AC/H rate measured near the ceiling and that measured at the middle of the room during two tests. In both cases, the outside temperature was cold and the furnace fan was in "continuous" mode. It was possible that stack effect and the continuous throw of air from the grilles may have induced greater variations of air change at the ceiling levels but this condition was not evaluated further.

The two sets of intensive tests were carried out during the coldest days included in the testing program. The majority of the testing was undertaken during the spring and early summer of 1995 when the outside temperature was much warmer. The height at which tracer gas readings were taken, therefore, was not believed to have as large an impact on calculated AC/H values at most houses as was shown in the initial two intensive room tests.

The AC/H measured at the mid height of rooms 300 mm from the corners was found to be as little as half of the value measured in the center. For practical considerations, the centre of the room was chosen for sampling.

8.2 Natural Air Infiltration

The apparent natural AC/H rates were measured with the HRV off, doors open, and furnace circulation fans running where applicable. For these tests, the outside ports of the HRV were not sealed and, hence, some induced air change could be expected for the HRVs connected to the furnace return air plenum. Figure 8.1 shows the results of this testing in five standardized locations within each home.

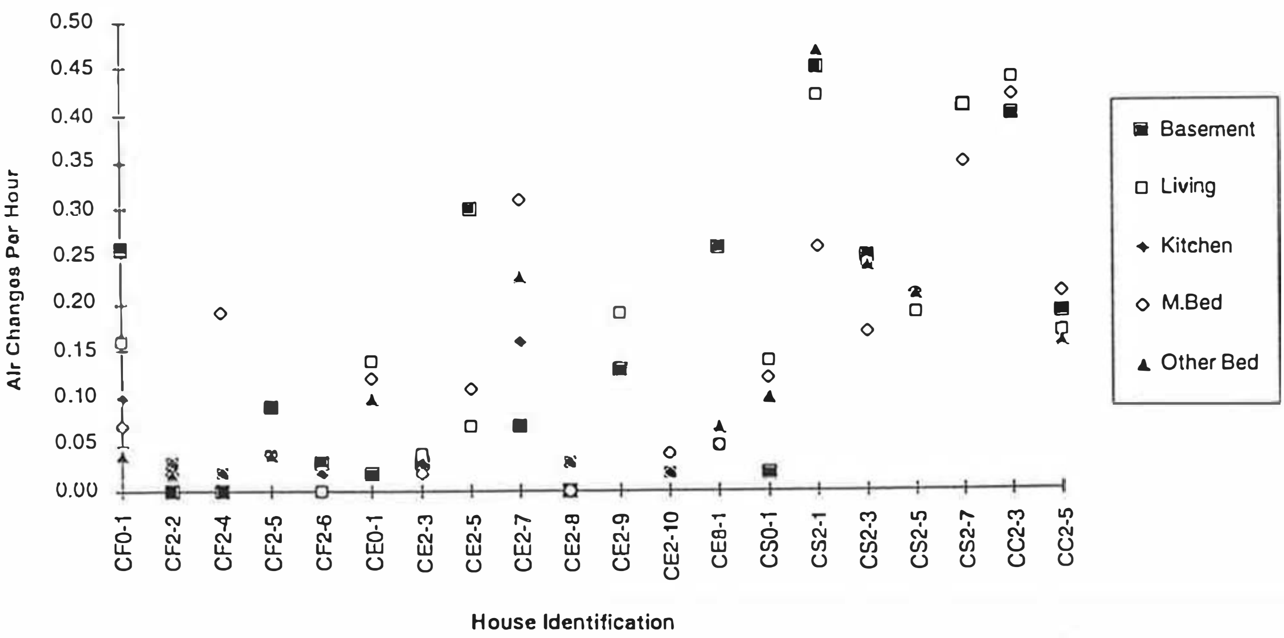


Figure 8.1: Apparent Natural AC/H Rates

Section 2.2 outlines the coding system used to identify the house and HRV system types.

From the chart, it can be seen that the difference between the greatest and smallest apparent natural AC/H rate calculated in the rooms was less than or equal to 0.08 AC/H in eleven of the twenty houses. This included 3 of the 5 fully ducted houses where circulation fans were not installed. In 5 houses, the apparent natural AC/H rate in the basement was found to be substantially different from those in other rooms, while in the remaining four houses other rooms varied from the norm.

The overall average of the natural infiltration rates for the houses tested was calculated to be 0.15 AC/H (see Table C.1).

8.3 Total Ventilation Air Change Rates

The apparent total AC/H rates – the combined apparent natural AC/H rates and apparent mechanical AC/H rates – were measured at each test house with the HRV operating as close to the current CAN/CSA-F326-M91 minimum ventilation capacity (MVC) as possible and all inside doors open.

Figure 8.2 summarizes the results for five sampling locations within each house.

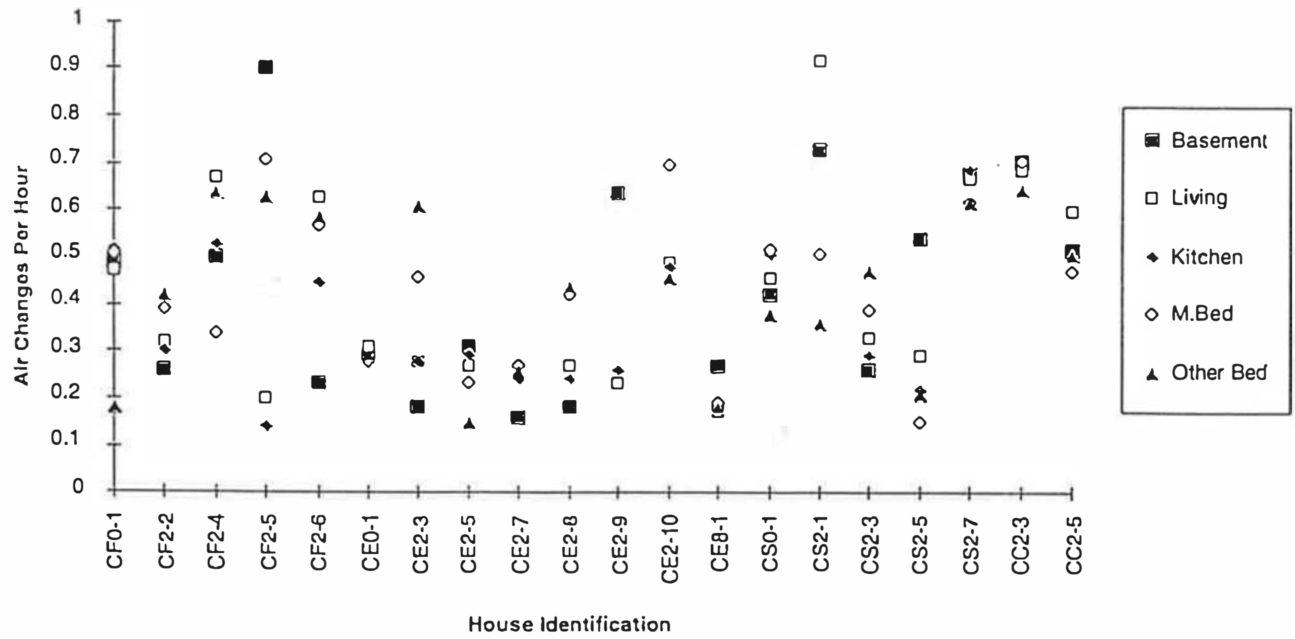


Figure 8.2 Apparent Total AC/H Rates

At the time of testing, the air change rate in all rooms in all houses was greater than 0.13 AC/H.

8.4 Apparent Mechanical AC/H Rates

This section investigates the apparent mechanical air change rate for each type of system with the HRV balanced at the CAN/CSA-F326-M91 required MVC, the distribution system running at the low speed ventilation rate, if applicable, and all inside doors open.

Air flow measurements at the HRV and furnace system registers indicated that the ventilation air provided to almost all rooms in all houses was in conformance with CAN/CSA-F326-M91. For a discussion of air flow measurements, see Appendix D.

The apparent mechanical AC/H rate was calculated by taking the apparent total AC/H rate and subtracting the average apparent natural AC/H rate for the rooms given in the chart above. Again, it must be noted that the natural air infiltration rates used in the analysis contain a component of air exchange induced by the connection of the HRV to the furnace return air duct for extended and simplified systems. This tends to decrease the calculated apparent mechanical ventilation rate for these systems.

Figure 8.3 illustrates the results for all homes.

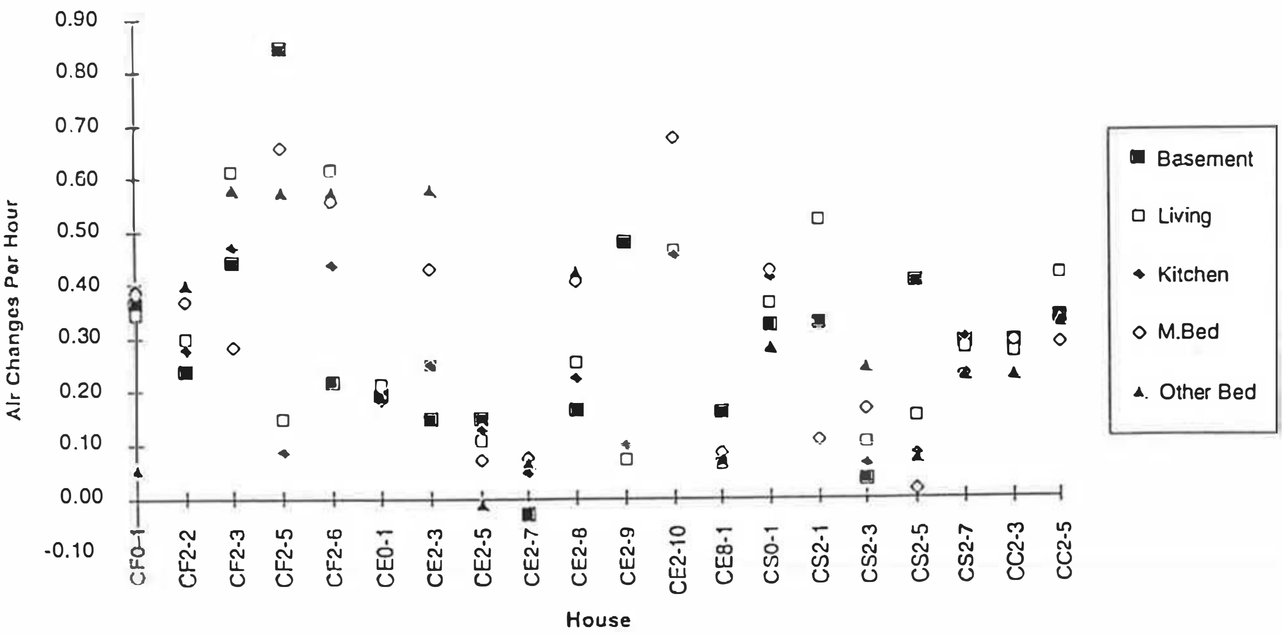


Figure 8.3 Apparent Mechanical AC/H Rates

Note: Negative values are a result of cumulative error factors involved in the measurement of natural and total apparent AC/H rates and the method of using these results to determine apparent mechanical AC/H rates.

Under CAN/CSA-F326-M91, the required minimum ventilation capacity to house volume ratio was smaller for large homes than for small houses. This was based on the rationale that larger houses tended to have larger rooms. As a result, the larger houses generally had lower average apparent mechanical AC/H rates for the whole house, and for individual rooms.

Of the houses tested, the average house with an extended HRV ventilation system was more than 50 per cent larger than the average house with a fully ducted or simplified HRV ventilation system. This contributed to lower apparent mechanical AC/H rates in many of the homes with extended systems.

Figure 8.3 illustrates the distribution of apparent mechanical AC/H rates within each house. Section 8.7 and 8.8 discuss the expected apparent mechanical AC/H rates in houses and individual rooms based upon air flow measurements of ventilation air provided to each.

The results shown in Figure 8.3 are examined in greater detail in Appendices C and D. The appendices include the calculation of apparent AC/H rates at return air registers, house plan reviews, and measurements of air flow rates for all supply and exhaust air registers. The following points highlight the important findings based on these results:

- Fully ducted, extended and simplified HRV systems can all be effective in delivering fresh outdoor air throughout the house.
- The apparent mechanical AC/H rates were more likely to be similar in the rooms throughout the house where the homes:
  - had a relatively 'open plan'
  - were bungalows
  - were relatively compact with duct runs of similar length throughout the house
  - had a relatively even ratio of supply air flow rate to room size throughout the house
- The apparent mechanical AC/H rates in the living areas (rooms other than basements) were generally lowest in bedrooms. The furnace fan flow rates were weaker two storeys above the location of the furnace.
- Homeowners who commented that the mechanical air flow was poor in a particular room were proved to be correct, both in terms of air flow measurements and apparent mechanical AC/H rates.
- For extended and simplified systems, the apparent mechanical AC/H rates measured in the center of room and at the return air grille within the room were found to be very similar, indicating short circuiting is not a significant problem. The only location where short-circuiting appeared to occur was in a bedroom where the supply register was on the same wall as a furnace return and an open doorway.

- Cross contamination within the HRV was less than 20 per cent for 80 per cent of the installations in the nine houses tested. The extent to which cross contamination occurred outside was found to be less than 10 per cent in 80 per cent of the installations and no results showed outside cross contamination to be greater than 20 per cent.

8.5 Effects of Door Closing and Circulation Fan Shut Down

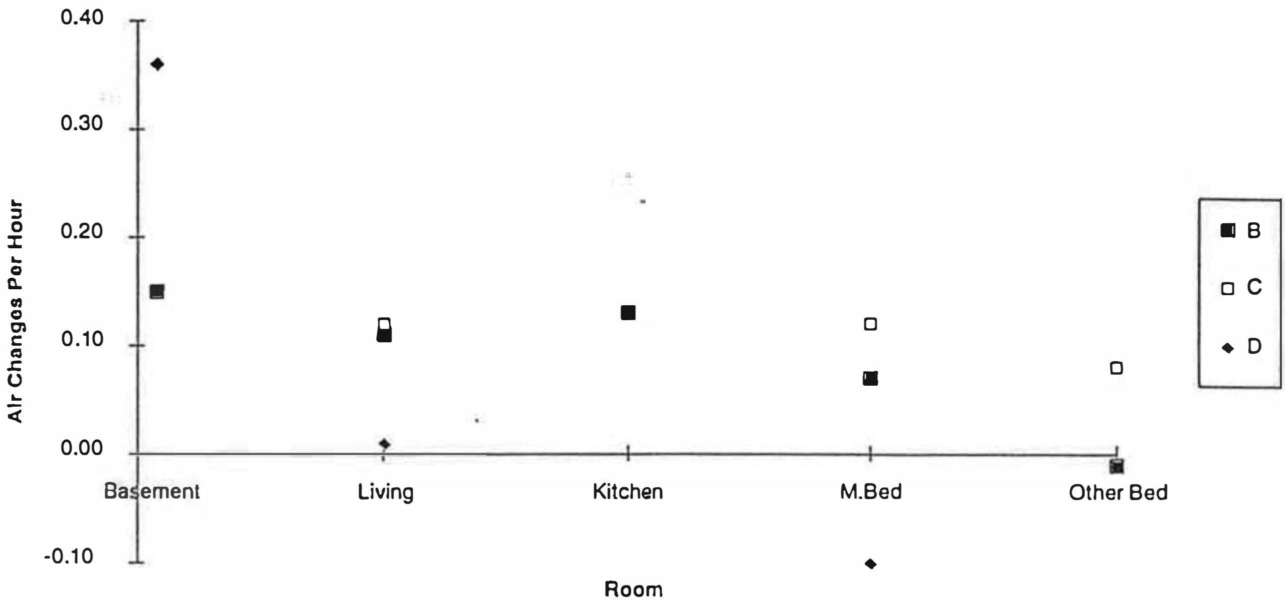
Testing was carried out at all houses to compare the apparent mechanical AC/H rates in rooms with the interior doors open and closed throughout the house. Testing with doors closed was carried out with the HRV system and circulation system, where applicable, fully operational.

Testing was also carried out in houses with extended and simplified systems with the HRV operating and the furnace fan shut down. The purpose of this was to determine how well fresh air from the HRV would be distributed through the forced-air system if the furnace fan was not running.

Figure 8.4 shows how these modes of operation affected the apparent mechanical AC/H rates at one of the houses included in the study. This house, CE2-5, was a relatively large two-storey home with an extended HRV system. The floor plans indicating the locations of the supply and return grilles as well as flow rates are provided in Appendix D. A description of similar testing at other houses is provided in Appendix C.

Circulation fan flow rates on the second storey of this house were similar to those on the first storey, and all bedrooms had return air grilles. Hence, closing doors had little effect on the air flow rates in each room. The increased apparent mechanical AC/H rates in bedrooms with the door closed were probably due to improved mixing within the rooms prior to the air being exhausted from the rooms.

With the circulation fan shut off, the apparent mechanical AC/H rates increased dramatically in the basement and became negligible elsewhere in the house. There was a 300 mm gap between the HRV supply and the furnace return in this house that would allow ventilation air to spill into the furnace room and influence the overall apparent basement ventilation rate.



Test	HRV	Circulation Fan	Doors
B	MVC Rate	Low	Open
C	MVC Rate	Low	Closed
D	MVC Rate	Off	Open

Note: Negative values are a result of cumulative error factors involved in the measurement of natural and total apparent AC/H rates and the method of using these results to determine apparent mechanical AC/H rates.

Figure 8.4 Effect of Door Closing and Ceasing Circulation Fan Operation at House CE2-5

The apparent mechanical AC/H rates at all houses with fully operational mechanical ventilation systems were compared with doors open and closed. The following observations were based on a review of the results from all houses and were not necessarily reflected at each house. It should again be stated that the errors involved in the measurement of natural and total apparent AC/H rates and the method of using these results to determine apparent mechanical AC/H were all cumulative in determining the apparent mechanical AC/H values. The differences between results with doors open and closed were often found to be small. The errors in this section, therefore, would be expected to have a larger impact on the conclusions here than they would elsewhere. For a discussion of errors, refer to Section 8.9.

The following trends were observed. For further details, refer to Appendices C and D.

- The apparent mechanical AC/H rates increase in rooms where supply air rates were robust in comparison to room size when doors were closed.

- The apparent mechanical AC/H rates stayed relatively constant in open areas, such as living rooms and basements, when doors were closed.
- For houses with fully ducted systems, the apparent mechanical AC/H rates dropped in rooms without supply air registers when doors were closed, and increased in rooms with supply registers.

For extended and simplified systems, running the HRV without the circulation fan led to the following results:

- The apparent mechanical AC/H rates increased in the basement.
- The apparent mechanical AC/H rates became negligible on the main floor with the following exception. For installations where the HRV supply was hard ducted to the furnace return, some rooms on the main floor with return air grilles close to the HRV supply connection to the furnace plenum had reduced, but not negligible, apparent mechanical AC/H rates.
- The apparent mechanical AC/H rates in the second storey were found to be negligible.

8.6 Mean Age of Air

The tracer gas concentrations rose slightly in some rooms during testing. This is most likely due to weighted averaging factors. These included:

- uneven distribution of the tracer gas at the beginning of the test, and
- overstated natural AC/H rates due to open HRV ports.

This condition led to a calculated negative apparent AC/H rate which, of course, was not possible, and reflected air movement into a room from other rooms with slightly higher initial tracer gas concentrations. These rooms clearly did not receive much fresh air under test conditions. It was, therefore, essential to consider the mean age of air in these rooms. To graphically show these results in the following figures, all negative apparent AC/H rates were arbitrarily set at a mean age of air of 80 hours. No other rooms had a mean age of air in this range. (Note that the mean age of air is the inverse of the air change rate.)

8.6.1 Mean Age of Air with Natural Air Infiltration Only

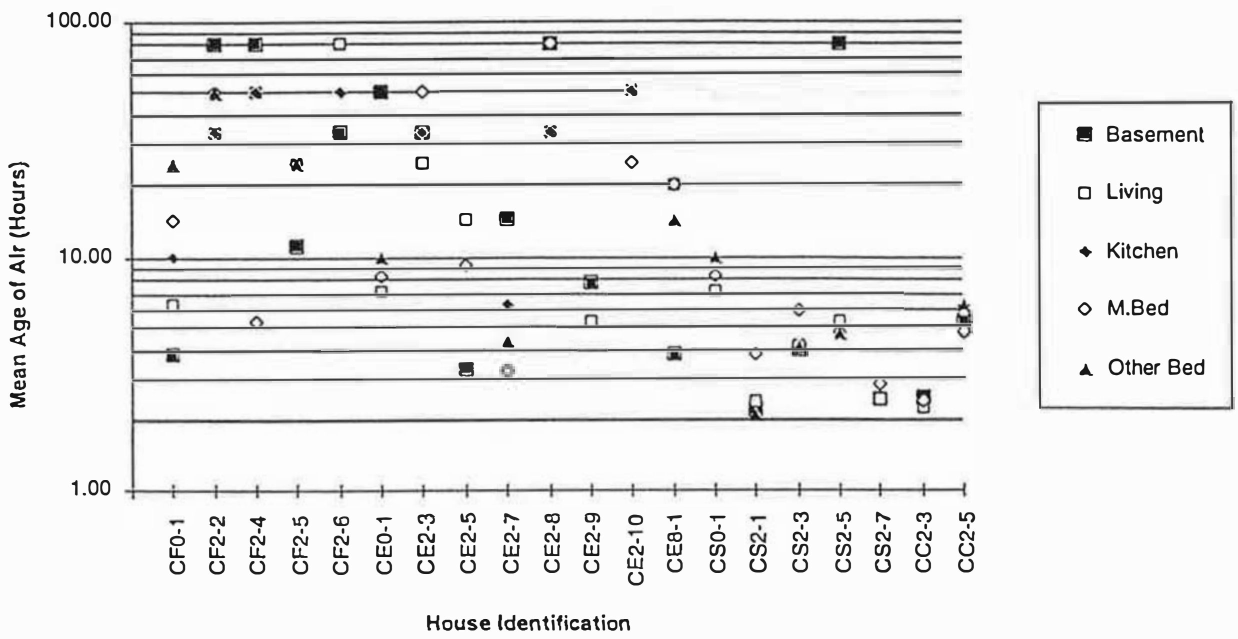


Figure 8.5 Mean Age of Air for Homes with Natural Air infiltration Only

In four houses, the majority of the rooms had a mean age of air of under 4 hours. In these houses, natural infiltration alone may have provided sufficient ventilation, at least during test conditions. It should be noted that the presence of unsealed HRV supply and air ducts in some of the four houses may have contributed to the overall "natural" ventilation during the tests.

The high mean age of air in rooms within the majority of homes clearly indicated the need for mechanical ventilation.

8.6.2 Mean Age of Air with Natural and Mechanical Ventilation and Doors Open

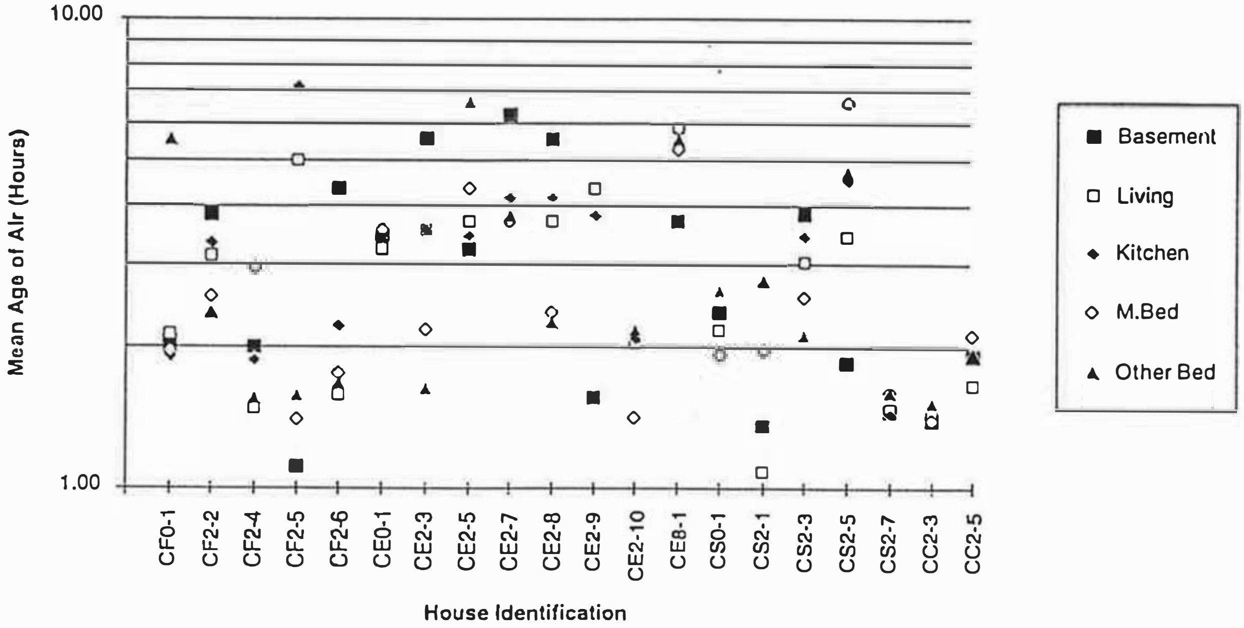


Figure 8.6 Mean Age of Air With Natural Ventilation and Ventilation/Circulation Systems Fully Operational and Doors Open

When natural ventilation and the ventilation systems were operating, in most of the rooms of 12 of the 20 homes, the mean age of air was under 3 hours. The majority of the rooms in all houses had a mean age of air under 4.5 hours. Only one house had a mean age of greater than 7 hours (room not shown on graph).

8.6.3 Mean Age of Air with Mechanical Ventilation and Doors Open

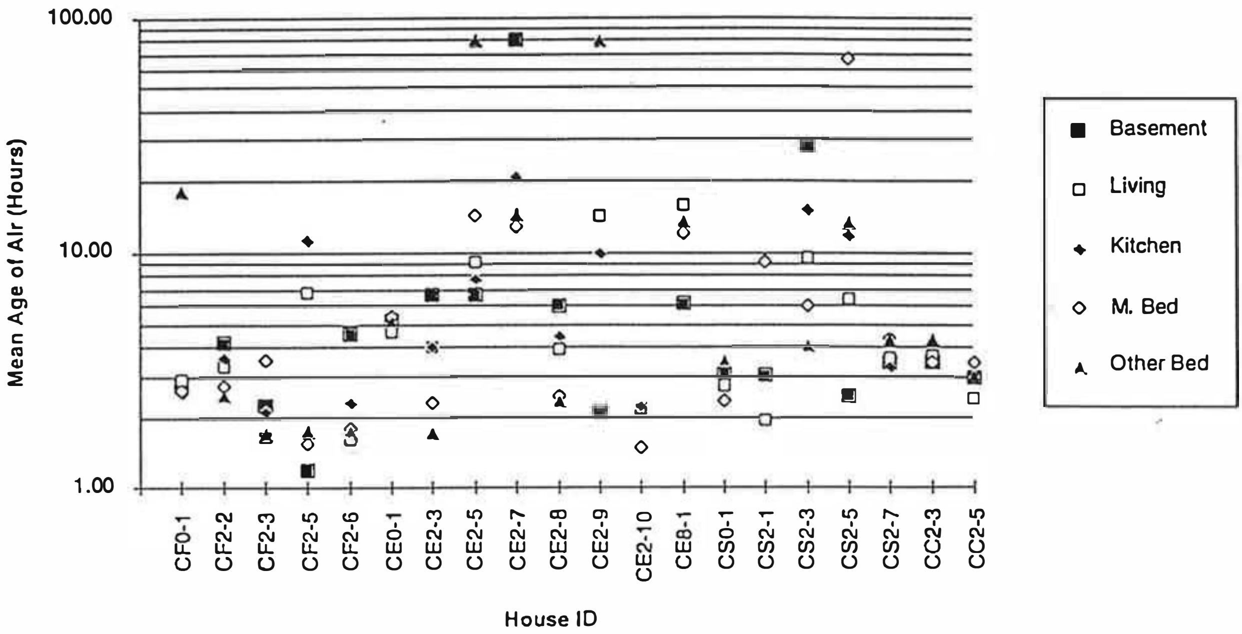


Figure 8.7 Mean Age of Air for Ventilation/Circulation System Fully Operational with Doors Open

Natural ventilation was netted out for the above chart.

In 40 per cent of the houses, the mechanical air supply and distribution alone were calculated to have provided a mean age of air of 5 hours or less in all rooms tested.

For comments on the systems, refer to Section 8.4 where net mechanical AC/H is discussed. (Note that net mechanical AC/H is the reciprocal of the mean age of air.)

8.7 Whole House Mechanical AC/H Comparisons

Figure 8.8 is a comparison of whole house mechanical AC/H rates based upon:

- HRV system flow rate predictions
- tracer gas testing calculations

The mechanical AC/H rates calculated from the HRV system were based on the larger of the two flow rates through each HRV system divided by the house volume.

-The mechanical AC/H rates calculated using the tracer gas method were based on average apparent mechanical AC/H rates. For instance, if mechanical AC/H rates were calculated for two rooms on a given floor, the average of the two was taken to be representative of the floor.

The houses in the following chart were sorted from lowest to highest HRV predicted whole house AC/H rates to make the chart easier to review.

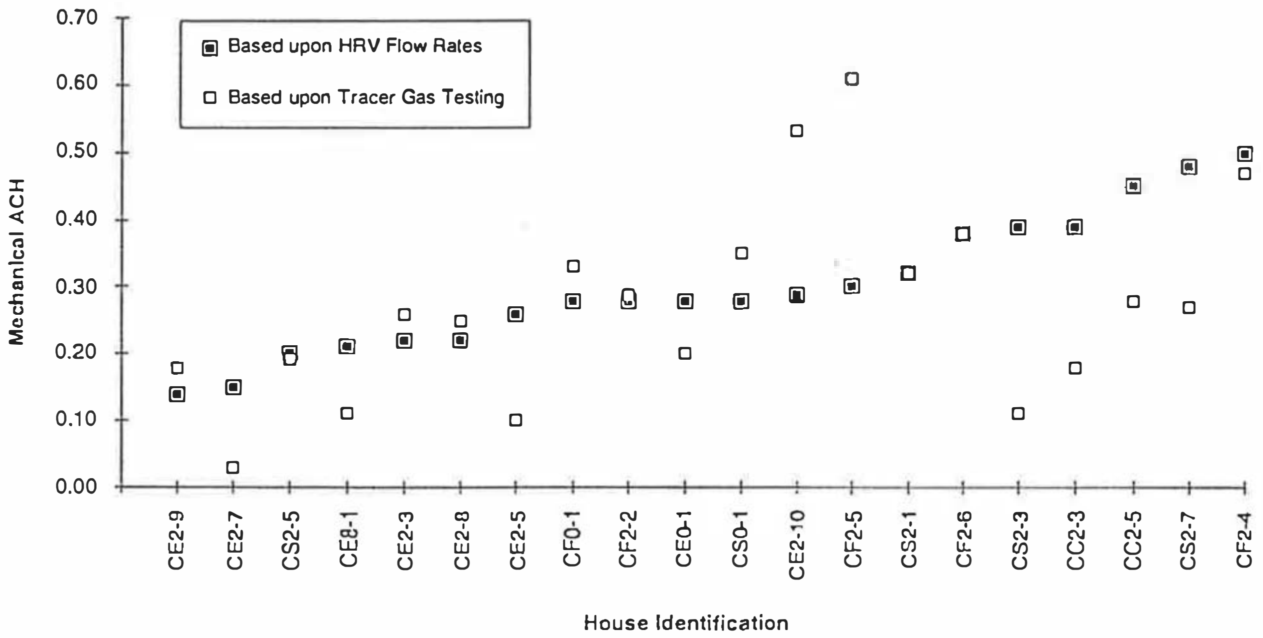


Figure 8.8 Comparison of Whole House Mechanical AC/H Rate Results

Note: Due to the similarity of the two results, only a single marking is shown for houses CS2-1 and CF2-6.

The difference for each house was less than 30 per cent of the lower prediction of mechanical AC/H for half of the houses. On the other end of the spectrum, this difference was greater than 100 per cent at 4 of the 20 houses.

Factors contributing to some of the variation between the tracer gas-based results and those based on HRV flow measurements include:

- Cross contamination within the HRV and between outside ports would make the predicted AC/H rates through the HRV flow measuring station higher than they actually were.
- Short circuiting of fresh air through the furnace plenum for cross furnace installations would make the HRV flow measuring station predicted AC/H rates higher than they actually were.

- Natural AC/H rates included ventilation by the furnace through the unsealed HRV ports.
- The assumption that there was no leakage of HRV supply air as it passed through the ductwork system and that 100% of the air brought in by the HRV was delivered to the habitable rooms only (not the closets, hallways and other adjacent spaces).

A number of other factors caused the discrepancies between the two calculated mechanical AC/H rates at each house. For a discussion of these, refer to Section 8.9, Error Factors.

8.8 Room Air Flow Measurements

Air flow was measured at the HRV system supply and exhaust grilles and circulation system supply and return registers at all houses. The results of this testing are provided and discussed in Appendix D. House plans are also provided in this appendix to provide a context to these findings.

By calculating the percentage of ventilation air supplied to each room, an approximation for the mechanical AC/H in each room was estimated. These results were compared to the apparent mechanical AC/H in rooms at four of the test houses in Appendix D.

As an example, the following chart shows the results at house CE2-8. It should be noted that the air flows at the furnace supply registers within this house were estimated using two techniques, a bag inflation/deflation method, and the CMHC duct test rig. Both techniques resulted in similar calculated ventilation air proportions to each room.

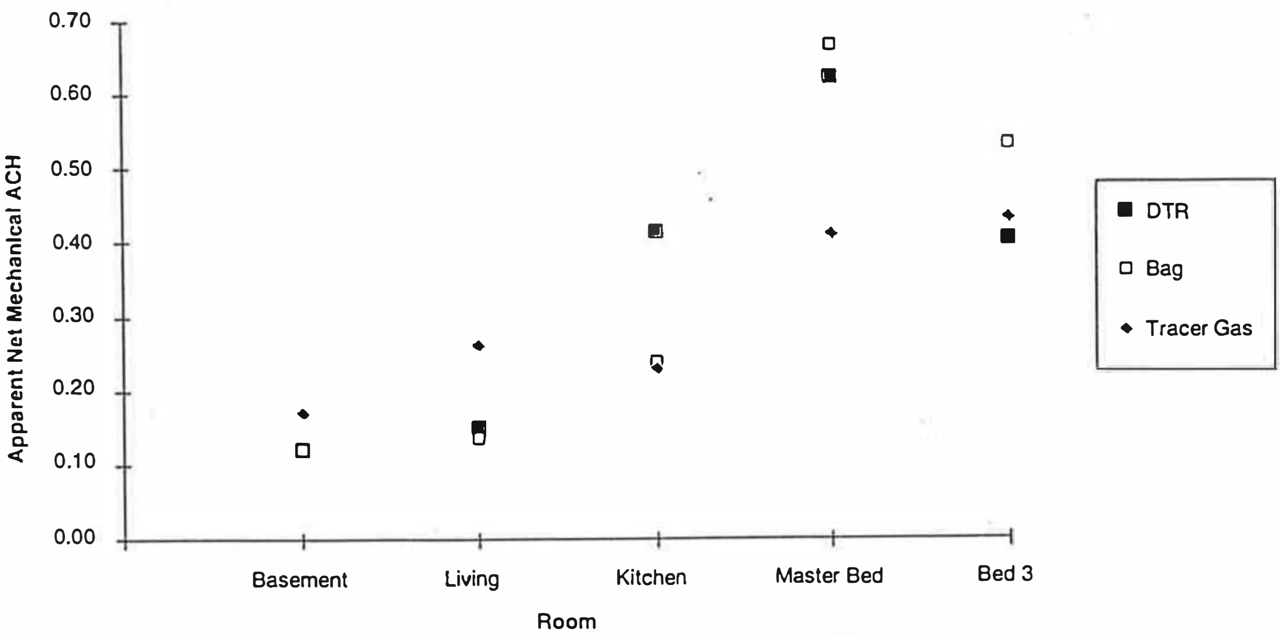


Figure 8.9 Comparison of Room Mechanical AC/H Rates at house CE2-8

The graph shows that the predicted air change rates based upon the duct test rig flow rates and those based upon the bag method are similar in most rooms.

There is also a fairly good correlation between the air change rates based on the air flow measurements and those based upon the tracer gas measurements. The only room where the largest predicted air change rate is double the lowest is the living room. This room is different from the others as it is an open plan and would thus be affected by air flow through the registers in adjacent rooms in the open zone. As discussed in Appendix D, these were not accounted for in predicting air change rates.

It must be noted that this is one of the 11 houses where the natural AC/H values were found to be similar throughout the house based upon the tracer gas testing results. This common base for calculating the apparent net mechanical AC/H values may have been a significant factor in finding the results were similar using the test methods. As can be seen in Appendix D, room mechanical AC/H rates results varied more than this at a typical house.

8.9 Error Factors

Many factors affected the accuracy of measurements of the ventilation effectiveness testing. Each factor is discussed in the following:

Recirculation of Air

As discussed previously, the methodology used in the study did not make it possible to distinguish between:

- air provided from outside after testing began and then recirculated into a room, and
- air supplied directly from outside a room.

Tracer Gas Monitoring Probe Location Within Rooms

The probe measured the air change rate in the center of each room at a height of 1.2 metres. Intensive room testing showed that the apparent AC/H values calculated in this location was likely to be higher than it was in locations such as corners and was therefore not representative of all locations within rooms.

Mixing

The test protocol was revised in the latter half of the house tests to include greater monitoring to ensure complete mixing of the tracer gas prior to testing. However, perfect mixing prior to testing was not always possible. Imperfect mixing would have led to some variation in the calculated air change rates due to air moving from areas of higher initial tracer gas concentration within the home to areas of lower initial tracer gas concentration.

Total Test Time

Each calculated AC/H was based on a series of three tracer gas measurements. Depending on the test carried out, the number of probes would have varied between three and eight. The time between tracer gas measurements at any one probe was directly proportional to the number of probes. Recirculation air was expected to play a smaller role in faster tests and the variation in air change rates was expected to be greater on tests with fewer probes.

Natural Infiltration Rate Variation

Natural air change rates were likely to vary over time with variations in outside weather conditions such as wind and temperature. As testing was carried out chronologically, this would lead to different natural AC/H and cause percentage reductions in tracer gas concentration in the test results used to calculate natural and total apparent ventilation rates.

Mechanical ventilation may also have affected the magnitude of natural air change. No attempt was made to measure this effect.

Tracer gas Test Equipment

The tracer gas test equipment was accurate to within plus or minus 6 per cent in the range of concentrations used in the study.

Limited Number of Rooms tested

It was not within the scope of the study to set probes in all rooms to calculate air change rates. Hence, apparent air change rates calculated in some rooms had to be assumed to be representative of air change rates throughout larger zones.

Mechanical Ventilation Rates Calculated from Testing

The apparent mechanical ventilation rates were calculated based on two sets of testing, one to determine the apparent natural ventilation air change rate and one to determine the apparent total ventilation air change rate. The apparent mechanical ventilation rate was the difference between the two. Therefore, the error for the mechanical ventilation rates was the error in determining the other two rates added together.

Air Flow Measurement

It was found that the CMHC duct test rig was not capable of measuring flow rates at HRV grilles and appears to substantially underestimate air flows at furnace supply and return air registers. Timing bag inflation/deflation was used to substantiate the percentages of air flowing to each room.

The mechanical fresh air rate was measured by a flow measuring station in the HRV ductwork. For extended and simplified systems, the fresh air rate at each circulation fan grille was taken to be the total mechanical fresh air rate times the air flow percentage at that grille. No attempt was made to measure circulation system air flows near the fan so that duct leakage was not accounted for.

9.0 PHASE IV – ALTERNATIVE VENTILATION SYSTEMS – EFFECTIVENESS TESTING RESULTS

Table 9.1 summarizes the system configurations tested. See Section 2.4 or Appendix E for a discussion of the rational for each system configuration, including schematic drawings. Appendix E also contains a table of air flow rates measured for each configuration.

Table 9.1: Summary of Test Configurations

System	HRV Operation	Furnace Fan Operation	Bedroom Doors	Comments
System 1-1	MVC (1)	Off	Open	Backdraft damper open
System 1-2	MVC	Off	Open	Backdraft damper closed
System 1-3	MVC	ECM low	Open	
System 1-4	MVC	Low	Open	
System 1-5	MVC	High	Open	
System 2-1	MVC	Off	Open	Backdraft damper open
System 2-2	MVC	Off	Open	Backdraft damper closed
System 2-3	MVC	ECM low	Open	
System 2-4	MVC	Low	Open	
System 2-5	MVC	High	Open	
System 3-1	MVC	Off	Closed(2)	HRV supply to main floor
System 3-2	MVC	Off	Closed(3)	HRV supply to basement
System 4-1	MVC	Off	Closed(2)	HRV supply to main floor
System 4-2	MVC	Off	Closed(3)	HRV supply to basement
Fully Ducted	MVC	Low	Open	
Extended	MVC	Low	Open	
Simplified	MVC	Low	Open	

Notes:

1. HRV balanced at CAN/CSA-F326-M91 Minimum Ventilation Capacity (MVC) air flow rate
2. Bedroom doors closed only – ensuite door open
3. Bedroom doors closed only – ensuite door closed

Figure 9.1 shows the mechanical AC/H rates calculated from tracer gas reading in the centers of rooms for each of the systems summarized in the Table 9.1.

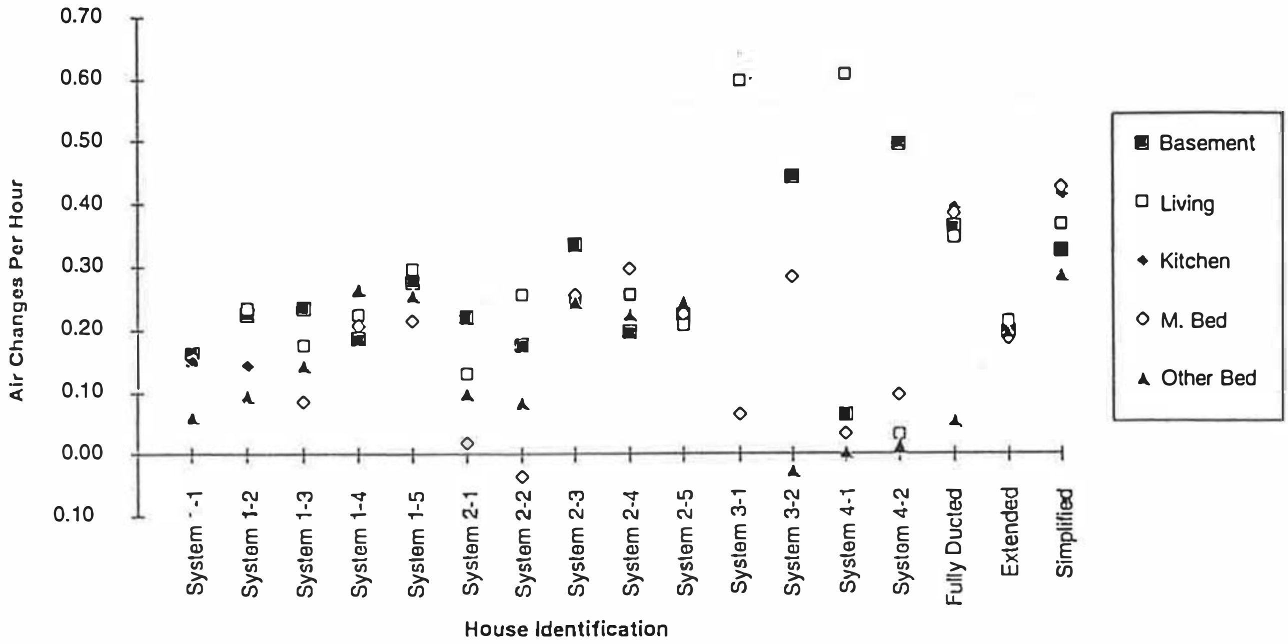


Figure 9.1: Summary of Net Mechanical AC/H Rates By Ventilation System Type and Operation

9.1 Systems 1 and 2

The first two options for the first two systems, system configurations 1-1, 1-2, 2-1, and 2-2, are all options where the furnace fan was off. In the latter option of each pair, the backdraft damper was closed, forcing all ventilation air to flow through the supply system. The results show that, when the damper was closed, there was a marginal increase in the net mechanical AC/H in the living room, a room far from the furnace. The AC/H in a second room equally far from the furnace, the second bedroom, stayed relatively constant with damper open and shut.

For both the modified simplified and the modified extended systems, there was little difference between the results with the furnace fan operating at the three different speed settings – high speed, low speed and ECM low speed. The lowest net mechanical AC/H values in this testing were recorded in the master bedroom in system configuration 1-3 (the simplified system on ECM low speed). Note that the ensuite exhaust may have induced air into this room in the extended system configuration.

The distributions of net mechanical AC/H rates with the furnace fan operating were similar to those found for standard fully ducted, extended, and simplified systems.

9.2 Systems 3 and 4

The two systems where the HRV supplied a central location and the exhaust fans in the bedrooms were used to induce ventilation elsewhere both produced negligible net mechanical AC/H values in all rooms monitored with the exception of the room supplied directly.

The lone exception to this was the relatively high net mechanical AC/H value in the master bedroom in the test where fresh air was only supplied to the basement. In this test, the door between the master bedroom and the ensuite was open. The combined effect of the 20 L/s exhaust from the master bedroom and the 14 L/s exhaust from the ensuite may have drawn air into the master bedroom from the basement below through the open return air ductwork for the furnace.

In system configuration 3-1, the opening in the return air system was such that it was likely that the majority of the air being induced into the bedrooms was coming from unventilated areas. Hence, further testing in houses without forced-air systems may be advisable.

10.0 DISCUSSION

10.1 Phases I and II
Field Inspection, Occupant and Telephone Survey

10.1.1 General

The majority of the HRV ventilation systems investigated under the study were operating and were perceived to be beneficial by the occupants of the houses. The potential existed for systems to be much more beneficial, however, as considerable improvements were possible in installation practice, system performance, occupant understanding and occupant interaction with their system.

One of the most troubling aspects identified in the study related to the recent installation and use of HRVs in the Central Region. All of the simplified systems in the study were installed in tract housing in the last 2 to 4 years. These systems have quickly taken over a large share of the market in the Central Region. When a comparison was made of the findings from the simplified systems with the extended and fully ducted system findings, it was found:

- HRVs were less likely to be balanced during installation;
- more than 25 per cent of the furnace fans were not equipped with switches to allow them to operate continuously;
- the average occupant understood less about what their HRV was intended to do, how it was installed, how to operate it properly, and the possible negative effects of misuse; and
- the average occupant was more likely to perceive their HRV to be of little or no value.

These trends must be reversed as the use of HRVs becomes even more prevalent in new homes across the country. Standard installation practice must be improved - simple and inexpensive measures can dramatically improve the ability of HRV ventilation systems to perform adequately. Information transfer must be improved to encourage the average occupant to use their HRV optimally, maintain it properly, and believe it to be of greater value.

10.1.2 Installation and Performance

Codes and Standards

The most defined and stringent ventilation standard or code is CAN/CSA-F326-M91. The 1993 OBC requirements for HRV installations are very similar to those of CAN/CSA-F326-M91. The 1990 NBC has far less stringent requirements for HRV installations than CAN/CSA-F326 or the 1993 OBC. Most notably, it does not set any tolerances for HRV balancing.

Had the 1993 OBC or CAN/CSA-F326-M91 been in place, made mandatory and enforced at the time that the systems included in this study were installed, the installation deficiencies would have been substantially reduced and the performance of many systems would have been greatly improved. This would have been true irrespective of system type.

The HRAI HRV installer's manual was available throughout the period investigated under this study. Had all of the HRV installations met the standards of good practice set out in the manual, the performance of the HRV ventilation systems would have been found to be better.

Pollutant Sources

The prime purpose for operating an HRV is to provide fresh air to the home. It is essential to avoid locating HRV air supply ports near pollutant sources and it is essential to avoid drawing contaminants and pollutants in the living space from combustion appliances and other sources.

Unbalanced Operation

When HRVs are operated in an unbalanced state, they can cause potentially harmful environments in the living space related to combustion spillage and moisture loading of wall cavities. The HRVs investigated under this study were frequently found to be unbalanced. Mainly due to installation-related causes, this could have been avoided by strict adherence to the installation guidelines outlined in the current codes and standards. It is necessary to enforce the balancing of HRV systems due to issues of performance, safety and durability.

Since the current codes and standards do not require HRV installations to provide appropriate locations for easily verifying air flow rates, verification will remain cumbersome, and high balancing infraction rates will continue to occur.

Inadequate Minimum Ventilation Capacities

In the vast majority of extended and fully ducted HRV installations, the HRV and ductwork were adequately sized.

In the simplified installations, the HRVs were usually adequately sized. The excessive use of flexible ductwork and compressed flexible ductwork, however, reduced air flow rates to well below those required by CAN/CSA-F326-M91 in many installations.

Furnace Fan Operation

In the simplified and extended ductwork HRV installations, the intention was to use the furnace fan to circulate fresh air throughout the house. In 25 per cent of the simplified installations, however, switches were not provided to allow the furnace fan to operate continuously. In these cases, the mechanical provision of fresh air to living areas was insufficient. Installing a switch for the furnace fan and educating the occupants in the appropriate use of their ventilation system would be a minimum solution to ensure fresh air was provided to the living space. Installing an interlock would permit automatic operation of the furnace fan when the ventilation system was operating and reduce occupant involvement.

Exterior Ports

The unbalanced operation of the inspected HRVs was often caused by the buildup of particles clogging the exterior ports. The following installation practices contributed to the occurrence of this problem:

- ports installed in inaccessible locations;
- ports close to ground level;
- ports with covers impeding the ability to clean the screens; and
- exhaust ports with obstructions to cleaning the upstream side of the bird screen.

Installers and builders need further training as to where to place ports, and as to which port assemblies are more likely to perform well. Manufacturers need to be made aware of maintenance problems with some port assemblies.

Humidity Control

The fact that only 36 per cent of the HRVs had low speed air flow rate settings that were less than 60 per cent of the high speed air flow setting partially explains occupant observations regarding air inside their homes being too dry during the winter. Many homeowners had installed humidifiers in their furnace ductwork, further illustrating the need to address dryness in a substantial proportion of homes.

A variety of solutions may be worth investigating to reduce the problem of dryness in winter months. Reduced air exchange strategies involving the use of timers and lower air flow settings, improved remote controls to reduce air flows, and using moisture recovery are all possible solutions.

Durability

As systems age, components are more likely to fail. During the course of the investigation, the item causing the most concern was the failure of a supply side fan motor. Because the exhaust fan continued to operate in the HRV and the occupants heard the same sounds and felt the same vibrations from the unit, they were not aware of the breakdown of the supply fan. The electric resistance defrost mechanisms were found to be more likely to fail than damper-type defrost mechanisms in the houses inspected.

This problem of failures will increase with time as the number and average age of HRV installations increases. It could lead to increased problems with the back drafting of combustion equipment. Better performance and maintenance indicators are required (for example, lights indicating operation or fail-safe switches) to ensure safe operation.

HRV service contracts and seasonal servicing of HRVs at the same time as furnace servicing would reduce the average length of time before deficiencies are noted and resolved.

Cross Furnace Installations with Exhaust from Warm Side of Furnace

The air in the warm side of simplified cross furnace installations was noted to be very hot during and after furnace operation. This will inherently lead to greater heat loss throughout the cores of the HRVs in these installations.

As the connection of the HRV exhaust to the furnace plenum is downstream of the HRV supply connection to the furnace plenum, these installations also inherently lead to the exhaust of fresh air before it is used within the living space. The balance of these installations was also found to be most affected by furnacc opcration.

10.1.3 Occupant Understanding, Usage and Maintenance

The optimal use of the HRV system was largely dependent upon occupant understanding of the purpose, function, operation and maintenance of their HRV. Although most understood the general purpose of their HRV, comprehension of the technical aspects required to use the HRV system properly was low. It was essential occupants understood:

- the affect of maintenance on performance;
- furnace fan operation was required to circulate fresh air within the house in simplified and extended HRV system installations;
- the affect of the dehumidistat controls on the HRV to properly maintain and control humidity in their home;
- the operation of the HRV defrost and how some defrost mechanisms could cause spillage of combustion products;
- the location of all HRV componcnts requiring maintenance and the importance of proper maintenance; and
- the interaction of the HRV with the other systems in the house.

Since less than half of the surveyed occupants clearly comprehended these points, further efforts were required to better educate them. More than half of the occupants reported the operation of their HRV had been explained to them. Most had been provided with a manual for their HRV, and three quarters claimed to have read some of the literature provided with the unit.

Although most of the occupants reported that they regularly cleaned the HRV system components, a number of systems were clogged to the point of becoming dysfunctional. The most commonly clogged element was also the one reportedly cleaned by the least number of occupants – the exterior ports. The fact that occupants installed fine mesh screens on their supply intakes was an indication of their concern about debris entering their HRV. This practice, however, caused another problem as screens quickly became clogged with debris.

Based on the condition and performance of the inspected systems, it was clear that existing information transfer mechanisms were not sufficient and/or occupants were not willing or able to follow up.

Occupants with simplified HRV systems were less likely to understand their HRVs or to perceive benefit from the use of their HRVs. Generally these systems were installed in tract housing. The occupants were given little or no introduction and training for their ventilation systems and, since the systems were less obvious, they received little attention.

Occupants report that they are using their HRVs. Most surveyed occupants used their HRVs continuously in the winter and shoulder seasons; the remainder used them intermittently. Most HRVs were used at least intermittently during the summer.

The lack of occupant understanding of the relationship between dehumidistat controls and HRV operation was contributing to problems with dry air during the winter. Other HRV system-related factors causing low winter-time humidity levels have been discussed in Section 10.1.2.

10.2 Testing of Common HRV Ventilation Systems

The HRV ventilation systems that performed well during the testing were defined as those meeting the following criteria:

- the system was capable of exchanging inside air with outside air;
- the system was able to distribute air to all rooms in the house; and
- the system was able to circulate air within individual rooms.

Based upon this definition, the Phase III testing of the ventilation systems demonstrated that three types of ventilation systems included in the study – fully ducted, extended, and simplified systems – can all be installed and operated to provide effective ventilation for dwellings. Significant variations in performance existed, however, between installations of the same type of system in different houses.

The rooms furthest from the circulation fans were far more likely to have lower circulation fan air flow rates leading to lower apparent mechanical AC/H rates (and high apparent mechanical mean age of air values). Careful design and installation practices are required to ensure even distribution.

As a corollary to the above, the design of the house was found to be an important factor in the equilibrium of the distribution. Small compact homes with relatively open plans had the best distribution. These home designs were much more forgiving in the event that duct design and installation were not carried out as well as they could have been.

Closing doors increased the apparent mechanical AC/H rates where the supply air flow rates to bedrooms were higher in relation to room volume. Although the assessment of room air mixing potential was not a part of this study, it was hypothesized that the higher air change rates in closed bedrooms may have been a result of improved mixing conditions in the rooms when the doors were shut. To ensure adequate fresh air rates to bedrooms when doors are closed at night, air flows to these rooms should be relatively high.

The flow through many second storey return air registers was found to be low. Improvements in the design and installation of the return air system are needed to reduce leaks in ductwork and equalize the proportions of return air drawn from each floor, zone or room. In retrofit situations where there is no return air duct in a bedroom, low flow capacity fans may be able to assist air return from rooms when doors are closed.

Leaving an opening between the HRV supply duct and the furnace return resulted in higher ventilation of basements in comparison to living spaces even when the circulation fan was running. Subject to manufacturer's approval, the HRV supply should be connected directly to the furnace return or connected with a relief Y-section that forces all air from the HRV to enter the furnace return.

For extended and simplified systems, the operation of an HRV without a circulation fan to distribute the fresh air resulted in the over-ventilation of basements and inadequate fresh air distribution to other living areas. Circulation systems must be in operation to distribute fresh air throughout the house when an extended or simplified system HRV is in operation.

For most of the houses tested, it was found that natural ventilation alone was insufficient for the provision of adequate ventilation in most of the rooms served. These results tend to confirm the position that houses require mechanical ventilation.

Total cross contamination of supply side air on the warm side of the HRV was found to average 2 per cent. The balanced supply and exhaust air flows were therefore actually providing roughly 20 per cent less fresh air. This inefficiency was a cause of more concern in extended and fully ducted systems where air drawn from areas with pollutant sources was recirculated throughout the house. A need exists for improved quality control on the part of HRV manufacturers to reduce cross contamination within the HRV. A need also exists for improved exterior port configuration to reduce outside cross contamination.

10.3 Ventilation Effectiveness – Alternative Systems

Low-Speed Furnace Fan Operation

The ventilation air flow rates obtained in a very low-speed circulation system using an ECM motor are much lower than the low-speed air flow rates associated with the 'typical' furnace fan found in Canadian housing stock. However, test results showed that there was very little difference in ventilation effectiveness when a fan provided flow rates associated with a typical permanent split capacitor motor low-speed setting, and an ECM motor low-speed setting.

In both houses where the use of the low speed setting on an ECM motor was simulated – the alternative system house and the one home included in Phase III with an ECM furnace fan motor – the circulation system air flow rates were evenly distributed. It should be noted that the seemingly adequate distribution of ventilation air may have also been a function of the relatively short, well made duct systems and the compact size of the two test houses.

Alternative Configuration for the Use of Furnace Fan Distribution System Without Furnace Fan Operation

It was noted that the use of a backdraft damper within the furnace plenum would improve the distribution of ventilation air when the forced air system fan was not in operation. The backdraft damper helped to concentrate the ventilation air in the supply ductwork of the forced air system where it could then be distributed to the rooms of the house rather than being diluted through both the supply and return air ductwork system. However, the operation of the forced air system fan greatly improved the distribution of ventilation air.

It would appear that the operation of the forced air system fan is required in houses where the ventilation system relies on the forced air system ductwork for distribution of the ventilation air. Space conditioning air flows in conventional houses can be 10 times higher than the required ventilation system airflows. Accordingly, the ductwork systems for the space conditioning systems are vastly oversized for ventilation system airflows alone. In such cases, when the forced air system (i.e. furnace) fan is not operating, air system pressures, developed by ventilation fans alone, would seem to be entirely insufficient to ensure the adequate distribution of ventilation air.

Central Point Supply Systems

Central point fresh air supply systems with additional fans above bedroom doors did not provide adequate ventilation throughout the house tested. Intended to induce fresh air into the bedrooms, the installations tested were not particularly successful.

11.0 RECOMMENDATIONS FOR STAKEHOLDERS

Based upon the observations made in the inspected houses, the occupant survey results, and the ventilation effectiveness testing, the following recommendations are listed in order of priority for each stakeholder.

11.1 HRV Manufacturers

1. Trouble Indicators/Maintenance

   The unbalanced operation of an HRV can lead to significant problems, such as the backdrafting of heating equipment. A large proportion of HRVs were not running in a balanced state for a variety of reasons. Unbalanced operation was usually undetected by the homeowner.

   Sensors or gauges could be used to determine whether or not supply and exhaust air flows were similar. When the flows are unbalanced, a light on the remote HRV control panel could be used to indicate the HRV ventilation system is in need of service. For more sophisticated applications, built-in balancing equipment and air flow measurement devices could be installed for occupants to make their own adjustments.

   At the very least, all HRVs should have a trouble light indicator that comes on when the supply or exhaust side motor fails. Alternatively, the failure of one motor should shut down the other.

   The trouble light on the HRV's remote control panel should also be turned on by an ice build-up in the heat recovery core. Lights controlled by timers or sensors could also be used to indicate the need for filter and screen cleaning.

2. Dehumidistat Controls

   A large proportion of occupants did not understand the use of their dehumidistat. Many believed it set their indoor humidity level. A digital humidity readout on the control panel for the HRV would indicate the actual humidity in the home in relation to the humidity setting. This would greatly improve the occupants' understanding of how their dehumidistat works. It would also be useful for occupants should they call for service regarding humidity problems, and to help catch many humidity related problems before they cause considerable damage, such as cracks in hardwood flooring.

   Given the extent of occupants who found their homes were too dry during the winter, providing occupants with the ability to operate their HRVs on an intermittent mode would be beneficial.

Manufacturers may also want to consider an outdoor sensor to automatically turn off the dehumidistat during the summer months when fresh air will often be more humid than air within the house.

3. HRV Connection to Furnace Return

Currently, some manufacturers do not permit the rigid connection of the HRV supply ductwork to the furnace return. In order to provide adequate ventilation to living areas and to prevent the over ventilation of the rooms containing the HRVs, the rigid connection of the supply ductwork to the furnace return should be permitted in all extended and simplified systems.

4. Coupling System for HRV Operation and Furnace Fan Operation

For extended and simplified systems, the ventilation air supplied by the HRV was not adequately distributed unless the forced air system circulation fan was also in operation. Furnace manufacturers could provide a low voltage connection point on the furnace for the attachment of low voltage wiring from the HRV to operate the furnace fan when the HRV is operating.

5. Information Transfer Mechanisms

Currently, the main source of information for occupants with HRV ventilation systems is the installation and maintenance booklet left with the HRV. Despite a high proportion of occupants who read the literature when they first move in, the percentage of occupants who properly maintain their HRVs is low.

Manufacturers could improve information transfer by using other techniques as well. Videos supplied with each HRV may provide a way for occupants to learn about their HRV and its maintenance. Since HRVs are generally located in mechanical rooms, large information charts could be stuck on HRVs with illustrations of how to perform basic maintenance duties. These charts would be specifically targeted at the user (occupant) rather than the installer. Sections could be provided for the user to date each time maintenance duties are carried out. Viewing the charts on a regular basis should keep maintenance on the user's agenda and lead to increased diligence. A user's manual should be provided to complement the large charts.

Manufacturers should also provide occupants with information on the hazards of not operating and maintaining HRVs. The manual provided should also make owners aware that they have a service contract option. Manufacturers should have a service contractor network in the event that homeowners call them.

6. Installer Information

Manufacturers should be aware of the qualifications and capabilities of those installing their equipment. It was strongly suspected that a poor installation tends to reflect poorly on the equipment. It is in the manufacturer's best interest to provide installation instructions with sufficient information to permit the installer to assemble a properly performing installation. Manufacturers need to improve their quality control programs with respect to mechanical installers and installations.

Installers should be advised that the code references to distance from pollutant sources and heights above grade are minimums, and where possible, these minimums should be exceeded.

11.2 HRV System Designers and Mechanical Installers

1. HRV Balancing

The most significant problem with the HRV ventilation systems was the percentage operating in an unbalanced condition. A high percentage were never balanced while others became unbalanced due to maintenance problems.

CAN/CSA-F326-M91 and other codes and standards have been devised to provide the optimal range of high and low speed flow rates for Canadian housing. Installations should be balanced at the rates set in the applicable standard. Balancing dampers must be provided in both air streams to allow for present and future adjustment. Air flow should be measured in locations and ways in accordance with HRAI guidelines or manufacturer's recommendations.

Installers should be required to pass the installations and designers training programs offered by the HRAI. HRV installations should be certified (signed) and labeled with the name, installer certification number, date, and air flow information as documented by the installer.

For those who may later maintain or troubleshoot the HRV ventilation system, the installation should permit the measurement of air flows using common techniques without disturbing any ductwork. In installations without flow measuring stations, locations should be provided for temporary flow measuring grids.

Alternatives, such as measuring flows across the HRV core, should be explored. This would require the development of appropriate flow measurement procedures.

(Also refer to Section 11.3 Regulating Agencies item 1).

2. Exterior Ports

The second most common cause of HRV imbalance was found to be clogged supply air grilles. Even at the current building code elevation requirements, a large proportion quickly became clogged with debris. Supply air ports should be moved well above the current minimum height of 450 mm above grade. Alternatively, larger sections could be screened at the opening of the supply port to reduce the suction effect at the screen surface. This would reduce the amount of debris being held against the screen.

Exterior ports should always be in readily accessible and obvious locations.

Bird screens at ports should be protected by covers that do not have to be removed for cleaning.

3. Flexible Ductwork

The only HRV ventilation systems that could not achieve the MVC requirements of CAN/CSA-F326-M91 contained excessive lengths of flexible ductwork.

The use of flexible ductwork should be minimized in order for HRVs to obtain maximum high speed flow rates. Limiting flexible ductwork to providing vibration isolation may be optimal in many installations. Flexible ductwork should be supported at no more than one metre intervals so that the static pressure the HRV fans are operating against it is not increased due to sagging ductwork. Strapping used to support insulated cold side ductwork should be at least 50 mm wide to avoid compressing the insulation. Since constrictions greatly reduce air flows, flexible ductwork must not be squeezed in header spaces or other constricted areas.

Although the informed installer should be aware of the problems associated with the use of flexible ductwork, many systems are still installed with these problems. Installer education, certification and, finally, inspections may be required to improve installation practices.

4. Simplified Cross Furnace Installations

Variations in the furnace fan operating speed were found to create considerably greater imbalance in the HRV operation for simplified cross furnace installations than for other system types. Such systems should be discouraged.

5. HRV Connections to Furnace Return

For extended and simplified systems, the HRV supply ductwork should be rigidly connected to the furnace return in order to ensure that it is possible to provide adequate mechanical ventilation to living areas on other floors and to prevent the over ventilation of the area close to the connection.

6. Circulation System Supply Air Ductwork
   In houses where the furnace ductwork provides the distribution of ventilation air, the ductwork system design should consider ventilation air distribution on low speed circulation mode as well as higher speed heating and cooling modes. Each room should meet the requirements of CAN/CSA-F326-M91 for ventilation air delivery in low speed circulation mode.

7. Furnace Circulation Fan Flow Rates
   For extended and simplified systems using the furnace system to circulate fresh air, operating speed did not appear to significantly affect ventilation within homes.

8. Circulation System Return Air Ductwork
   More attention must be paid to the design and installation of the return air system. Total return air flow from each storey or zone should be proportionally similar to supply air.

9. Maintenance Opportunities
   Many occupants were not maintaining their HRVs properly. As well, HRVs require periodic balancing measurements to ensure they are operating properly. Installers should be encouraged to develop and offer HRV maintenance agreements to homeowners. This may also be of benefit to builders, the principal clients of the installers, who would otherwise be called back due to homeowner complaints. Home builders must be made aware of the necessity for this to be successful.

11.3 Government and Regulatory Agencies

1. Regulatory Trends
   In order to improve HRV ventilation system performance, the regulatory agencies should continue with the current trend towards greater regulation of HRV system installation practice and system requirements. Building codes must be updated to more closely resemble CAN/CSA-F326-M91, as it is the most recognized and comprehensive standard for ventilation systems. Most of the deficiencies noted in this study contravened CAN/CSA-F326-M91.

   In updating the building code, some additional prescriptive requirements would make it easier to inspect and improve quality control on HRV installations for the performance-based requirements of CAN/CSA-F326-M91.

   The HRAI HRV installer course outlines standards of good practice that would preclude most of the installation deficiencies found in this study.

Encouraging or requiring installers to take such a course and be certified by a body such as the HRAI should reduce the number of installation deficiencies. It would also provide a body through which action could be taken to decertify or require further training for installers who utilize inadequate design and installation practices.

2. HRV Balancing

Given the extent to which the performance of the HRV ventilation system depends on appropriate and balanced air flows, building codes must require the balancing of HRV systems when they are installed. A balancing report should be a condition of the occupancy permit from the local building department.

3. HRV Balancing Methods

At the time an HRV is installed, the technique chosen for balancing the HRV should permit easy evaluation and modification of the balancing in the future. This would be beneficial both at the time of installation and later when checking for possible problems with the HRV ventilation system. It would also make performance requirements more enforceable. This will lead to a reduction in poor installation practices, such as leaving HRVs unbalanced and the use of inappropriate ductwork.

Building Codes should require the installation of balancing dampers in the main duct for both the supply and exhaust air streams. Flow measuring stations, or taped and labeled holes in ductwork for flow measuring devices, should be required in the locations specified in the HRAI publication *Installation Manual for Residential Mechanical Ventilation Systems*. Inspectors could then use a gauge and existing or inexpensive temporary flow measuring stations to check HRV ventilation system air flow rates.

Alternatives such as measuring flows across the HRV core, should be permitted where the flows can be compared to independent testing to ensure acceptable accuracy. Flow measurements across the HRV core would require access provisions by the manufacturer and the manufacturer's recommendations for appropriate procedures.

The balanced flow rates for the HRV on high and low speeds should be marked on labels left on the machines. The labels should also identify the name of the company, person who balanced the HRV and their HRAI certification number (where applicable).

4. HRV Operation Coupled to Circulation Fan Operation

For extended and simplified systems, the ventilation air supplied by the HRV was not adequately distributed unless the forced-air system circulation fan was also in operation. A mechanism is required to automatically cause the circulation fan to turn on when the HRC is operating. Once available, governments should consider making such devices mandatory in extended and simplified installations.

5. Supply Intake Design and Location

The suction at the HRV supply intake caused debris to settle on the supply screen and clog the supply intake at many houses in this study. Homeowners noted that the debris built up quickly. Clogged grilles were found to cause imbalanced HRV operation.

Government researchers should carry out a study to determine the best ways of resolving this problem. The research effort should address the relationship between the height of the grille and the rate of debris accumulation. It should also investigate the use of larger intake openings to be fitted with screening. A determination should be made of the opening size to air flow rate ratio at which various debris falls to the ground instead of being held against the screen face by suction.

Based upon the results of this research, regulatory agencies should make changes to HRV intake and exhaust hood installation requirements to reduce this problem.

6. Simplified Cross Furnace Installations

The HRV exhaust was taken from the supply side of the furnace in all simplified cross furnace installations included in this study. The balance of the HRV installation was found to be most affected by varying the furnace speed in these systems. Inherently, this will lead to exhausting some of the supply air brought in by the HRV before it is used.

These systems may be less than optimal in other ways as well. Energy losses with these systems may inherently be much greater. Further research could be undertaken to determine if this is true.

The use of these systems should be discouraged.

7. HRV Trouble Indicators

For a discussion of these devices, refer to Section 11.1 item 1. The HRV industry should be encouraged to develop trouble indicating devices or fail safe controls. Once effective, reliable devices are in production, regulatory agencies should eventually mandate them. To best phase in the requirements for these devices, a date could be set requiring such devices in CAN/CSA-F326-M91.

8. Kitchen Grease Filters

Building codes should require washable metal grease filters at kitchen exhaust inlets in all cases. The present alternative of a duct that is accessible for cleaning is impractical and leads to a variety of interpretations that are not always appropriate.

9. Flexible Ducting

A single case was found where the interior surface of the flexible ducting had collapsed and was preventing air flow through the supply side ductwork. This problem was found only after other possible causes of the negligible supply air flow readings had been investigated and eliminated. This problem may warrant further study to determine if it has the potential to be a significant issue. The first step should be to investigate existing standards and quality control practices to ensure the interior liner of flexible ducting does not separate from the supporting ribbing that provides it with form.

11.4 Government Research and Development

This project points to a number of ventilation issues where further research and development efforts would benefit the Canadian public. The future undertakings can be divided into three groups:

- continued investigations of the performance of existing systems;
- continued efforts to develop innovative, cost-effective high performance ventilation systems;
- development of products and standards with industry to improve the performance of commonly installed HRV ventilation systems (a number of such products are outlined elsewhere in Section 11.0, Recommendation for Stakeholders).

The specific areas of recommended study are as follows.

1. Ventilation Effectiveness Testing of Homes With Exhaust Only Ventilation Systems

The comprehensive air flow distribution testing carried out on the HRV ventilation systems has not been carried out on traditional exhaust-only ventilation systems.

Carrying out such testing would make it possible to compare the ventilation effectiveness of HRV and exhaust only ventilation systems. This would be very appropriate information for making decisions in the rapidly changing area of ventilation requirements in building codes.

2. Development of Innovative Ventilation Systems

Development of innovative high performance, energy efficient, low cost ventilation systems should continue to be a focus of government research. For new housing, this effort should concentrate on supplying fresh air directly to all living areas of the house.

The distribution of indirect alternative ventilation systems requires further testing, both for those systems included in this study and for others that may be proposed.

Appendix A

Inspection Results

FIELD SURVEY OF HEAT RECOVERY VENTILATION SYSTEMS

PHASE 1 –INSPECTION RESULTS

Questions:

1. Is there a dehumidistat that properly controls the HRV?
2. Are there any operable remote controls for the HRV?
3. Are there any operable remote controls for the HRV in the living area?
4. Are there any operable remote controls for the HRV in the bathrooms?
5. Are there filters and core(s) present and installed correctly?
6. Are the filters and core(s) clean?
7. Is there a grease filter in the kitchen exhaust port?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	Q #1	Q #2	Q #3	Q #4	Q #5	Q #6	Q #7
ALL SYSTEMS		100	83	61	23	60	81	48	23
GROUPED BY SYSTEM									
1	Fully Ducted	42	83	58	27	61	83	38	20
2	Extended Ducting	40	83	92	29	88	78	55	27
3	Simplified Ducting	18	82	0	0	0	80	60	N/A
GROUPED BY REGION									
1	Central	50	83	40	17	38	67	44	50
2	Central w/o simplified	32	84	63	28	61	59	35	50
3	East	25	100	79	21	73	87	53	14
4	West	25	64	87	36	93	100	50	0
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	83	50	12	47	82	56	26
2	2 to 4 years w/o simplified	38	83	74	18	70	83	54	26
3	5 to 7 years	22	83	69	38	69	85	50	15
4	8 years plus	20	83	83	36	91	70	20	27
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	86	29	17	33	67	17	57
2	Central Extended	20	83	83	33	75	55	45	45
3	Central Simplified Standard	10	67	0	0	0	80	60	N/A
4	Central Cross Furnace	8	100	0	0	0	80	60	N/A
5	East Fully	15	100	63	38	56	78	33	11
6	East Extended	10	100	100	0	100	100	83	20
7	West Fully	15	63	78	25	88	100	56	0
8	West Extended	10	67	100	50	100	100	40	0

FIELD SURVEY OF HEAT RECOVERY VENTILATION SYSTEMS

PHASE 1 –INSPECTION RESULTS

Questions:

8. Do HRV ports have appropriate bird screens that are not blocked?
9. Is the condensate tube trapped?
10. Does the HRV have a defrost mode?
11. Does the HRV have a damper type defrost mechanism?
12. Is the defrost mechanism working properly?
13. Does the ductwork appear to be sized according to applicable building code?
14. Is all vibration isolation installed? (i.e. meets all criteria listed)

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	Q #8	Q #9	Q #10	Q #11	Q #12	Q #13	Q #14
ALL SYSTEMS		100	72	37	68	71	90	72	82
GROUPED BY SYSTEM									
1	Fully Ducted	42	68	28	56	85	100	84	88
2	Extended Ducting	40	79	48	70	82	88	88	75
3	Simplified Ducting	18	67	36	91	36	80	9	82
GROUPED BY REGION									
1	Central	50	64	62	83	61	84	47	67
2	Central w/o simplified	32	63	78	79	76	87	68	58
3	East	25	73	20	100	92	100	93	93
4	West	25	87	7	0	N/A	N/A	100	100
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	79	43	80	75	89	69	83
2	2 to 4 years w/o simplified	38	83	46	75	100	94	96	83
3	5 to 7 years	22	69	23	25	33	100	77	85
4	8 years plus	20	58	36	75	86	88	75	75
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	43	57	71	67	100	43	57
2	Central Extended	20	75	91	83	82	80	83	58
3	Central Simplified Standard	10	67	50	83	33	80	0	100
4	Central Cross Furnace	8	67	20	100	40	80	20	60
5	East Fully	15	78	33	100	100	100	100	100
6	East Extended	10	67	0	100	83	100	83	83
7	West Fully	15	78	0	0	N/A	N/A	100	100
8	West Extended	10	100	17	0	N/A	N/A	100	100

PHASE 1 –INSPECTION RESULTS

Questions:

15. Is cold side ductwork installed properly? (i.e. meets all criteria listed)
16. Do exterior hood assemblies meet all standards of good practice?
17. Are there any pollutant sources within 6 feet of the supply port?
18. Are flow measuring stations permanently installed?
19. Have balancing dampers been installed in both the main supply and exhaust ducts?
20. Was the HRV operational (not blocked or broken) at time of inspection?
21. Are the HRV supply and exhaust flow rates balanced within 10% on typical operating speed?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	Q #15	Q #16	Q #17	Q #18	Q #19	Q #20	Q #21
ALL SYSTEMS		100	52	82	22	27	50	93	47
GROUPED BY SYSTEM									
1	Fully Ducted	42	60	76	21	32	52	92	45
2	Extended Ducting	40	50	92	21	29	42	96	50
3	Simplified Ducting	18	36	73	27	9	64	91	45
GROUPED BY REGION									
1	Central	50	40	77	17	30	50	90	46
2	Central w/o simplified	32	42	79	11	42	42	89	46
3	East	25	80	93	27	13	60	93	43
4	West	25	47	80	27	33	40	100	54
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	57	80	24	26	57	97	48
2	2 to 4 years w/o simplified	38	67	83	22	33	54	100	50
3	5 to 7 years	22	38	77	8	23	38	92	55
4	8 years plus	20	50	92	33	33	42	83	33
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	43	71	0	43	57	86	40
2	Central Extended	20	42	83	17	42	33	92	50
3	Central Simplified Standard	10	33	83	33	17	50	83	50
4	Central Cross Furnace	8	40	60	20	0	80	100	40
5	East Fully	15	89	89	44	22	56	89	38
6	East Extended	10	67	100	0	0	67	100	50
7	West Fully	15	44	67	11	33	44	100	56
8	West Extended	10	50	100	50	33	33	100	50

PHASE 1 –INSPECTION RESULTS

Questions:

22. Are the HRV supply and exhaust flow rates balanced within 40% on typical operating speed?
23. Does furnace fan operation cause the HRV balance to be effected by more than 20 cfm (e.g. difference in supply vs. exhaust)
24. At the time of inspection, was the HRV capable of running within 10% of presently required F326 flow rates?
25. At the time of inspection, were low speed flow rates less than 60% of high speed flow rates?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	Q #22	Q #23	Q #24	Q #25
ALL SYSTEMS		100	71	10	35	36
GROUPED BY SYSTEM						
1	Fully Ducted	42	68	0	55	43
2	Extended Ducting	40	72	6	28	17
3	Simplified Ducting	18	73	18	9	55
GROUPED BY REGION						
1	Central	50	71	16	42	42
2	Central w/o simplified	32	69	13	69	31
3	East	25	64	0	15	38
4	West	25	77	0	42	23
GROUPED BY AGE OF HRV						
1	2 to 4 years	58	77	10	39	39
2	2 to 4 years w/o simplified	38	80	0	55	30
3	5 to 7 years	22	64	0	30	45
4	8 years plus	20	56	20	25	13
GROUPED BY REGION & SYSTEM						
1	Central Fully	12	80	N/A	80	60
2	Central Extended	20	63	13	63	13
3	Central Simplified Standard	10	100	17	17	67
4	Central Cross Furnace	8	40	20	0	40
5	East Fully	15	50	N/A	29	57
6	East Extended	10	83	0	0	17
7	West Fully	15	78	0	63	22
8	West Extended	10	75	0	0	25

HRV FLOW RATE SUMMARY CHART - PHASES 1 & 2

HOUSE ID	YEAR INSTALLED	CURRENT F326 REQ'D FLOW RATE (L/s)	FLOW RATES AS FOUND HIGH SUPPLY (L/s)	HIGH EXHAUST (L/s)	IMBALANCE SUP - EX (L/s)	IMBALANCE	F326 SUPPLY DIFFERENCE	F326 EXHAUST DIFFERENCE	BALANCED CAPACITY AS LEFT (% OF F326)	COMMENTS
Central										
CF0-1	1995	52	N/A	N/A	N/A	N/A	N/A	N/A	100%	
CF2-1	1991	42	31	55	-25	-44%	-28%	30%	100%	does not operate on low
CF2-2	1992	52	49	53	-5	-9%	-6%	3%	100%	
CF2-3	1993	38	40	44	-4	-10%	6%	18%	100%	
CF2-4	1992	57	60	44	16	27%	6%	-23%	100%	
CF2-5	1993	57	52	52	0	0%	-8%	-8%	100%	
CF2-6	1992	47	45	45	0	0%	-5%	-5%	100%	
CF5-1	1989	52	0	0	0	N/A	N/A	N/A	N/A	broken supply motor
CF5-2	1989	52	33	12	21	64%	-36%	-77%	45%	unit, ductwork undersized
CF8-1	1982	57	NR	NR	NR	NR	NR	NR	NR	octupus flexible ductwork
CE0-1	1995	52	52	52	0	0%	0%	0%	100%	
CE2-1	1993	47	38	37	1	3%	-20%	-22%	100%	
CE2-2	1992	104	NR	NR	NR	NR	NR	NR	NR	rectangular ductwork no fms
CE2-3	1993	66	64	71	-7	-10%	-4%	7%	100%	
CE2-4	1991	47	67	44	23	35%	42%	-7%	100%	
CE2-5	1992	66	66	62	4	6%	-1%	-6%	100%	
CE2-6	1991	71	66	66	0	0%	-7%	-7%	100%	
CE2-7	1992	104	67	67	0	0%	-36%	-36%	64%	long coldside flex ducting
CE2-8	1993	61	64	64	0	0%	4%	4%	100%	
CE2-9	1992	71	0	66	-66	-100%	-100%	-7%	100%	
CE2-10	1995	57	53	53	0	0%	-7%	-7%	100%	
CE5-1	1990	57	NR	NR	NR	NR	NR	NR	NR	homeowner installation
CE8-1	1986	61	28	72	-44	-61%	-54%	18%	100%	
CE8-2	1984	66	94	95	-1	-1%	43%	44%	100%	
CE8-3	1987	76	133	76	56	42%	76%	1%	100%	
CE8-4	1986	76	NR	NR	NR	NR	NR	NR	NR	ductwork disconnected

Notes:

1. High speed settings are maximums possible for HRV, they do not necessarily reflect operating speeds of HRVs at time of inspection.
2. Imbalance column is based on the flow rate difference (supply - exhaust) as a percentage of the higher flow rate.
3. NR: Flow rates not recorded

HRV FLOW RATE SUMMARY CHART - PHASES 1 & 2, continued

HOUSE ID	YEAR INSTALLED	CURRENT F326 REQ'D FLOW RATE (L/s)	FLOW RATES AS FOUND: HIGH SUPPLY (L/s)	HIGH EXHAUST (L/s)	IMBALANCE SUP - EX (L/s)	IMBALANCE	F326 SUPPLY DIFFERENCE	F326 EXHAUST DIFFERENCE	BALANCED CAPACITY AS LEFT (% OF F326)	COMMENTS
Central, continued										
CS0-1	1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
CS2-1	1994	61	67	47	20	30%	10%	-23%	80%	
CS2-2	1993	71	49	53	-4	-8%	-31%	-25%	69%	undersized unit
CS2-3	1992	57	53	53	0	0%	-6%	-6%	100%	
CS2-4	1993	66	53	64	-10	-16%	-19%	-4%	81%	poor installation
CS2-5	1993	71	51	44	8	15%	-27%	-38%	62%	long runs of flex ducting
CS2-6	1993	76	53	69	-16	-23%	-29%	-9%	71%	long runs of flex ducting
CS2-7	1995	52	0	54	-54	-100%	-100%	4%	100%	collapsed flex ducting
CC2-1	1992	57	44	69	-25	-36%	-23%	22%	78%	
CC2-2	1991	61	49	53	-4	-8%	-20%	-13%	62%	flexible ducting compressed
CC2-3	1992	61	62	76	-14	-18%	1%	23%	100%	
CC2-4	1992	61	38	41	-3	-8%	-38%	-33%	62%	excessive coldside ducting
CC2-5	1992	57	40	94	-54	-58%	-29%	67%	100%	
East										
EF2-1	1992	52	35	35	0	0%	-32%	-32%	68%	excessive coldside ducting
EF2-2	1991	52	65	30	35	54%	25%	-42%	100%	
EF2-3	1991	66	82	44	38	46%	24%	-34%	66%	
EF5-1	1990	52	49	52	-3	-5%	-5%	0%	100%	
EF5-2	1990	52	34	67	-34	-50%	-35%	30%	100%	
EF8-1	1987	66	89	90	-1	-2%	34%	36%	100%	
EF8-2	1985	61	0	45	-45	-100%	-100%	-27%	0%	supply motor broken
EF8-3	1987	76	0	42	-42	-100%	-100%	-44%	56%	ductwork concealed
EF8-4	1987	52	82	61	20	25%	57%	18%	100%	

Notes:

1 High speed settings are maximums possible for HRV, they do not necessarily reflect operating speeds of HRVs at time of inspection.
2 Imbalance column is based on the flow rate difference (supply - exhaust) as a percentage of the higher flow rate.
3 NR: Flow rates not recorded

HRV FLOW RATE SUMMARY CHART - PHASES 1 & 2, continued

HOUSE ID	YEAR INSTALLED	CURRENT F326 REQ'D FLOW RATE (L/s)	FLOW RATES AS FOUND: HIGH SUPPLY (L/s)	FLOW RATES AS FOUND: HIGH EXHAUST (L/s)	FLOW RATES AS FOUND: IMBALANCE SUP - EX (L/s)	FLOW RATES AS FOUND: IMBALANCE	FLOW RATES AS FOUND: F326 SUPPLY DIFFERENCE	FLOW RATES AS FOUND: F326 EXHAUST DIFFERENCE	BALANCED CAPACITY AS LEFT (% OF F326)	COMMENTS
East, continued										
EE2-1	1993	71	61	50	12	19%	-13%	-30%	70%	occupant adjusted flows
EE2-2	1993	57	101	53	48	47%	79%	-6%	100%	
EE2-3	1991	66	54	57	-3	-5%	-19%	-14%	81%	unit undersized
EE2-4	1991	66	90	87	2	3%	36%	32%	100%	
EE5-1	1988	76	59	61	-2	-4%	-22%	-19%	78%	maximum capacity within 10%
EE8-1	1984	57	41	57	-16	-28%	-28%	0%	83%	
West										
WF2-1	1992	57	45	47	-2	-4%	-20%	-17%	80%	occupant dampered flows
WF2-2	1993	71	62	67	-5	-8%	-12%	-5%	100%	
WF2-3	1992	80	85	76	9	11%	6%	-6%	100%	
WF5-1	1988	52	88	47	41	47%	70%	-9%	129%	
WF5-2	1989	76	41	51	-10	-20%	-46%	-32%	54%	
WF5-3	1989	66	73	69	4	6%	11%	4%	100%	
WF5-4	1988	71	47	67	-20	-30%	-33%	-5%	67%	filter added to supply side
WF8-1	1987	76	34	71	-37	-53%	-56%	-6%	100%	
WF8-2	1985	57	56	53	2	4%	-2%	-6%	100%	
WE2-1	1992	80	78	77	1	1%	-2%	-4%	100%	
WE2-2	1992	76	57	53	3	6%	-25%	-29%	71%	unit properly sized
WE2-3	1991	90	68	52	16	23%	-24%	-42%	73%	undersized unit
WE5-1	1990	61	189	99	90	48%	208%	61%	147%	
WE5-2	1988	71	170	80	90	53%	140%	13%	100%	
WE5-3	1988	61	120	93	27	22%	96%	52%	100%	

Notes:

1. High speed settings are maximums possible for HRV, they do not necessarily reflect operating speeds of HRVs at time of inspection.
2. Imbalance column is based on the flow rate difference (supply - exhaust) as a percentage of the higher flow rate.
3. NR: Flow rates not recorded

Appendix B

Occupant and Telephone Survey Results

FIELD SURVEY OF HEAT RECOVERY VENTILATION SYSTEMS

PHASE 1 – OCCUPANT SURVEY RESULTS

Questions:

1. Was the operation of the HRV explained to the occupant?
2. Was literature provided with the unit?
3. Given that literature was provided with the unit, did the occupant read it?
4. Where there was a furnace or boiler, did the occupant have an arrangement with a company to maintain their furnace?
5. Did the occupant have an arrangement with a company to maintain their HRV?
6. Did the occupant understand the purpose of their HRV?
7. Did the occupant rate the air quality in their home as being good or better?

Responses:

The following percentages are for affirmative responses to the above questions.

	% of total	*1*	*2*	*3*	*4*	*5*	*6*	*7*
ALL SYSTEMS	100	63	85	78	18	10	85	81
GROUPED BY SYSTEM								
1 Fully Ducted	42	64	88	77	20	13	80	86
2 Extended Ducting	40	67	79	89	25	13	96	83
3 Simplified Ducting	18	55	91	60	0	0	73	64
GROUPED BY REGION								
1 Central	50	47	87	77	12	7	87	73
2 Central w/o simplified	32	42	84	88	20	11	95	79
3 East	25	67	73	64	13	0	80	83
4 West	25	93	93	93	36	27	87	93
GROUPED BY AGE OF HRV								
1 2 to 4 years	58	66	89	77	17	12	83	80
2 2 to 4 years w/o simplified	38	71	88	82	28	17	88	88
3 5 to 7 years	22	62	77	80	30	17	77	73
4 8 years plus	20	58	83	80	14	0	100	91
GROUPED BY REGION & SYSTEM								
1 Central Fully	12	29	86	83	0	17	86	86
2 Central Extended	20	50	83	90	25	8	100	75
3 Central Simplified Standard	10	67	100	33	0	0	50	50
4 Central Cross Furnace	8	40	80	100	0	0	100	80
5 East Fully	15	56	78	57	50	0	67	83
6 East Extended	10	83	67	75	0	0	100	83
7 West Fully	15	100	100	89	20	22	89	89
8 West Extended	10	83	83	100	50	33	83	100

PHASE 1 – OCCUPANT SURVEY RESULTS

Questions:

8. Did the occupant believe the HRV ventilation system had any impact on the air quality in their home?
9. Does the occupant clean HRV system kitchen grease filter once a year or more?
10. Does the occupant clean HRV filters once a year or more?
11. Does the occupant clean HRV filters every three months or more?
12. Does the occupant clean HRV bird screens once a year or more?
13. Does the occupant clean HRV bird screens every three months or more?
14. Does the occupant clean HRV core once a year or more?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	8	9	10	11	12	13	14
ALL SYSTEMS		100	79	67	81	26	51	15	63
GROUPED BY SYSTEM									
1	Fully Ducted	42	95	57	83	26	50	25	58
2	Extended Ducting	40	79	75	83	29	63	8	67
3	Simplified Ducting	18	45	N/A	73	18	27	9	64
GROUPED BY REGION									
1	Central	50	70	80	76	34	47	17	60
2	Central w/o simplified	32	84	80	78	44	58	21	58
3	East	25	83	50	80	7	33	7	53
4	West	25	93	33	93	29	79	21	79
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	74	88	80	31	46	20	66
2	2 to 4 years w/o simplified	38	88	88	83	38	54	25	67
3	5 to 7 years	22	82	25	92	33	58	17	50
4	8 years plus	20	91	67	73	0	58	0	67
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	100	100	67	67	57	43	43
2	Central Extended	20	75	71	83	33	58	8	67
3	Central Simplified Standard	10	33	N/A	67	17	33	0	50
4	Central Cross Furnace	8	60	N/A	80	20	20	20	80
5	East Fully	15	100	0	78	0	22	11	56
6	East Extended	10	67	100	83	17	50	0	50
7	West Fully	15	89	33	100	25	75	25	75
8	West Extended	10	100	N/A	83	33	83	17	83

PHASE 1 – OCCUPANT SURVEY RESULTS

Questions:

15. Does the occupant clean HRV core every three months or more?
16. Did the occupant understand the use of their dehumidistat and its effect on humidity in the home?
17. Was the occupant aware of how the HRV defrost mechanism worked?
18. Did the occupant know how operating the furnace fan influenced the effectiveness of the ventilation system?
19. Was the occupant aware of any negative effects that could result from the HRV not being balanced?
20. Did 2 or more people interact with the HRV?
21. Do the occupants usually use high speed timers in bathrooms?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	15	16	17	18	19	20	21
ALL SYSTEMS		100	10	42	16	53	23	66	68
GROUPED BY SYSTEM									
1	Fully Ducted	42	8	40	0	50	20	78	53
2	Extended Ducting	40	8	57	28	61	33	75	81
3	Simplified Ducting	18	18	18	18	36	9	18	N/A
GROUPED BY REGION									
1	Central	50	10	43	18	48	23	45	75
2	Central w/o simplified	32	5	59	18	57	32	61	75
3	East	25	0	47	13	50	33	93	69
4	West	25	21	33	N/A	80	13	79	62
GROUPED B Y AGE OF HRV									
1	2 to 4 years	58	9	41	22	50	23	56	79
2	2 to 4 years w/o simplified	38	4	52	25	53	29	74	79
3	5 to 7 years	22	25	22	0	57	0	75	44
4	8 years plus	20	0	64	10	60	50	83	70
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	14	33	0	50	29	50	67
2	Central Extended	20	0	73	25	58	33	67	78
3	Central Simplified Standard	10	17	17	0	17	0	17	N/A
4	Central Cross Furnace	8	20	20	40	60	20	20	N/A
5	East Fully	15	0	44	0	N/A	33	89	43
6	East Extended	10	0	50	33	50	33	100	100
7	West Fully	15	13	40	N/A	N/A	0	88	57
8	West Extended	10	33	25	N/A	80	33	67	67

FIELD SURVEY OF HEAT RECOVERY VENTILATION SYSTEMS

PHASE 1 – OCCUPANT SURVEY RESULTS

Questions:

22. During the winter, is the occurrence of window condensation seldom or never?
23. During the winter, is the basement dampness noted rarely or never?
24. During the winter, is the air acceptably moist most of the time?
25. Is the HRV used intermittently or continuously in the spring?
26. Is the HRV used continuously in the spring?
27. Is the HRV used at all during the summer?
28. Is the HRV used intermittently or continuously in the summer?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	22	23	24	25	26	27	28
ALL SYSTEMS		100	95	93	68	87	62	75	75
GROUPED BY SYSTEM									
1	Fully Ducted	42	100	96	72	100	76	84	88
2	Extended Ducting	40	92	92	83	83	54	75	75
3	Simplified Ducting	18	91	91	27	64	45	55	45
GROUPED BY REGION									
1	Central	50	93	97	63	73	47	63	60
2	Central w/o simplified	32	95	100	84	79	47	68	68
3	East	25	93	87	47	100	53	73	80
4	West	25	100	93	100	100	100	100	100
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	94	94	66	83	63	71	69
2	2 to 4 years w/o simplified	38	96	96	83	92	71	79	79
3	5 to 7 years	22	92	85	85	92	69	77	85
4	8 years plus	20	100	100	58	92	50	83	83
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	100	100	71	100	57	86	86
2	Central Extended	20	92	100	92	67	42	58	58
3	Central Simplified Standard	10	83	83	17	83	50	67	50
4	Central Cross Furnace	8	100	100	40	40	40	40	40
5	East Fully	15	100	89	44	100	67	67	78
6	East Extended	10	83	83	50	100	33	83	83
7	West Fully	15	100	100	100	100	100	100	100
8	West Extended	10	100	84	100	100	100	100	100

PHASE 1 – OCCUPANT SURVEY RESULTS

Questions:

29. Is the HRV used intermittently or continuously in the fall?
30. Is the HRV used continuously in the fall?
31. Is the HRV used intermittently or continuously in the winter?
32. Is the HRV used continually in the winter?
33. Did the occupant have a reason for not running their HRV continuously for part of the year?
34. Did the occupant have a reason for not running their HRV continuously during the winter?
35. Are all components in the occupants HRV, the ones that originally came in the unit?

Responses:

The following percentages are for affirmative responses to the above questions.

		% of total	29	30	31	32	33	34	35
ALL SYSTEMS		100	92	70	100	82	77	69	82
GROUPED BY SYSTEM									
1	Fully Ducted	42	100	80	100	84	80	75	80
2	Extended Ducting	40	83	63	100	71	71	67	78
3	Simplified Ducting	18	91	64	100	100	86	N/A	100
GROUPED BY REGION									
1	Central	50	83	60	100	83	84	71	80
2	Central w/o simplified	32	79	58	100	74	83	71	68
3	East	25	100	60	100	60	73	67	80
4	West	25	100	100	100	100	0	N/A	93
GROUPED BY AGE OF HRV									
1	2 to 4 years	58	94	74	100	89	83	80	113
2	2 to 4 years w/o simplified	38	96	79	100	83	75	57	104
3	5 to 7 years	22	92	69	100	69	83	75	75
4	8 years plus	20	83	58	100	75	57	50	42
GROUPED BY REGION & SYSTEM									
1	Central Fully	12	100	57	100	71	100	100	71
2	Central Extended	20	67	58	100	75	78	60	67
3	Central Simplified Standard	10	100	67	100	100	67	N/A	100
4	Central Cross Furnace	8	80	60	100	100	100	N/A	100
5	East Fully	15	100	78	100	78	83	50	78
6	East Extended	10	100	33	100	33	60	75	83
7	West Fully	15	100	100	100	100	0	N/A	89
8	West Extended	10	100	100	100	100	N/A	N/A	83

TELEPHONE SURVEY QUESTIONS AND RESULTS

(Note: Question numbers correspond to numbers on the survey form.)

OCCUPANT'S KNOWLEDGE OF THEIR HRV SYSTEM

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
1	How many occupants understood the purpose of their HRV?	67%	10 of 15
2	How many occupants understood how their HRV worked?	27%	4 of 15
3	How many occupants said they could tell their HRV was running?	73%	11 of 15
4	Was the HRV unit located in the basement?	100%	15 of 15
5	How many occupants could confirm that the HRV was connected to the furnace ductwork?	57%	8 of 14
6	How many occupants could confirm that their HRV exhausted directly from the kitchen and bathrooms.	7%	1 of 15
7	How many occupants had had the operation and maintenance of their HRV explained or demonstrated to them?	20%	3 of 15
8	How many occupants said an operation and maintenance manual had been provided with their HRV?	80%	12 of 15
9	How many of the occupants who were provided with operations manuals had actually read them?	92%	11 of 12
11	How many occupants found the explanations and instructions in their manuals clear?	60%	9 of 15

OCCUPANT'S OPERATION OF THEIR HRV SYSTEM

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
12	How many occupants said they operated the HRV?	80%	12 of 15
13	The reasons cited for not doing so by those who said they did not operate their HRV were:		
	• the HRV dried out the house too much;	7%	1 of 3
	• the supply air was ducted too close to the thermostat, causing the heating system to run continuously and, therefore, to overheat the other rooms of the house; and,	7%	1 of 3
	• it was unnecessary to run the HRV.	7%	1 of 3
14	How many occupants responded that they did use different speed settings for their HRV?	73%	11 of 15

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
15	During the warm weather months, how many occupants operated their HRV:		
	a) all the time?	40%	6 of 15
	b) sometimes?	20%	2 of 15
	c) never	47%	7 of 15
16	The reason cited most often for not operating the HRV all the time during warm weather months was that it was preferable to open windows for fresh air.		
17	During the cold weather months, how many occupants operated their HRV?		
	a) all the time?	67%	10 of 15
	b) sometimes?	20%	3 of 15
	c) never?	13%	2 of 15
19	How many occupants reported that they had one of the following controls for their HRV in their home?		
	a) central dehumidistat?	0%	0 of 15
	b) dehumidistat on unit?	47%	7 of 15
	c) remote on/off switch	20%	3 of 15
	d) intermittent switch	13%	2 of 15
22	Of the occupants who reported they had dehumidistats for their HRV unit, how many adjusted this dehumidistat?	100%	7 of 7
23	How many occupants operated their furnace fan on:		
	• "Auto"?	71%	10 of 14
	• "Continuous"?	29%	4 of 14
24	Three of the ten occupants who ran their furnace fans on "auto" cited the following reasons for not running the fan on "continuous": • that is what they had done in their previous home • the furnace fan cycled on and off enough to distribute fresh air • on "auto", the fan comes on when it needs to.		
25	How many occupants were aware of a built-in defrost mechanism in their HRV unit?	0%	0 of 15

HRV MAINTENANCE

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
26	Did someone in the house perform maintenance on the HRV unit?	67%	10 of 15
29	Did the occupant know if there were filters in their HRV?		
	• yes	73%	11 of 15
	• no	0%	0 of 15
	• was not sure	27%	4 of 15
30	How often did the occupant clean the filter in their HRV?		
	• every 3 months or more?	7%	1 of 15
	• once a year or more?	53%	8 of 15
	• never?	40%	6 of 15
31	How many occupants knew where their HRV's outside intake and exhaust port were?	60%	9 of 15
32	Did the occupants know if their HRV ports outside were equipped with bird screens?		
	• yes	40%	6 of 15
	• no	0%	
	• did not know	60%	9 of 15
33	How many occupants cleaned their bird screens at least once a year?	7%	1 of 15
34	How many occupants knew that there was a removable core in their HRV?	27%	4 of 15
35	How many occupants cleaned the cores in their HRVs? (Those that did clean the cores did so approximately once a year)	20%	3 of 15

OCCUPANT'S PERCEPTION OF INDOOR AIR QUALITY IN THEIR HOME

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
38	During the cold weather months, how many occupants found the air in their house to be:		
	• very fresh	27%	4 of 15
	• acceptable	67%	10 of 15
	• stale	7%	1 of 15
39	During the cold weather months, how many occupants found the humidity in their home to be:		
	• acceptable?	40%	6 of 15
	• too humid?	7%	1 of 15
	• too dry?	53%	8 of 15

Question No.	Question	Percentage of Positive Responses	No. of Applicable Responses
40	During the warm weather months, how many occupants found the air in their home to be:		
	• very fresh?	46%	6 of 13
	• acceptable?	38%	5 of 13
	• stale?	15%	2 of 13
41	During the warm weather months, how many occupants found the humidity in their home to be:		
	• acceptable?	69%	9 of 13
	• too humid?	23%	3 of 13
	• too dry?	8%	1 of 13
42	How many occupants found that excess humidity was removed at an acceptable rate from their kitchen and washrooms?	86%	12 of 14
43	How many occupants reported the occurrence of window condensation:		
	• always?	14%	2 of 14
	• sometimes?	43%	6 of 14
	• never?	43%	6 of 14
44	How many occupants opened their windows?	100%	15 of 15
45	The occupants reported that they liked to open windows to ventilate their home.		
46	How many occupants had noticed mould growth on their windows?	33%	5 of 15
47	How many occupants had noticed mould growth on their walls?	7%	1 of 15
48	How many occupants found the basement to be damp or musty smelling:		
	• sometimes?	47%	7 of 15
	• never?	53%	8 of 15
49	How many occupants found the temperature of the air being distributed in their home to be:		
	• comfortable?	87%	13 of 15
	• too cool?	13%	2 of 15
	• too warm?	0%	
50	For those occupants who said the air temperature was too cool, how many said this would prompt them to turn off their HRV?	100%	2 of 2
51	How many occupants found that odours generated in the home dissipated quickly?	100%	15 of 15

Appendix C

Ventilation Effectiveness Results

Contents

C.0 Mixing Within Rooms

Intensive room tests were undertaken three times to determine the appropriateness of using a center-of-room sampling point to represent the room air change rate. In all cases, the master bedroom was used, and the ventilation system was fully operational. Two of the tests were carried out on simplified systems, while the third was carried out on a fully ducted system. The results were as follows:

House ID → Location	CF0-1 *(AC/H)*	CS0-1 *(AC/H)*	CS2-1 *(AC/H)*
Center of room at mid height	0.49	0.60	0.64
Center of room 300 mm below ceiling	0.33	0.26	0.64
Center of room 300 mm above floor	0.51	0.49	0.60
Corner of room at mid height	0.40	0.32	0.31

Appendix D contains illustrations of the plans of these homes and includes the register locations and air flow rates.

These tests were carried out at the first two houses (the first two tests were at the same house with different ducting configurations). At the first house (alternative systems house that was also used for CF0-1, CS0-1 and CE0-1), the outside weather conditions were far colder than at any house thereafter. The low AC/H values obtained close to the ceiling level during the tests at this house might have been due to cooler ventilation air staying at lower elevations within the room.

The middle of each room at a height of 1.2 m above floor level was arbitrarily decided to be the most appropriate sampling location for determining AC/H rates. These rates may not be representative of overall room AC/H.

C.1 Apparent Natural AC/H Rates

Natural air infiltration rates were measured with the HRV off, doors open, and circulation fans running where applicable. The following chart shows the results of this testing in five standardized locations within each home.

Table C.1 Apparent Natural AC/H Rate Results

House Id	R-2000	Basement	Living	Kitchen	M.Bed	Other Bed	Largest - Least	Average
CF0-1	•	0.26	0.16	0.10	0.07	0.04	0.22	0.13
CF2-2	•	0.00	0.03	0.03	0.02	0.02	0.03	0.02
CF2-4	•	0.00	0.02	0.02	0.19		0.19	0.06
CF2-5	•	0.09	0.04		0.04	0.04	0.05	0.05
CF2-6	•	0.03	0.00	0.02			0.03	0.01
CE0-1	•	0.02	0.14		0.12	0.10	0.12	0.10
CE2-3	•	0.03	0.04	0.03	0.02		0.02	0.03
CE2-5		0.30	0.07		0.11		0.23	0.16
CE2-7		0.07		0.16	0.31	0.23	0.24	0.19
CE2-8	•	0.00	0.03	0.03	0.00		0.03	0.02
CE2-9	•	0.13	0.19				0.06	0.16
CE2-10	•		0.02	0.02	0.04		0.02	0.03
CE8-1		0.26	0.05		0.05	0.07	0.21	0.11
CS0-1	•	0.02	0.14		0.12	0.10	0.12	0.10
CS2-1		0.45	0.42		0.26	0.47	0.21	0.40
CS2-3		0.25	0.24		0.17	0.24	0.08	0.23
CS2-5		-0.07	0.19		0.21	0.21	0.28	0.14
CS2-7		0.41	0.41		0.35		0.06	0.39
CC2-3		0.40	0.44		0.42		0.04	0.42
CC2-5		0.19	0.17		0.21	0.16	0.05	0.18
Overall Average								0.15
Average R-2000								0.06
Average Non R-2000								0.25

Note:

1. CF systems are fully ducted and, therefore, did not have a circulation fan in operation during natural air infiltration testing.
2. House plans and air flow rates at registers are provided in Appendix D.
3. Where values are not included, other rooms were considered to be representative of large zones within the house, or the error in sampling data was unacceptably high.
4. A blank space indicates testing was not carried out in the given location, or the error in the test results was too high.

From the table, it can be seen that the difference between the greatest and smallest natural ventilation rate calculated in these rooms was less than or equal to 0.08 AC/H in eleven of the twenty houses. This included three of the five fully ducted houses where circulation fans were not running. In five houses, the natural ventilation rate in the basement was found to be substantially different from those in other rooms, while in the remaining four houses it was other rooms that varied from the norm.

For each house, the average of the natural air change rates recorded in these rooms was the amount used to reduce all gross air change rates to calculate the mechanical ventilation rates (net AC/H).

The overall average of the natural infiltration rates was found to be 0.15 AC/H. Although daily climatic conditions would have a considerable bearing on the natural ventilation rates found at each house, it is interesting to note that the average natural ventilation rate for the R-2000 houses was a quarter of that for the non R-2000 houses. Also note that these figures are in agreement with normally assumed values for R-2000 and non-R-2000 housing.

C.2 Apparent Total AC/H Rate Results

The apparent total AC/H rates (the apparent natural combined with the apparent mechanical AC/H rates) were measured at each test house with the HRV operating as close as possible to the current F326 minimum ventilation capacity (MVC), and all doors within the home were open.

The following graph summarizes the results for five commonly chosen sampling locations within each house.

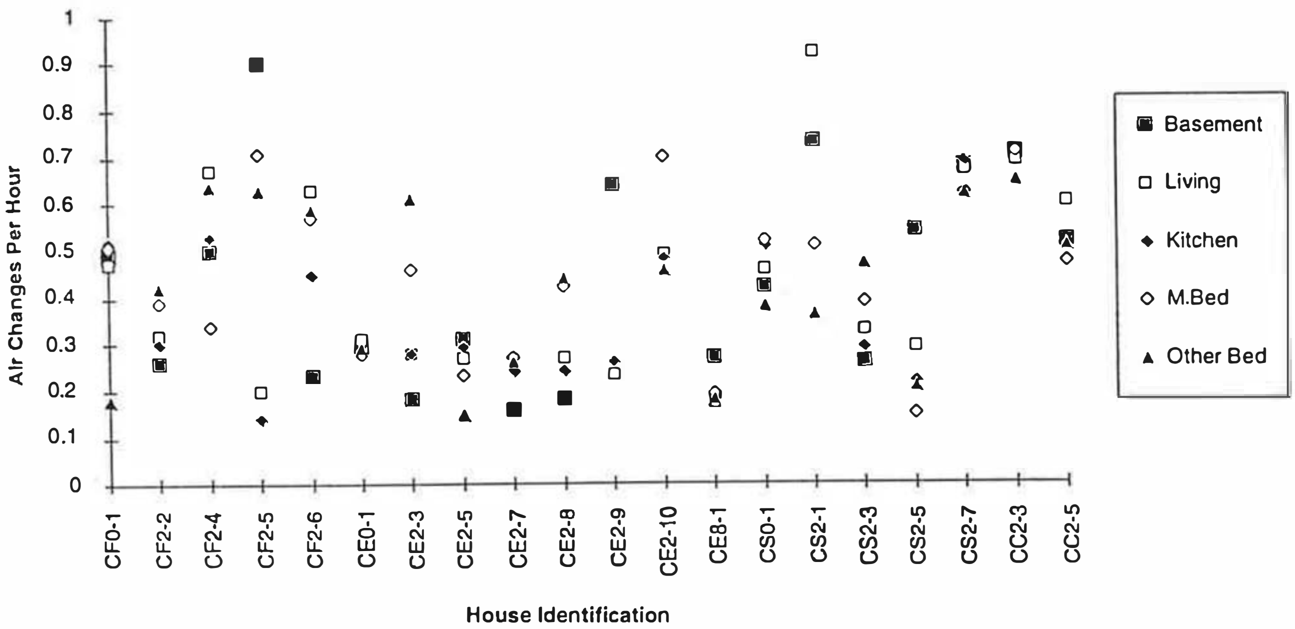


Figure C.1 Graph of Total Air Change Rates

In chart format, the results are as follows:

Table C.2 Total Air Change Rates Chart

House ID	*R-2000*	*Basement*	*Living*	*Kitchen*	*M.Bed*	*Other Bed*	*Largest-Least*	*Average*
CF0-1	•	0.49	0.47	0.52	0.51	0.18	0.34	0.43
CF2-2	•	0.26	0.32	0.30	0.39	0.42	0.16	0.34
CF2-4	•	0.50	0.67	0.53	0.34	0.64	0.33	0.54
CF2-5	•	0.90	0.20	0.14	0.71	0.63	0.76	0.52
CF2-6	•	0.23	0.63	0.45	0.57	0.59	0.40	0.49
CE0-1	•	0.29	0.31		0.28	0.29	0.03	0.29
CE2-3	•	0.18	0.28	0.28	0.46	0.61	0.43	0.36
CE2-5		0.31	0.27	0.29	0.23	0.15	0.16	0.25
CE2-7		0.16		0.24	0.27	0.26	0.11	0.23
CE2-8	•	0.18	0.27	0.24	0.42	0.44	0.26	0.31
CE2-9	•	0.64	0.23	0.26			0.41	0.38
CE2-10	•		0.49	0.48	0.70	0.46	0.24	0.53
CE8-1		0.27	0.17		0.19	0.18	0.10	0.20
CS0-1	•	0.42	0.46	0.51	0.52	0.38	0.14	0.46
CS2-1		0.73	0.92		0.51	0.36	0.56	0.63
CS2-3		0.26	0.33	0.29	0.39	0.47	0.21	0.35
CS2-5		0.54	0.29	0.22	0.15	0.21	0.39	0.28
CS2-7		0.68	0.67	0.69	0.62	0.62	0.07	0.66
CC2-3		0.71	0.69		0.71	0.65	0.06	0.69
CC2-5		0.52	0.6		0.47	0.51	0.13	0.53
Average		0.44	0.44	0.36	0.44	0.42		0.42

At the time of testing, the apparent total AC/H rate in all rooms in all houses was found to be greater than 0.13 AC/H.

C.3 Fully Operational HRV Ventilation Systems

This section investigates the net mechanical air change rates for each type of system with the HRV balance at the F326 required MVC, the distribution system running at the low speed ventilation rate, and all doors within each home open.

As illustrations of the performance of each system type, specific houses are discussed in the following sections. For supplementary house plan and air flow rate information, please view appendix D.

C.3.1 Fully Ducted Systems

The apparent mechanical AC/H rates for all rooms were found to fall into a band between 0.2 AC/H and 0.6 AC/H in three of the five fully ducted houses.

The following house-specific discussion relates to the two houses where the apparent mechanical AC/H rates were low or varied the most.

CF2-5

The apparent mechanical AC/H rates varied the most at house CF2-5. At this house, the 300 mm long supply duct to the basement was the first branch off the main trunk. Despite the damper being virtually closed within this branch duct, the net AC/H value in the basement was the highest net AC/H value found in any room in any fully ducted house.

The air flow rate measured in the living room was comparatively low. This is presumably the reason for the low net AC/H value in the living room. The kitchen had an exhaust port, but no supply port and was adjacent to the living room. Consequently, the low supply rate to the living room probably resulted in an even lower indirect supply rate to the kitchen; and hence, a low AC/H was calculated for it.

CF0-1

Net AC/H was also found to be low in the "other" bedroom at the CF0-1. This was at the new house where systems were being varied on an ongoing basis for this study and other ventilation testing research.

Graphically, the results for all homes with fully ducted systems are as follows:

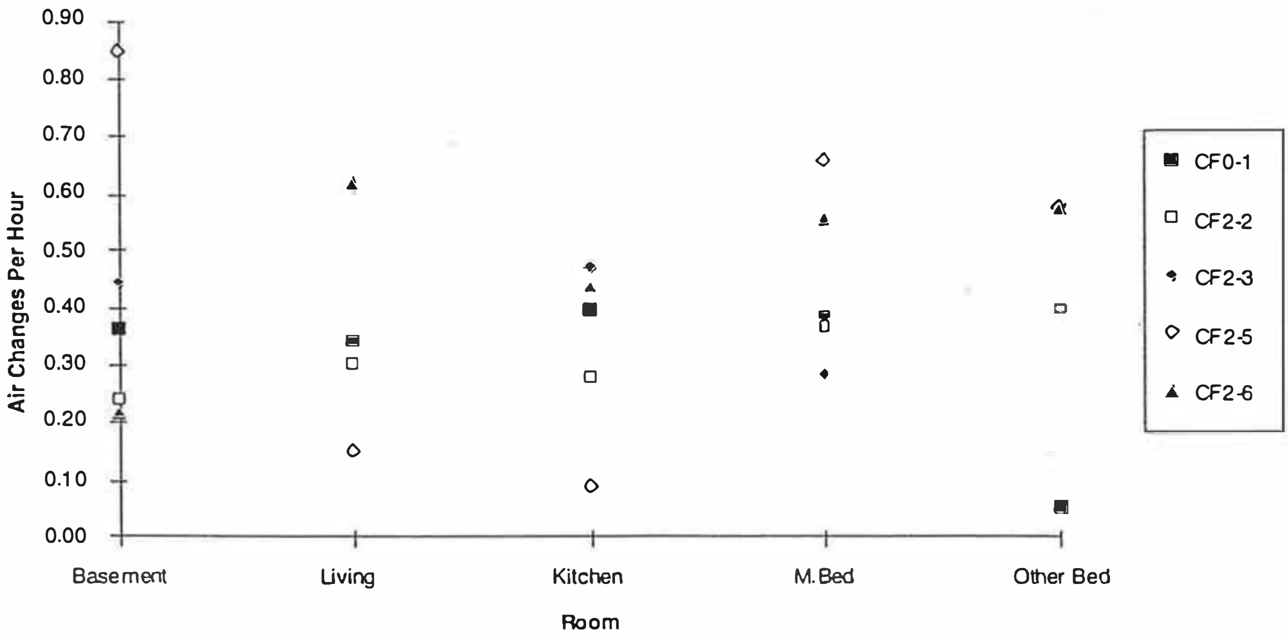


Figure C.2 Fully Ducted Systems – Apparent Mechanical AC/H Rates by Room

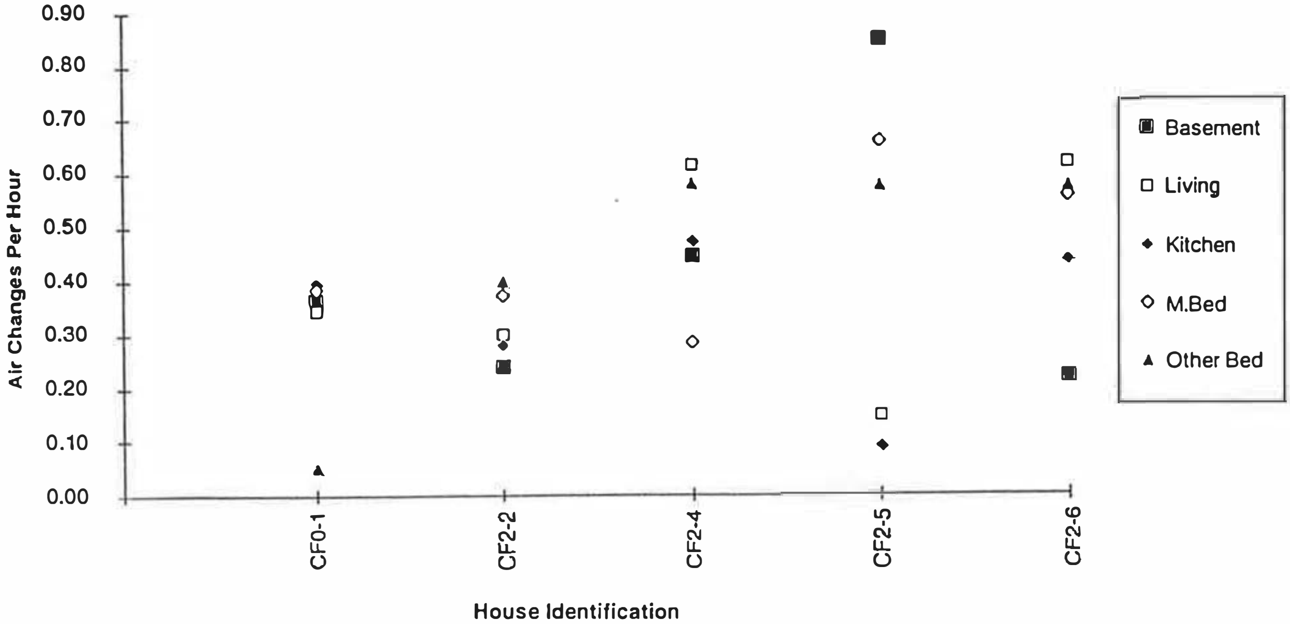


Figure C.3 Fully Ducted Systems – Apparent Mechanical AC/H Rates by House

C.3.2 Extended Systems

On average in the testing phase of the study, the houses with extended HRV ventilation systems were considerably larger than houses with other ventilation types (see table C.3). The HRV flow rates based on room count, therefore, translated into lower overall mechanical ventilation rates as a percentage of house volume. Therefore, the average AC/H per room would be expected to be lower.

The only house with net AC/H values within 25 per cent of each other in the sampled rooms was CE0-1, a relatively open concept bungalow with air supplies and returns in each room.

A relatively wide disparity of net AC/H was found at other houses.

Graphically, the results for all homes with extended systems are as follows:

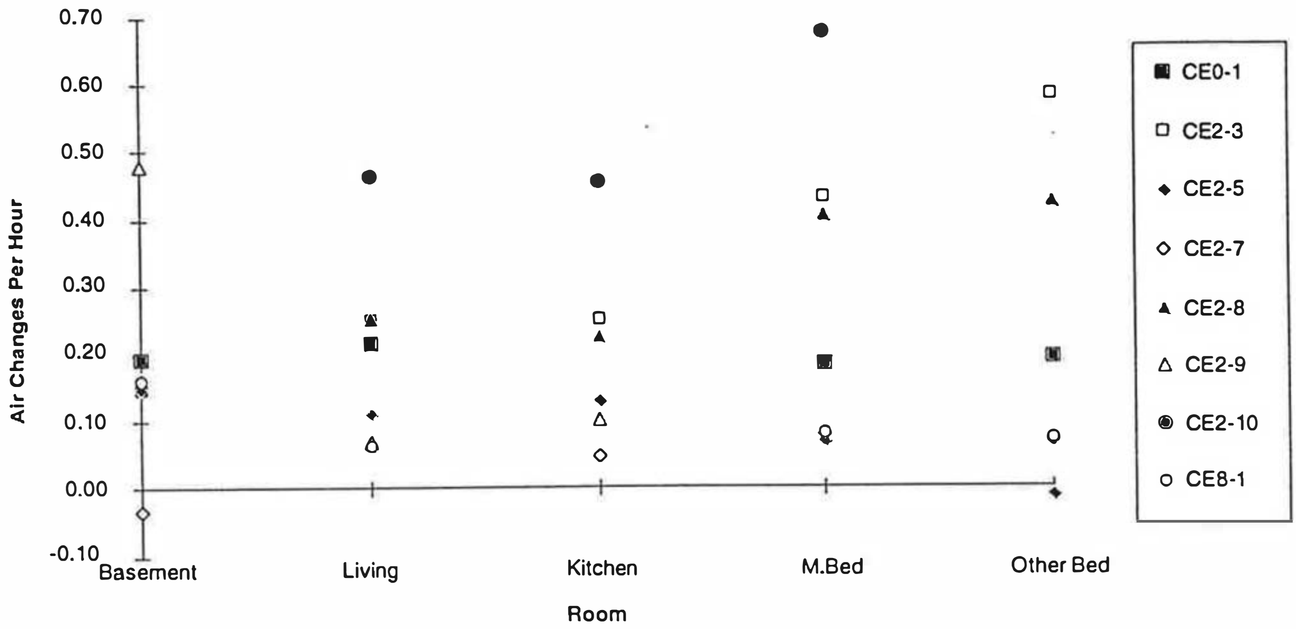


Figure C.4 Extended Systems – Apparent Mechanical AC/H Rates by Room

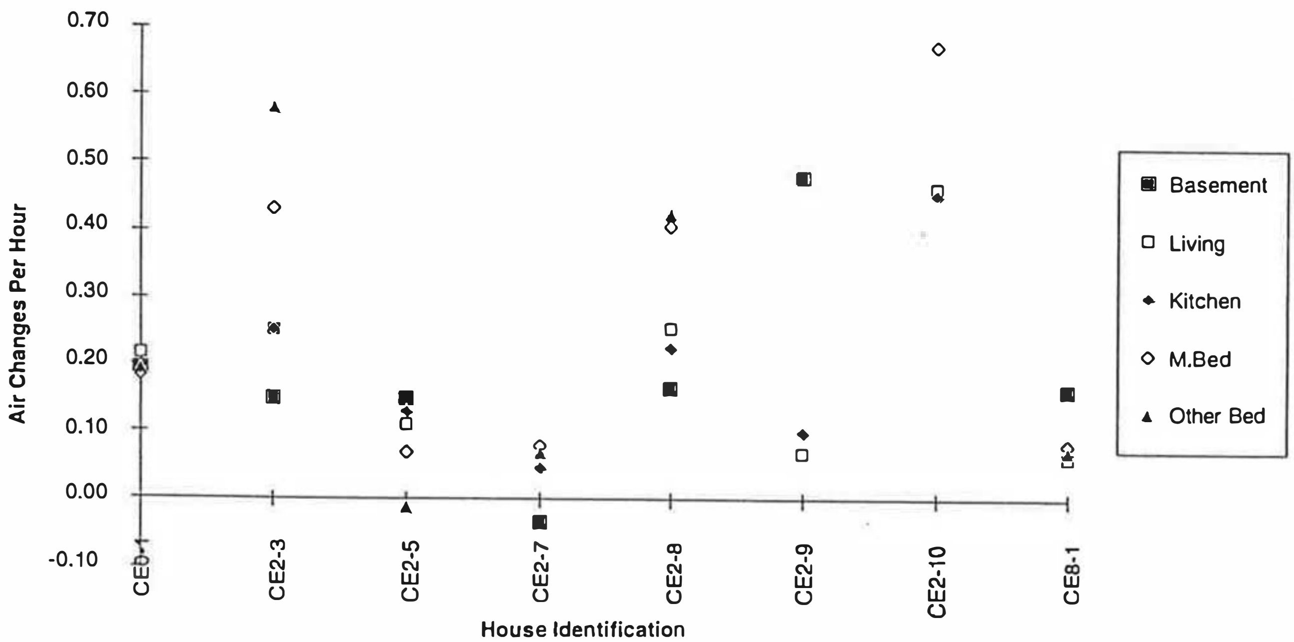


Figure C.5 Extended Systems – Apparent Mechanical AC/H Rates by House

The following comments relate to the testing undertaken at the individual houses.

CE0-1

The apparent mechanical AC/H rates throughout CE0-1 were found to be more uniform than at any other house. This house was a relatively small, open concept bungalow with a central open stairwell and return air grilles in both bedrooms.

CE2-3

This bungalow had relatively small bedrooms with comparatively high air flow rates leading to higher apparent mechanical AC/H rates in these rooms. All bedrooms also had return air grilles. The basement had a high ceiling throughout (3 m floor to ceiling). All supply grilles were at this level. A single basement return was located near the furnace. This return was not close to the sampling location. These may be contributing factors to the low apparent mechanical AC/H rate in the basement.

CE2-5

The apparent mechanical AC/H rate was found to be low in the "other" bedroom of this two storey home. The supply air flow rates in this bedroom and the master bedroom were found to be similar. In the master bedroom, the probe in the middle of the room was in a relatively direct line between the supply grille and the doorway and adjacent furnace return. In the other bedroom, the supply grille return air and door were all along the same wall. This may indicate that short-circuiting is occurring in the "other" bedroom.

This house also had a family room over a garage at the side of the house. The homeowner felt this room lacked air distribution and circulation and had, therefore, installed ceiling fans. The measured supply and return air flow rates in this room were found to be relatively low in comparison to other rooms in the house. The apparent mechanical AC/H rate in this room was found to be low enough to be within the margin of error for the test equipment. Therefore, the homeowner's perception of the distribution to this room was correct.

The basement supply air flow rates were found to be low comparative to flow rates for other floors in the house. No furnace return air grilles had been installed in the basement. However, the apparent mechanical AC/H rate in the basement was found to be marginally higher than the apparent mechanical AC/H rates found elsewhere. A contributing factor was likely the indirect connection of the HRV supply duct to the furnace return.

CE2-7

This home had an exceptionally large volume. The ratio of the F326 MVC flow rate to the volume was very low. This was one cause of the very low apparent mechanical AC/H rates in the house. In Section 8.7 the expected apparent mechanical AC/H rates for houses based on tracer gas measurements were compared with the HRV flow rate measurements.

The measured supply air flow rates from all seven basement grilles were negligible, since the homeowner had closed all supply dampers in the basement and the HRV supply was hard connected to the furnace return. This appeared to be the reason for the basement's apparent mechanical AC/H rate being so low that it was within the margin of error of the test equipment.

CE2-8

This two-storey home had returns in all bedrooms. The net AC/H values fell in the optimal range for each room reflecting the fact that the furnace air flow measurements were reasonable for the size of the given room.

CE2-9

The apparent mechanical AC/H rate in the basement was very high compared to values elsewhere in this house. The HRV supply was directed at an opening in the furnace return located 150 mm from the end of the HRV duct. The angle of incidence between the HRV supply duct and the furnace return was 45 degrees. The cause of the high apparent mechanical AC/H rate in the basement appeared to be the failure of most of the fresh air from the HRV to enter the furnace return.

This house was a large three-storey home with a basement. On the day of testing, the temperatures in each storey were 2°C warmer than on the floor below. The homeowner had noted insufficient air flow to and from the third floor. The air flows from the 6 supply registers and two return registers on the third-storey were too low to measure.

In all homes with circulation fans, it was possible to distribute the tracer gas evenly throughout the house using these fans in a period of less than half an hour. The only notable exception was the third floor of this house (comprised solely of one large room). After running the circulation fan for more than two hours, the concentration of tracer gas on the third floor was still lower than anywhere else in the house and was continuing to rise. Therefore, the apparent mechanical AC/H rate was lower on this floor than on any other included in the study when the mechanical ventilation system was fully operational at the F326 required MVC.

CE2-10

The furnace air flow rate was found reasonably proportional to room size in this single storey home. This was reflected by the similar net AC/H values in each sampled room. All bedrooms had return air registers.

CE8-1
This open concept home had very similar apparent mechanical AC/H rates on the first and second storey. The apparent mechanical AC/H was higher in the basement. Again, the HRV supply was not directly connected to the furnace return. A second factor may have been the high return air flow rate through a register at the base of the return plenum next to the furnace in the basement.

C.3.3 Simplified Systems

The following illustrate the results for all homes with simplified systems:

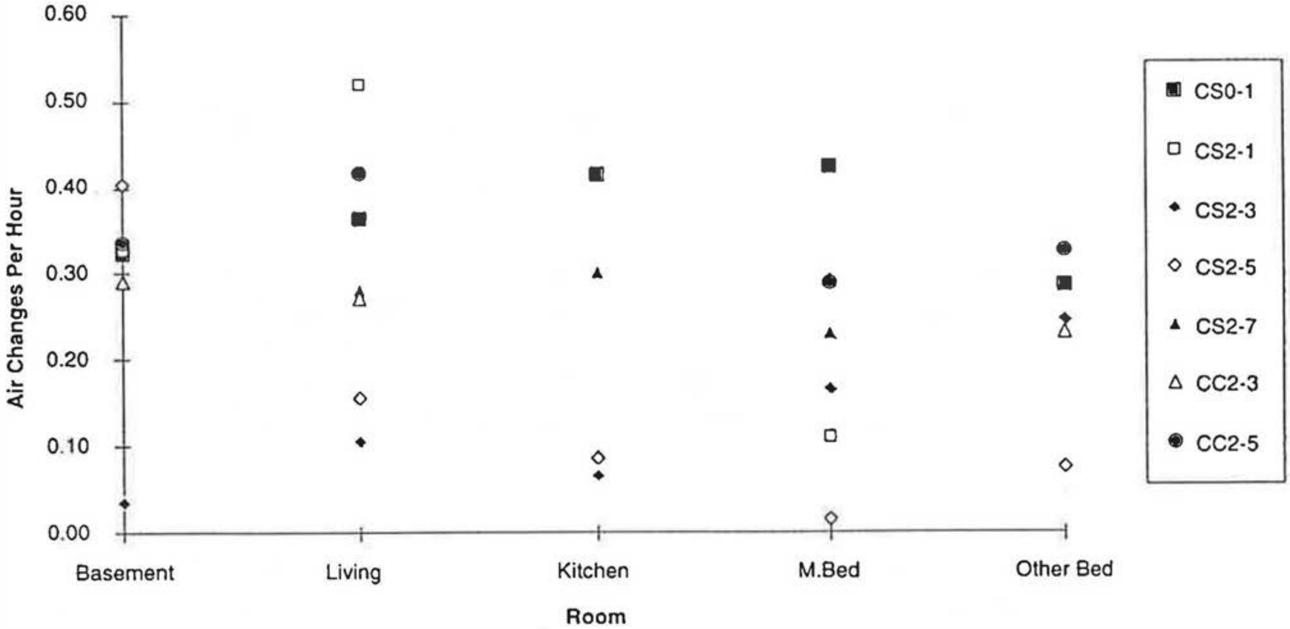


Figure C.6 Simplified Systems – Mechanical Ventilation Rates by Room

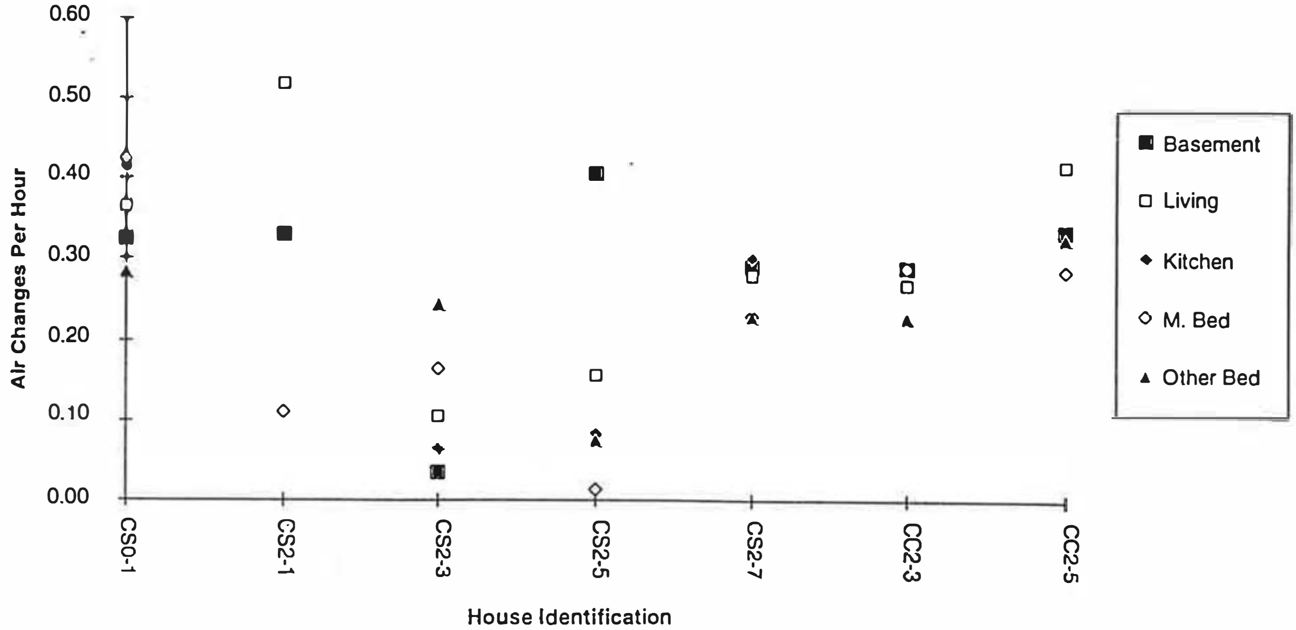


Figure C.7 Simplified Systems – Mechanical Ventilation Rates by House

<u>CS0-1</u>

The apparent mechanical AC/H rates were similar throughout this relatively open plan bungalow with return air grilles in each bedroom.

<u>CS2-1</u>

In this home, the furnace air supply to the second floor was roughly 60 per cent of that supplied to the first floor. Although there were two returns on the second floor – one in the master bedroom and one in the hallway – the return air flow rates were low. The total return air flow rate from the second floor was approximately 15 per cent of the flow rate from the only first floor return air register.

These appeared to be factors in the relatively low apparent mechanical AC/H rate found in the master bedroom in comparison to the apparent mechanical AC/H rate found in the living area.

<u>CS2-3</u>

The first and second floor supply and return air flow rates were relatively similar in CS2-3. The high supply rate to room volume ratio was the probable reason for the relatively high bedroom apparent mechanical AC/H rates.

On a floor-by-floor basis, the basement had the lowest supply and exhaust flow rates. Relatively low apparent mechanical AC/H rates in the basement correlated to these measured air flows.

CS2-5

The tracer gas concentration in the basement was slightly higher than elsewhere at the start of testing. This probably caused the calculated apparent mechanical AC/H rate in the basement to be particularly high.

The air supply rate to the second bedroom was low in comparison to other rooms in the house. The two upstairs return grilles were also far from this room. The low apparent mechanical AC/H rate in the second bedroom reflects this.

CS2-7, CC2-3, CC2-5

All three of these moderately sized, two-storey homes had relatively similar apparent mechanical AC/H rates for all rooms sampled. All three homes had supply and return air flow rates on the second floor that were similar to those on the first floor.

C.4 Short-Circuiting

Short circuiting involves the flow of air from the supply register to the return air register without being distributed throughout the rooms. To determine the extent of the short circuiting in a room, the apparent mechanical AC/H rate in the center of the room was compared with the apparent mechanical AC/H rate at the return air grille.

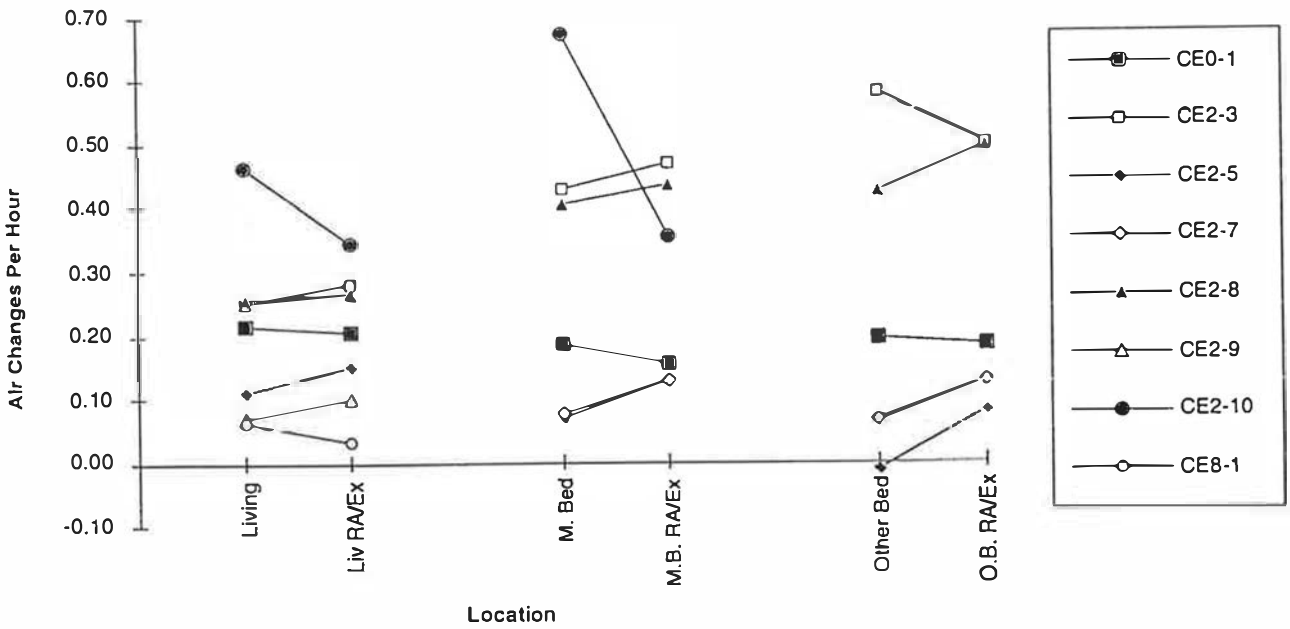


Figure C.8 Net AC/H for Rooms and Returns in Rooms for Houses With Extended Systems

These results are typical of all simplified systems too. In general, the apparent mechanical AC/H rates were very similar at the center of rooms and at the room return air grilles. Short circuiting did not appear to be a significant problem.

The above graph illustrates the apparent mechanical AC/H rate and not the apparent total AC/H rate; as a result, the differences appear to be greater. It should also be noted that error becomes a large factor when comparing relatively similar results at room center and room return air grilles.

The room, where short-circuiting most likely appeared to be occurring, was the other bedroom in house CE2-5. The return air apparent mechanical AC/H rate was greater than the room apparent mechanical AC/H rate. In terms of apparent total AC/H rates, the center of the room was 0.15, while the return air grille was 0.24.

The only other rooms where the apparent mechanical AC/H rate at the return was calculated to be appreciably greater than the apparent mechanical AC/H rate in the center of the room were the master bedroom at house CE2-5 and both bedrooms at house CE2-7. In these three rooms, the return air grille was next to an open doorway to a hallway. Air flowing into each return air grille could have been coming from the hallway as well. Dependent upon the rates at which air from the hallway entered these returns, and the difference in the apparent AC/H rates between bedrooms and hallways, the extent of short-circuiting may be more or less than that shown for these rooms in Figure C.8.

Therefore, the higher apparent mechanical AC/H rates at these grilles did not necessarily indicate short-circuiting. It is also possible that the tracer gas concentration decreased at a slower rate in the hallway than in the bedroom and that, as a result, more short-circuiting was occurring than would be indicated by these values.

It is interesting to note that, at house CE2-5, the airflow rates to the master bedroom and the other bedroom were similar, but the apparent mechanical AC/H rate in the master bedroom was 0.07 AC/H and the net AC.H in the other bedroom was negligible. The supply register in this room was on the same wall as the open door and the return air for the room. Thus, the direct air path to the exhausts was not via the center of the room.

C.5 Effects of Closing Doors and Shutting Down Circulation Fan

Testing was carried out to determine the effect of closing doors on the ventilation performance within each house when the ventilation and distribution systems were both fully operational.

The net AC/H values were also determined in locations within each house with an extended or simplified system when the HRV was operating and the circulation fan was shut down. This testing was carried out with the doors open throughout the house.

For discussion purposes, a few sample house results are evaluated based on comparison charts of the above two testing configurations and the benchmark testing carried out with HRV and circulation systems fully operational with the doors open.

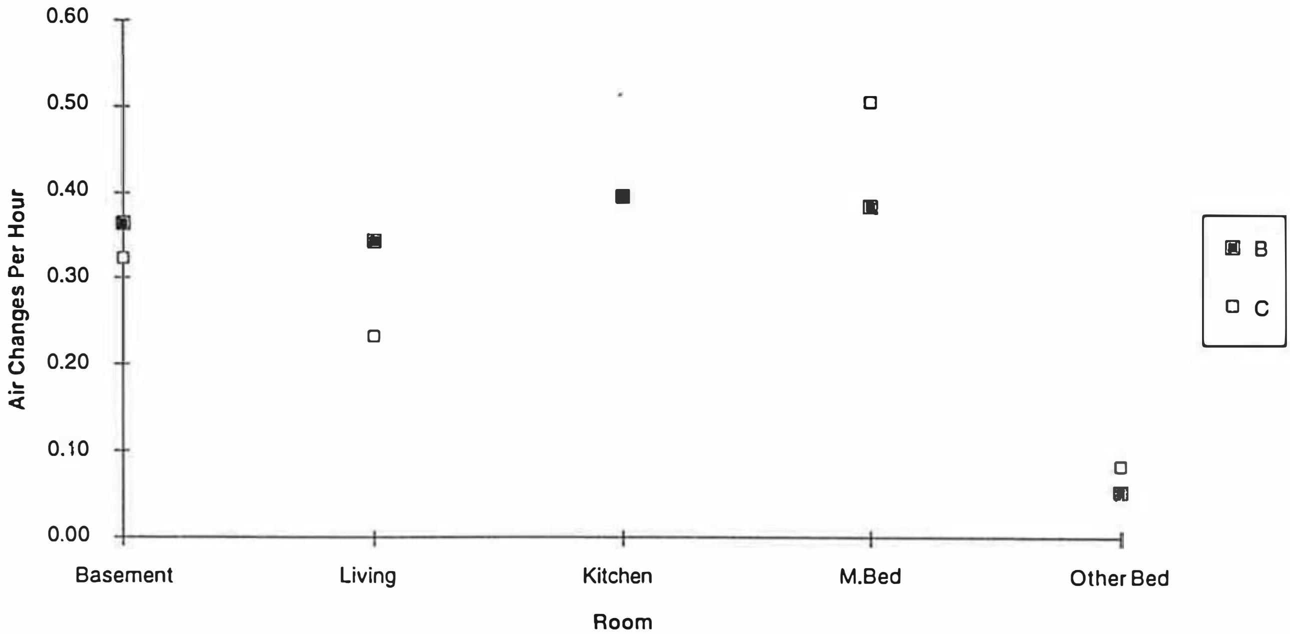
The effect of shutting doors varied from house to house. The following sections discuss some of the most plausible causes for the calculated results. The effect of turning off the circulation system for extended and simplified systems was consistent from house to house and led to more conclusive results.

For a review of air flows to rooms and house layouts, refer to Appendix D. Note that a single air flow reading was taken in each room. Measuring air flows again with doors closed and measuring pressure differentials between rooms was beyond the scope of this study.

C.5.1 Fully Ducted Systems

As there is no separate forced-air system circulation equipment in fully ducted houses, the following comparisons are of systems with doors shut and with doors open.

House CF0-1



Note:

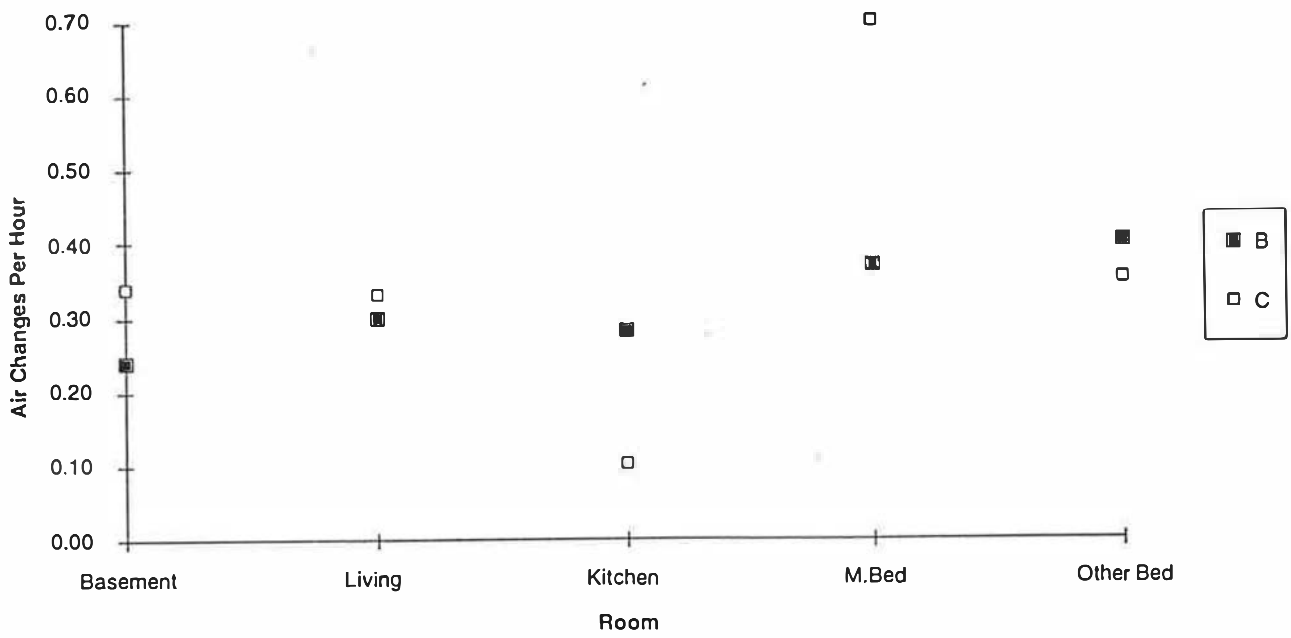
Test	HRV	Doors
B	MVC	Open
C	MVC	Closed

Figure C.9 Effect of Door Closing at CF0-1

Closing doors to the basement, bedrooms, and bathrooms had minimal effect on the apparent mechanical AC/H rates at this single storey home.

The doors were undercut by approximately one centimeter. Floor finishes, such as carpeting, were not yet installed and, thus, did not impede air flow through door undercuts.

House CF2-2



Note:

Test	HRV	Doors
B	MVC	Open
C	MVC	Closed

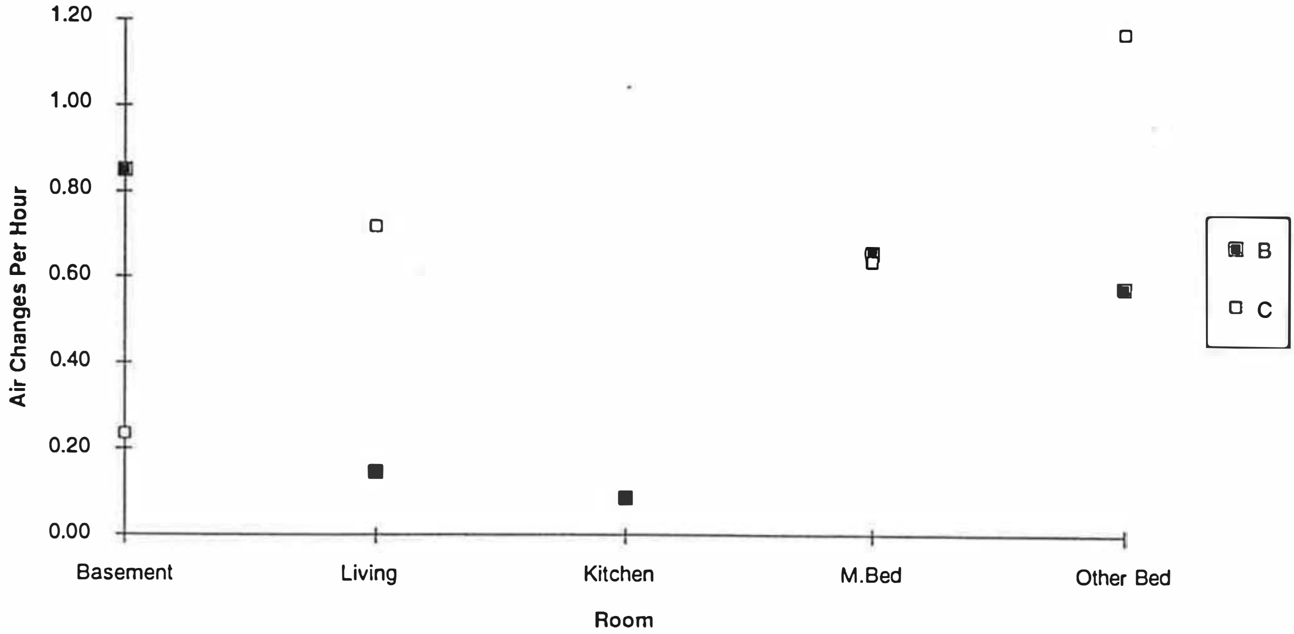
Figure C.10 Effect of Door Closing at CF2-2

At CF2-2, it is hypothesized that the apparent mechanical AC/H rate in the master bedroom increased with the door shut for the following reasons:

- The room had a relatively high ratio of ventilation air supply flow rate to room volume.
- Thc HRV supply for the master bcdroom was in an alcove pointing directly at the doorway to thc hall. Closing the bedroom door would have changed the circulation within thc room and presumably led to more fresh air being delivered to the sampling location in the center of the room.

By closing the bedroom doors, an additional barrier was created between the kitchen and three of the four HRV supply outlets at this house. The remaining HRV supply outlet was in the living room in the furthest corner from the kitchen. These are the probable causes of the apparent mechanical AC/H rate being reduced in the kitchen.

House CF2-5



Note:

Test	HRV	Doors
B	MVC	Open
C	MVC	Closed

Figure C.11 Effect of Door Closing at CF2-5.

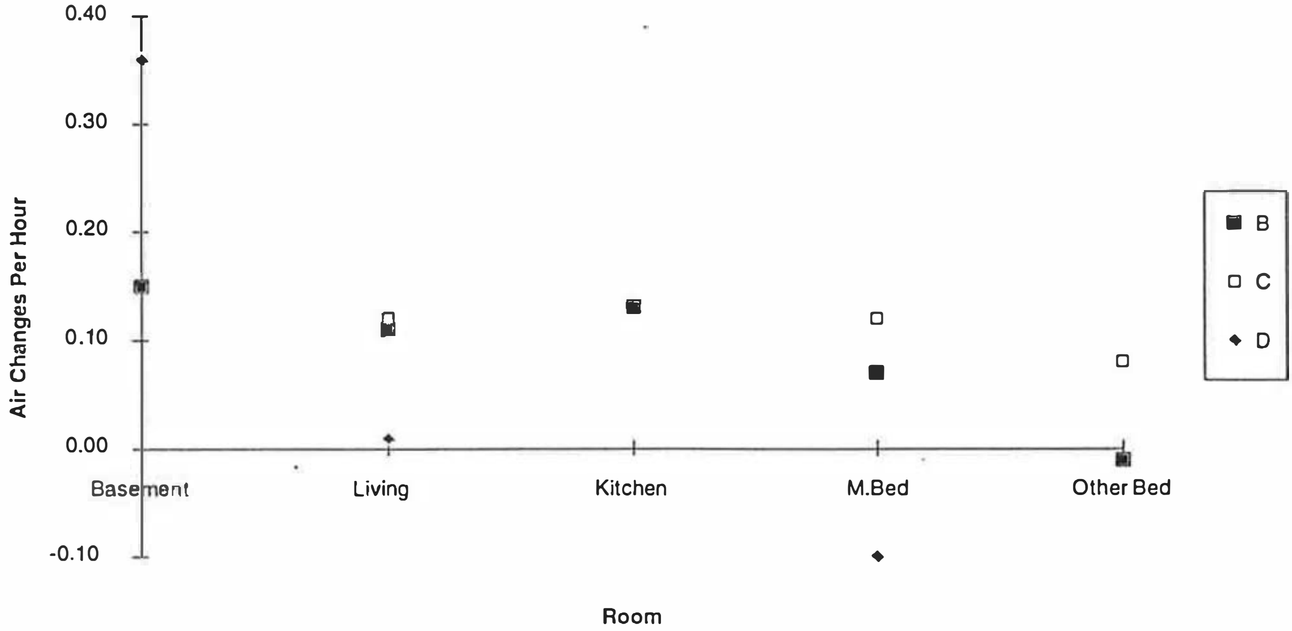
The effect of closing the doors at this house was more interesting than it was at any other fully ducted house. As a reference for the following discussion, use the house plans for CF2-5 in Appendix D.

The HRV supply to the now finished basement was in the mechanical room. By closing the door to this room, it is possible that it became pressurized and more air filtered into the living room above it. The low apparent mechanical AC/H rate in the kitchen likely reflects a reduced apparent mechanical AC/H rate in the basement, one of the two areas with the largest opening into the kitchen.

For a discussion as to the probable reason for the apparent mechanical AC/H rate rising in the other bedroom, please see the results discussion for house CF2-2.

C.5.2 Extended Systems

House CE2-5



Note:

Test	HRV	Circulation Fan	Doors
B	MVC	Low	Open
C	MVC	Low	Closed
D	MVC	Off	Open

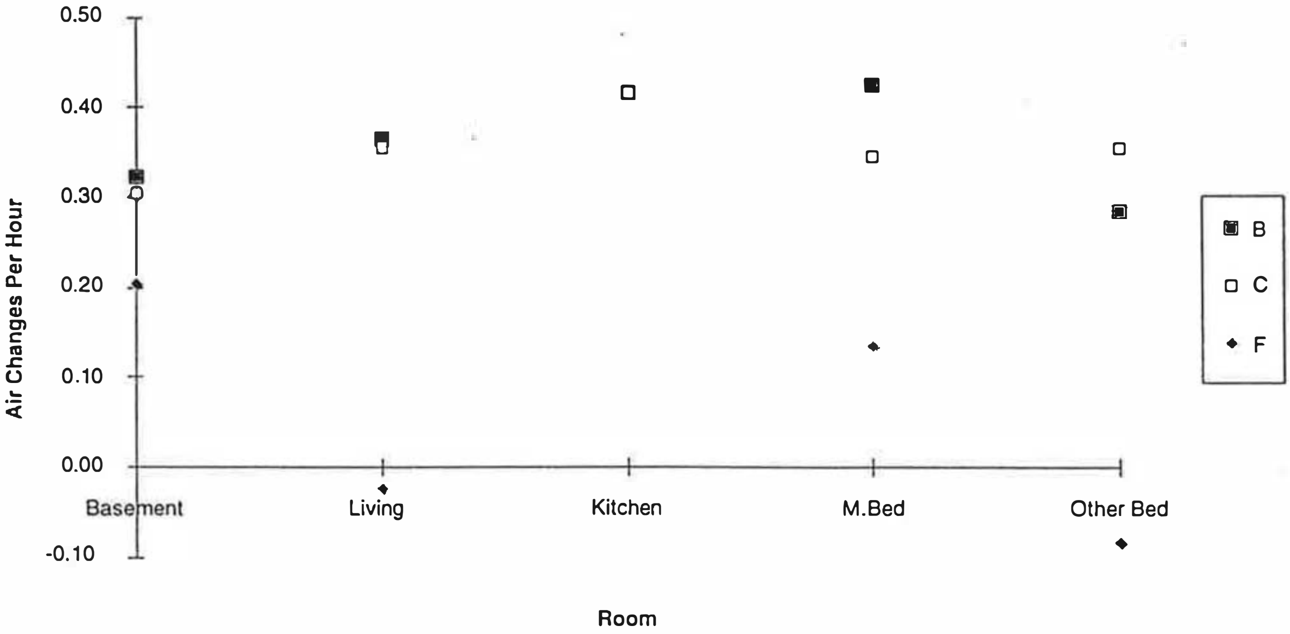
Figure C.12 Effect of Door Closing and Ceasing Circulation Fan Operation at House CE2-5

Circulation fan flow rates on the second storey of this house were similar to those on the first storey. All bedrooms had return air grilles. Closing doors, therefore, had little effect on the air flow rates in each room. The increased apparent mechanical AC/H rates in the bedrooms with the door closed were probably caused by the improved mixing within rooms prior to the air being exhausted from the room. In other words, short-circuiting was apparently reduced.

With the circulation fan shut off, net AC/H increased dramatically in the basement and became negligible elsewhere in the house. A 300 mm gap existed between the HRV supply duct and the furnace return in this house.

C.5.3 Simplified Systems

CS0-1



Note:

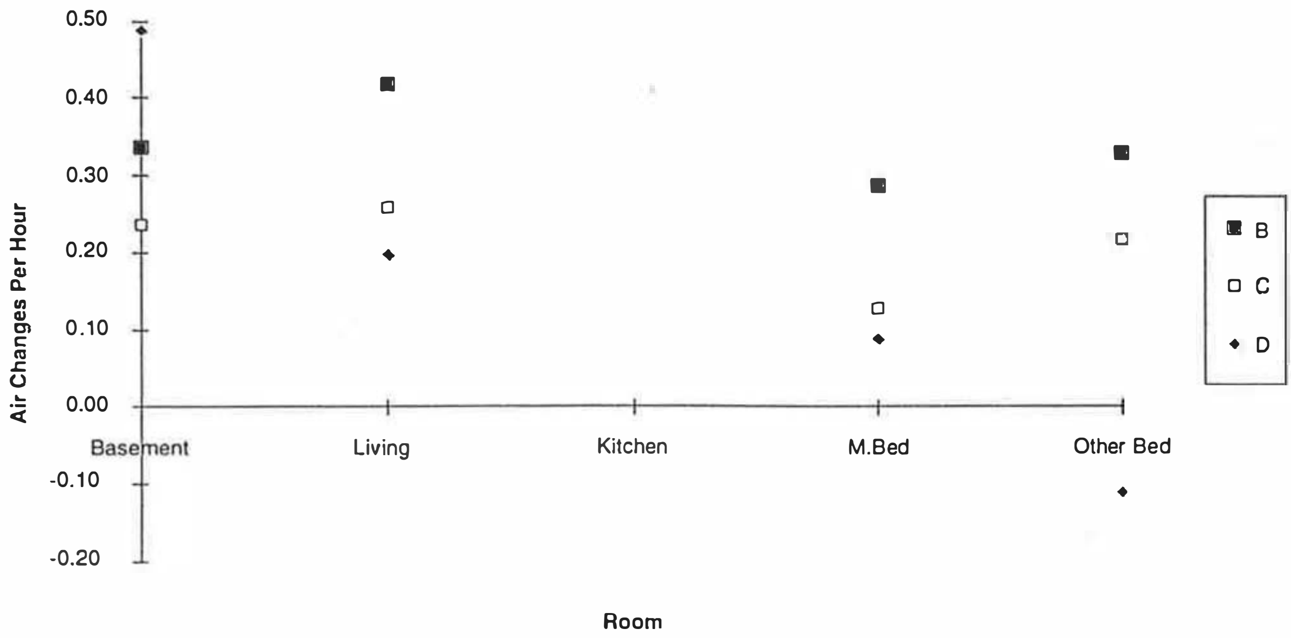
Test	HRV	Circulation Fan	Doors
B	MVC	Low	Open
C	MVC	Low	Closed
F	MVC	Off	Closed

Figure C.13 Effect of Door Closing and Ceasing Circulation Fan Operation at House CS0-1

Relatively little difference was observed in the net AC/H with doors open and doors closed in this compact single-storey home. Each bedroom had strong circulation system supply and return air flows.

The HRV supply was hard connected to the furnace return. Without the circulation system operating, the net AC/H became negligible in locations far from this connection point; namely, the living room and the "other" bedroom. The master bedroom was close to this connection point. Tracer gas readings indicated that fresh air was coming out of the return air grille in the master bedroom.

CC2-5



Note:

Test	HRV	Circulation Fan	Doors
B	MVC	Low	Open
C	MVC	Low	Closed
D	MVC	Off	Open

Figure C.14 Effect of Door Closing and Ceasing Circulation Fan Operation at House CC2-5

In this house, all rooms had lower apparent mechanical AC/H rates with the doors shut. The reason for the across-the-board lowering was not clear. The flow through the HRV should have remained very close to constant. If the apparent mechanical AC/H rates in the bedrooms were reduced due to increased pressure within the room and the reduced air flow to the room, then air flow would be expected to increase to the open plan basement and living area.

The HRV supply in this compact, two-storey home was hard connected to the furnace return. A return was located in the master bedroom, but not in the other bedroom where tracer gas concentrations were measured. With the circulation fan turned off, the apparent mechanical AC/H rate increased in the basement where the HRV supply duct hard connection to the furnace was located. The apparent mechanical AC/H rate decreased in the living room where the return register was close to this connection. The apparent mechanical AC/H rate was also reduced in the second-storey master bedroom (another room with a return air register), while it was found to be negligible in the upper floor bedroom where there was no circulation system air register.

C.6 Cross-Contamination

In order to determine the extent of cross-contamination from the outside HRV exhaust port to the supply port and through the HRV, single tracer gas measurements were taken at nine houses from the following locations:

- the warm side supply and exhaust ducts within 600 mm of the HRV,
- the cold side supply and exhaust ducts near the HRV where possible or at inside the outside ports

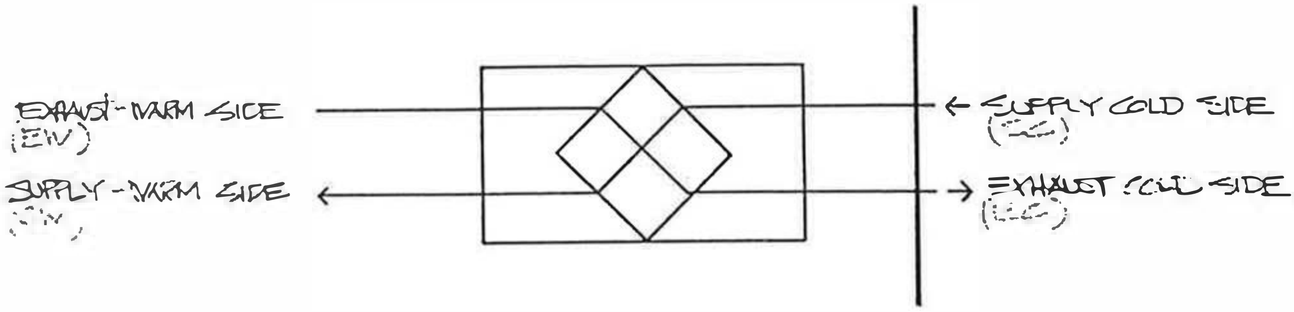


Figure C.15 tracer Gas Measurement Locations for Cross Contamination Calculations

The following four terms were used to define various ways fresh outdoor air was contaminated with air from within the house. The formulas used to calculate each value refer to the letters on the above drawing.

<u>Total Contamination (TC):</u> The extent to which the outdoor air supplied by the HRV was contaminated by indoor air

The formula for calculating this value was: TC = SW/EW

<u>Outside Contamination (OC)</u>: The extent to which fresh outdoor air at the supply port was contaminated by air exhausted from the HRV.

The formula for calculating this value was OC = SC/EC

<u>HRV Supply Side Cross Contamination (SSCC)</u>: The extent to which the outdoor air stream was contaminated through the HRV.

The formula for calculating this value was:

SSCC = (SW-SC)/(EW-SC)

HRV Exhaust Side Cross Contamination (ESCC): The extent to which the exhaust air stream took in supply side air. This item was of most interest in comparison to the HRV Supply Side Cross Contamination.

The formula for calculating this value was:

ESCC = (EW-EC)/(EW-SC)

Table C.3 lists the results of the cross-contamination tabulations.

Table C.3 Cross Contamination Outside and Across HRV

House ID	*Total Contamination*	*Outside Contamination*	*HRV Supply Side Cross Contamination*	*HRV Exhaust Side Cross Contamination*
CF2-2	15%	1%	15%	6%
CF2-5	21%	9%	14%	10%
CE2-3	13%	0%	13%	0%
CE2-3	*17%*	*0%*	*17%*	*5%*
CE2-5	27%	17%	14%	16%
CE2-8	8%	3%	5%	-2%
CE2-9	16%	1%	15%	-3%
CS2-3	49%	8%	45%	0%
CS2-7	22%	11%	15%	20%
CC2-5	24%	3%	21%	-15%
Average	22%	5%	18%	4%

Note: Measurements were take twice at house CE2-3.

The average total cross-contamination of 22 per cent indicates that the HRVs would have to move a similar percentage more air through the system above the CAN/CSA-F326 required rate to achieve the rate of fresh air delivery set out by the standard. In fully ducted and extended installations, this cross-contamination will lead to the recirculation of air from high pollutant exhaust locations; namely, bathrooms, kitchens, and laundry rooms.

In many HRVs, the supply air steam chamber in the HRV was pressurized by the supply fan, while the exhaust air stream chamber in the HRV was depressurized by the exhaust fan. In these cases, the fresh air stream would be expected to only contaminate the exhaust air stream. The supply side flow rate would be marginally reduced across the core chamber, while the exhaust side flow rate would be marginally increased.

As stated in the sections on errors, Section 8.8, the tracer gas test equipment was accurate to within plus or minus six per cent at all concentrations. The percentage difference in concentration readings was much greater on the supply side than on the exhaust side. Hence, supply side across HRV concentration differences and, therefore, cross contamination results should both be more accurate than those for the exhaust side.

The error involved in this testing was highlighted by the calculated results from two successive series of tests at house CE2-3. The variation in the total contamination percentage from one test series to the next was 4 per cent. Outside HRV exhaust side cross-contamination went from 0 to 5 per cent. It is conjectured that one reason that successive tests did not provide the same results was that outside air movement varied with time and that samples could not be taken at exactly the same time.

PHASE 3 - VENTILATION SYSTEM EFFECTIVENESS TESTING
SUMMARY CHART FOR HOUSES INCLUDED

HOUSE ID NUMBER	PH 1	PH2	NUMBER OF STOREYS	APPROX VOL (m3)	.3 ACH FLOW RATE (L/s)	F326 REQ'D FLOW RATE (L/s)	MEASURED FLOW RATE DURING TESTING (L/s)	.3 ACH SCALE FACTOR	HOUSE NOTES
CF0-1	•	•	1	679	57	55	52	1.09	Protocol house - furnace ductwork not in use
CF2-2	•	•	1	438	37	55	34	1.06	HRV on low speed during testing
CF2-4		•	2	394	33	60	55	0.59	Poor distribution prior to testing
CF2-5		•	1	621	52	60	52	0.99	Supply air flows at grilles matched F326
CF2-6		•	1	425	35	50	45	0.79	
Average								0.90	
CE0-1	•	•	1	679	57	55	52	1.09	Protocol house
CE2-3	•	•	1	1060	88	70	64	1.39	Good air flows throughout
CE2-5	•	•	2	924	77	70	66	1.17	Low air flows in family room, indirect connection
CE2-7	•	•	1.5	1635	136	110	66	2.06	
CE2-8		•	1	1022	85	65	64	1.34	Good air flows throughout
CE2-9		•	2.5	1320	110	75	53	2.08	Indetectable flows on third storey, indirect connection
CE2-10		•	1	871	73	75	71	1.03	
CE8-1	•	•	2	1027	86	65	61	1.40	Open concept home
Average								1.44	
CS0-1	•	•	1	679	57	55	52	1.09	Protocol house
CS2-1	•	•	2	550	46	65	49	0.93	Low supply air flows on second storey, very week returns
CS2-3	•	•	2	491	41	60	53	0.77	
CS2-5	•	•	2	914	76	75	51	1.48	
CS2-7		•	2	404	34	55	54	0.63	
CC2-3	•	•	2	567	47	65	61	0.77	
CC2-5	•	•	2	515	43	60	64	0.67	
Average								0.91	

Notes

1 Measured Flow Rate During Testing - All HRVs balanced within 10% during testing, larger of two values given
2 .3 ACH Scale Factor - F326 based on room count, results comparison must consider fresh air supply rate to volume ratio
3 Indirect Connection - HRV supply not hard ducted to furnace return

Appendix D

House Plans and Air Flow Measurements for Phase III and IV Houses

Contents

D.1. General

Appendix D contains the house-plans for the 20 homes included in the ventilation effectiveness testing. The locations of the HRV system supply and exhaust grilles and the furnace fan circulation system supply and return grilles are shown on each plan.

A summary table documenting the measured air flows at the identified grilles in each house is also included. The balanced flow rate measured at the HRV with a flow measuring station or flow grid is also included.

At four houses, CE0-1, CE2-5, CE2-8, and CS0-1, graphs are also included comparing the predicted air change rates based upon circulation system air flow rates with those found using tracer gas.

D.2 Air Flow Measurement Techniques

The CHMC duct test rig was intended to be used for all flow measurements. At the first house tested, an attempt was made to use the duct test rig to measure HRV flow rates. The total of the flow rates measured at the grilles on the supply and exhaust side of the HRV was roughly one third of the flow rates found using the flow measuring stations. The results obtained from estimating the time it took to inflate or deflate a bag of known volume led to total air flow rates confirming the values provided by the flow measuring stations.

From that point on, the air flows through the HRV supply and exhaust grilles were measured using the above-described 'bag method'.

The furnace system supply and exhaust air flow rates at each grille were typically far larger than those for HRV grilles. Thus, the duct test rig gave more reasonable flow rate measurements for forced-air system grilles.

The air flow measurements at the furnace system grilles was used for determining how much ventilation air was being delivered to each room. As the total amount of ventilation air was known due to measurement of the HRV supply rate at the flow measuring station, the percentage of furnace system supply air to each room rather than the total amount of supply air to each room was required. No attempt was made to account for duct leakage.

Although the air flows measured with the duct test rig were consistently far lower than those with the bag method, the percentage air flows were similar. (See the flow rate summary for house CE2-8 where the air flows at all grilles, other than those in the basement, were measured using both techniques.)

D.3 Comparison of Air Flow Measurement and Tracer gas Results

The following discussion relates to each of the houses where a chart was produced to compare the apparent mechanical AC/H rates based on various flow measuring techniques and different methods of calculating them based upon tracer gas measurements.

It should also be noted that the first house, CE2-8 is one of the 11 houses where the measured natural air change rates were similar (within 0.08 AC/H) throughout the house. (Table C.1 on page C-2 contains a listing of the natural air infiltration rates for the houses). Since the tracer gas mechanical air change rate calculations use the average natural air change rate, this may help explain why the results were closer for the various methods at CE2-8. The subsequent three houses were all houses where the natural air change rates varied more significantly.

CE2-8

Furnace System Flow Rate Comparisons

CE2-8 was the only house where it was possible to get three determinations of the total air flow at the supply grilles and return air registers. These included: with the duct test rig, the bag method and the furnace fan's electronically commutated (ECM) motor setting. The results were:

Method	Duct Test Rig	Bag Method	ECM Motor
Supply Rate (L/s)	134	233	329
Return Rate (L/s)	159	257	329

The flow rate based on the ECM motor setting was, by definition, different from the rate calculated using the other two methods because it was measured across the furnace box instead of at the grilles. Therefore, the flow rate based on the ECM motor setting included the losses in the ductwork; and these measurements were expected to provide a higher total flow rate.

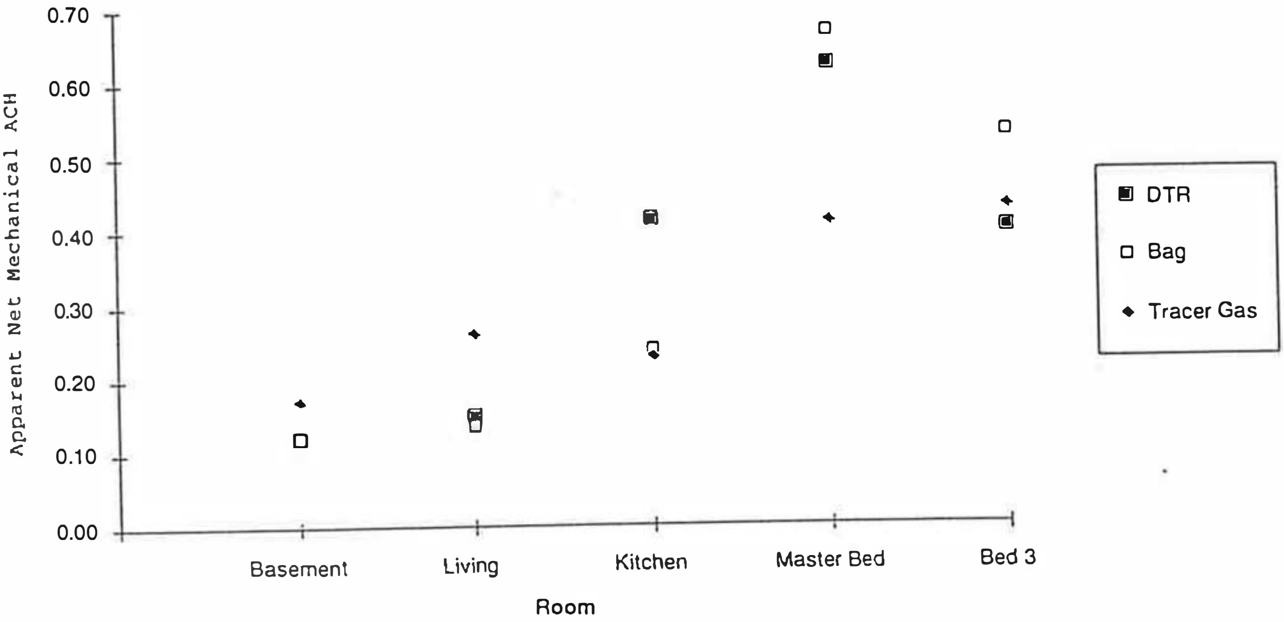
At most houses, the sum of the total measured flow rates on the supply side grilles greatly exceeded the sum of the total measured return air side grilles. Total measured air flow rates at this house were a rare exception.

The air flow to each room as a percentage of the total is relatively similar for the duct test rig flow measurements and the bag method flow measurements.

HRV System Flow Rate Comparisons

The total HRV exhaust flow, as calculated with the bag method was 61 L/s whereas the total flow measured with the flow measuring station was 63 L/s.

These results are much closer than they were at most other houses. However, total measured flow rates with the bag method and flow measuring stations were usually within 30 per cent of each other.



Comparison of Net Mechanical AC/H in CE2-8

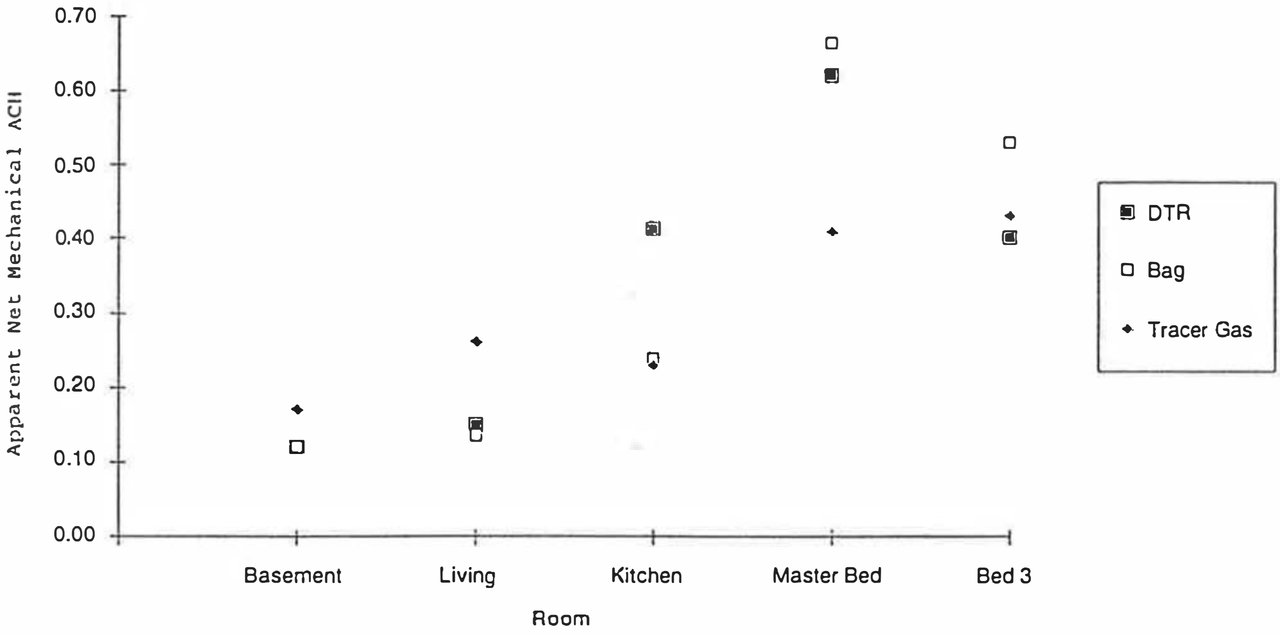
The predicted air change rate based on air flow measurements was based solely on the ventilation air supply rate to the room and the room volume.

Numerous other methods could have been used. A system could have been developed to factor in return air flow rates and rates in adjacent rooms where a room was a relatively open concept. These approaches would have involved judgement for each room. Such methods would be open to criticism that the results were skewed by judgement to be more similar to those found using tracer gas measurements. They were also beyond the scope of this study.

The graph shows that the predicted air change rates, based upon the duct test rig flow rates and the bag method, were very similar in most rooms.

There was also a fairly good correlation between the air change rates based on the air flow measurements and those based upon the tracer gas measurements. The only room where the largest predicted air change rate was double the lowest was the living room. This room was different from the others. It was an open plan design and would, thus, be affected by air flow through registers in adjacent rooms in the open zone. As discussed above, these considerations were not accounted for in predicting air change rates.

CE2-5



Comparison of Net Mechanical AC/H in CE2-5

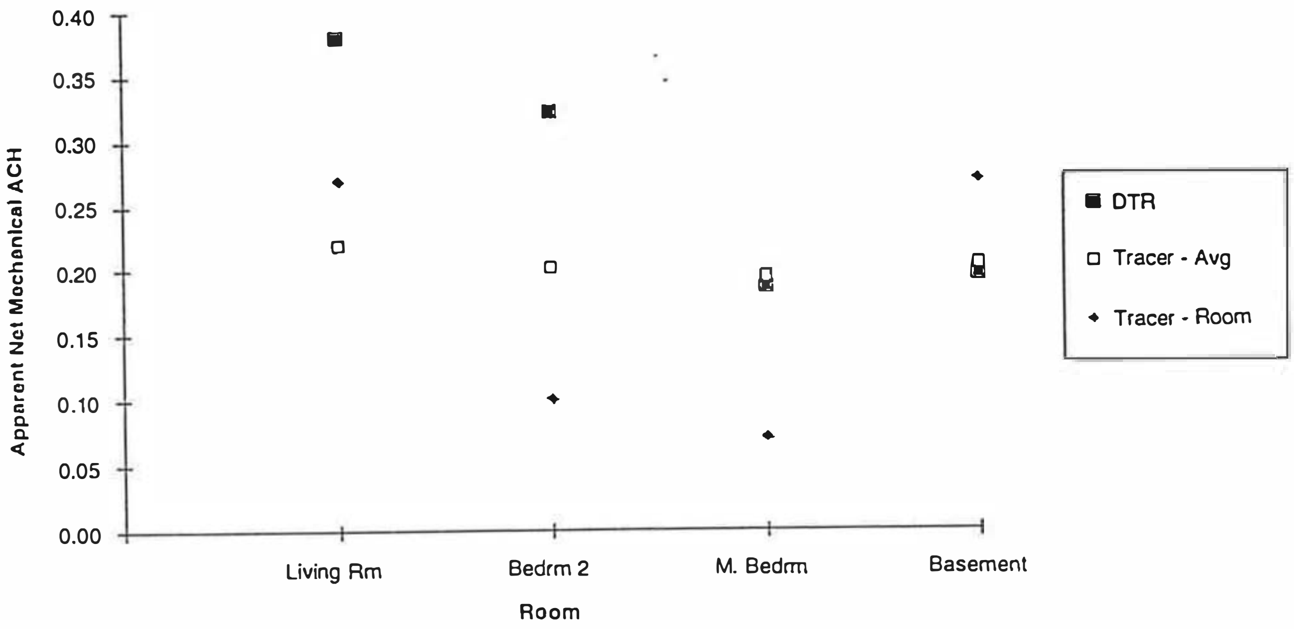
This graph compares the following three methods of assessing apparent mechanical air change rates:

- based on supply air flow measurements with the duct test rig
- based upon total minus natural air change rates in each room calculated upon tracer gas test measurements
- based upon total air change rates in each room minus house average natural air change rates, again both calculated upon tracer gas test measurements

All three methods produce widely divergent results. Tracer gas based apparent mechanical AC/H figures appear to be more similar to those based on the duct test rig when they use individual room natural AC/H rates.

It should be noted that the variation in natural AC/H from room to room was second largest at this house.

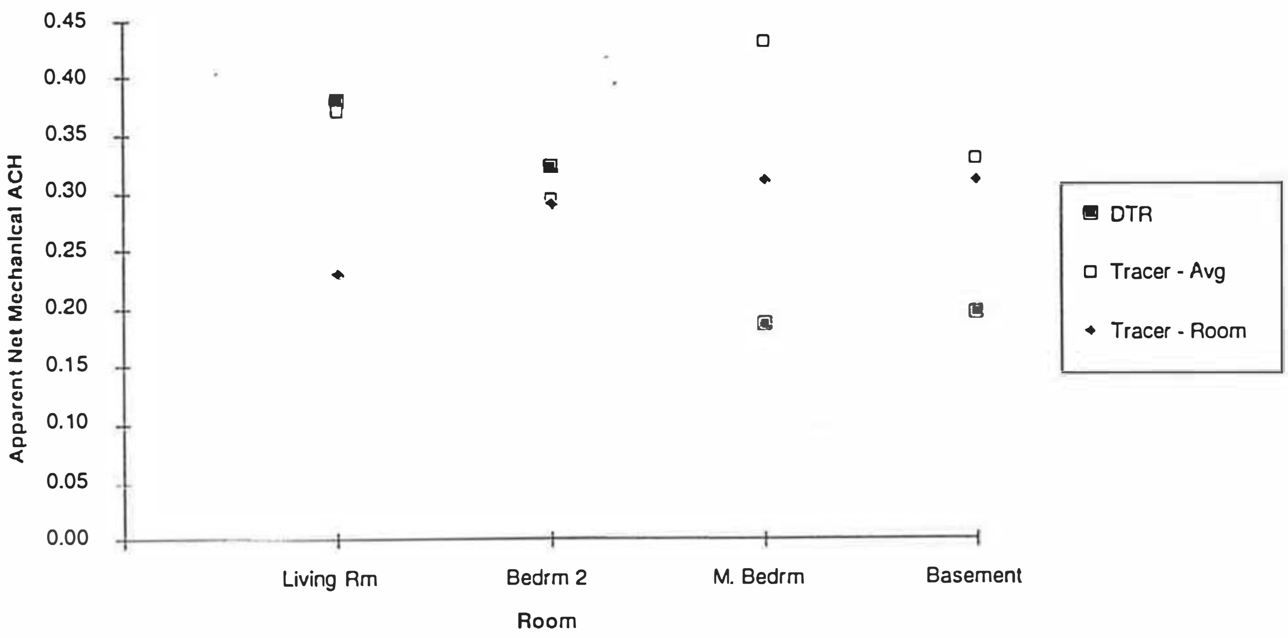
CE0-1



Comparison of Net Mechanical AC/H in CE0-1

This graph compares the same three methods of predicting or measuring and calculating air change rates. In this case, the calculated mechanical ventilation rates using the average natural ventilation rate rather than individual room rates is much closer to that predicted based upon air flow measurements.

CS0-1



Comparison of Net Mechanical AC/H in CS0-1

This graph compares the same three methods of predicting or measuring and calculating air change rates. In this case, the calculated mechanical ventilation rates using the average natural ventilation rate rather and those found using individual room rates were both off by similar amounts from those predicted based upon air flow measurements.

D.4 Adherence to CAN/CSA-F326-M91 Distribution Requirements

Very few deficiencies were noted with respect to the individual room ventilation requirements of the standard CAN/CSA-F326-M91, Residential Mechanical Ventilation Systems. The following table summarizes the locations in which measured air flow rates did not conform to the standard.

Table D.1: Adherence to CAN/CSA-F326-M91 Room-by-Room Distribution Requirements

HOUSE IDENTIFICATION	ROOMS NOT MEETING CAN/CSA-F326-M91	REQUIRED FLOW (L/s)	MEASURED FLOW (L/s)
CF0-1	Kitchen	30	22
CF2-2	Basement	10	6
	Master Bed	10	8
	Kitchen	30	9
CF2-4	Kitchen	30	24
CF2-5	Kitchen	30	21
CF2-6	Master Bed	10	8
	Kitchen	30	24
CE0-1	None		
CE2-3	None		
CE2-5	Basement	14	12
CE2-7	None		
CE2-8	None		
CE2-9	Third Floor Room	5	0
CE2-10	None		
CE8-1	None		
CS0-1	None		
CS2-1	None		
CS2-3	None		
CS2-5	None		
CS2-7	None		
CC2-3	None		
CC2-5	None		

Notes:
1. All furnace fans operated on lowest speed available at time of inspection. This included house CE2-8 where the furnace fan was operating on the lowest speed available from an ACM motor.
2. Most rooms in most houses met the CAN/CSA-F326-M91 air flow requirements on the supply rate option. Rooms in houses with extended and simplified systems met the requirements of CAN/CSA-F326-M91 based upon a combination of fresh air and the amount of recirculation air delivered directly to the given room.
3. Fresh air flow rates to rooms did not consider air lost through duct leakage.
4. In houses with extended and simplified systems where rooms did not meet the CAN/CSA-F326-M91 required rates in the above chart, air flow rates may well have actually been large enough that they did. The CMHC duct test rig used to measure furnace system flow rates provided readings that were significantly lower than actual rates in this range.
5. No attempt was made to consider any reduction in the fresh air supplied to the forced air system by extended HRV systems with indirect supplies to the forced air systems.
6. Kitchen and bathroom fan air flows were not measured because they were not in operation during any testing.

CAN/CSA-F326-M91 requires that fully ducted systems provide 10 L/s to basements and master bedrooms, and 5 L/s to all other rooms. Continuous exhaust air flow rates must be a minimum of 10 L/s in bathrooms and 30L/s in kitchens. The only location where air flow rates were noted to be significantly deficient with respect to these requirements was the kitchen exhaust.

With respect to CAN/CSA-F326-M91, the simplified and extended HRV distribution systems required less fresh air to be delivered directly to each room due to the rate of recirculation air that was also provided. The minimum total supply air flow rates to each room were based upon the fraction of fresh air provided. In general, the simplified and extended systems provided the ventilation air flow rates required by CAN/CSA-F326-M91 to rooms throughout the house.

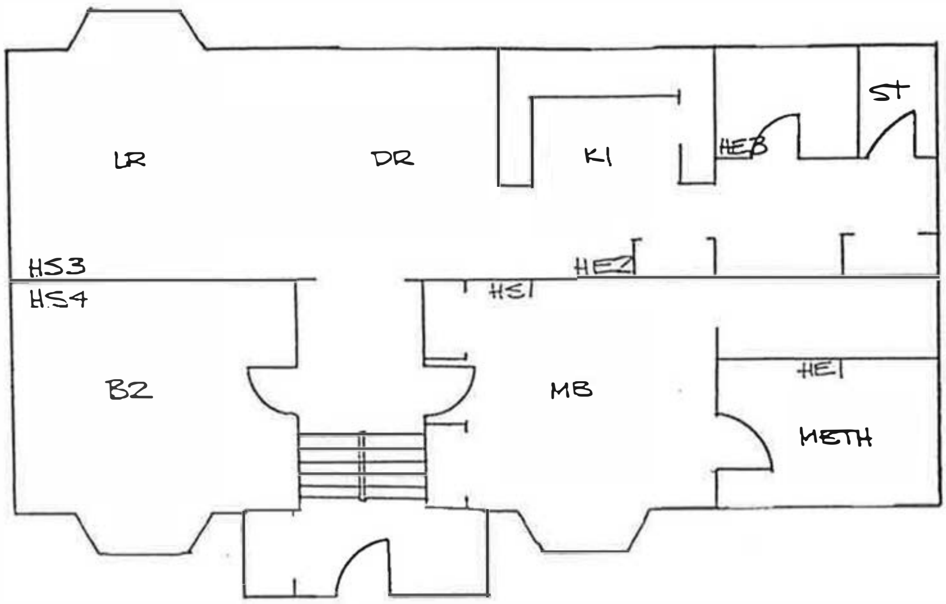
For extended HRV systems where the supply was indirectly connected to the furnace return, calculations to determine whether room air flow rates met CAN/CSA-F326-M91 did not consider fresh air losses at this connection. Tracer gas test results indicated that fresh air losses at indirect connections may be substantial.

D.5 House Plans and Air Flow Measurements

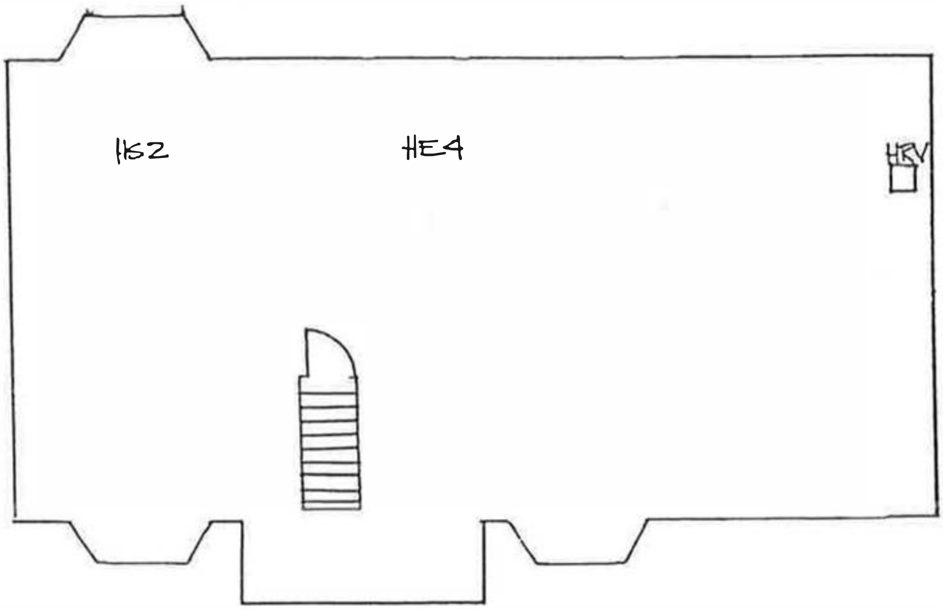
The following pages present the house plan on the left page and the air flow measurements for that house on the right-hand page. In some cases, the house plans required two pages and, in those instances, the air flow measurements are presented on the following pages.

House ID Number: CFO-1
House Volume: 679 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



MAIN FLOOR



BASEMENT

House ID: CF0-1

Notes

1 *HRV balanced at 52 l/s for all tests when HRV was running*
F326 requires 47 l/s - used 52 l/s to ensure flows were high enough at various intakes and outlets
2 *HRV exhausts were taped in the laundry and future basement bathroom for all testing*
3 *Basement supply air flows assumed based on total air flow*
* *Air flow rates measured with duct test rig to be less than 2 l/s*

HRV Supply

Loc. ID	Location	Air Flow Bag Method Trial #1 (l/s)	Air Flow Bag Method Trial #2 (l/s)	Air Flow Bag Method Average (l/s)	Percent	Fresh Air Supply (l/s)	Air Flow Duct Test Rig (l/s)
HS1	M. Bedrm	11.4	14.2	12.8	25%	12.8	*
HS2	Den	6.6	3.3	5.0	10%	5.0	*
HS3	Living Rm	18.9	14.2	16.6	32%	16.5	7
HS4	Basement	15.1	20.3	17.7	34%	17.7	*
Total		52.0	52.0	52.0	100%	52.0	

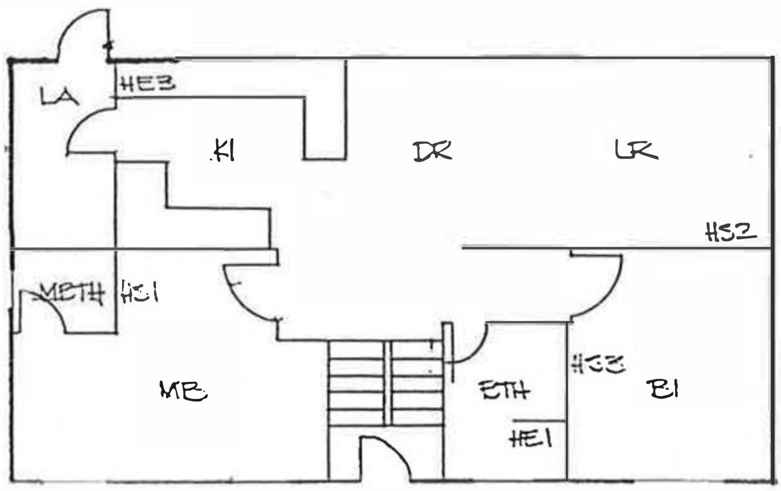
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method Trial #1 (l/s)	Air Flow Bag Method Trial #2 (l/s)	Air Flow Bag Method Average (l/s)	Air Flow Duct Test Rig
HE1	Kitchen	22.2	31.2	26.7	10
HE2	Bathroom	19.4	13.2	16.3	*
HE3	Ensuite	12.8	13.2	13.0	4
Total		**54.4**	**57.7**	**56.1**	

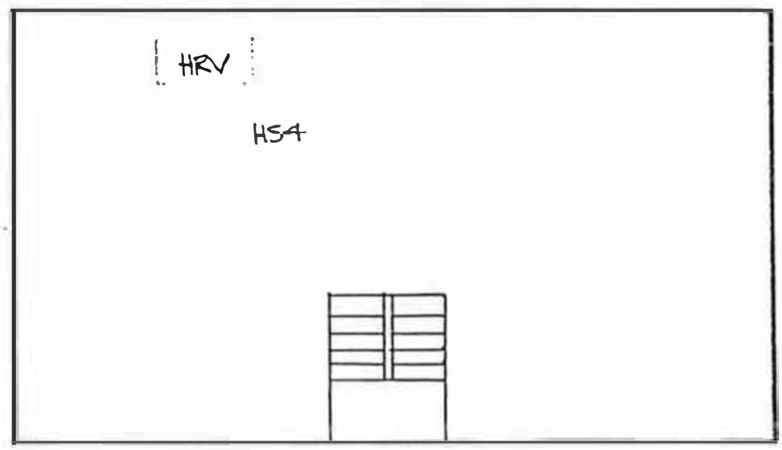
HRV Balance During Testing (l/s) 52

House ID Number: CF2-2
House Volume: 435m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



MAIN FLOOR



BASEMENT

House ID: CF2-2

HRV Supply

Loc. ID	Location	Air Flow Bag Method (l/s)		
LS2	Living Room	14.0	44%	14.9
MS1	Master Bed	8.0	25%	8.5
BS3	2nd Bed	4.0	13%	4.3
BS4	Basement	6.0	19%	6.4
Total		32.0	100%	34.0

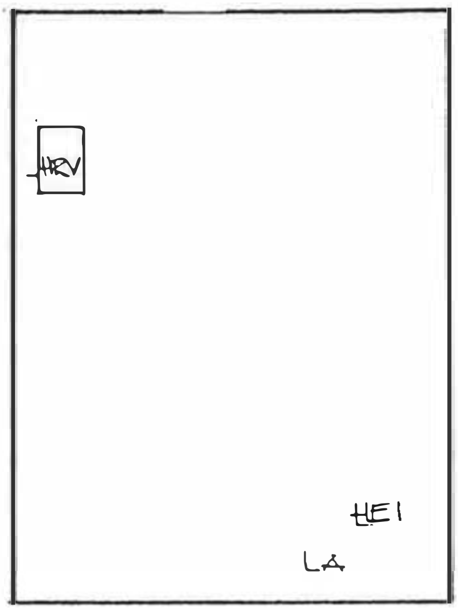
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
BE1	Main Bath	14.0
BE2	Master Bath	11.0
KE3	Kitchen	9.0
Total		34.0

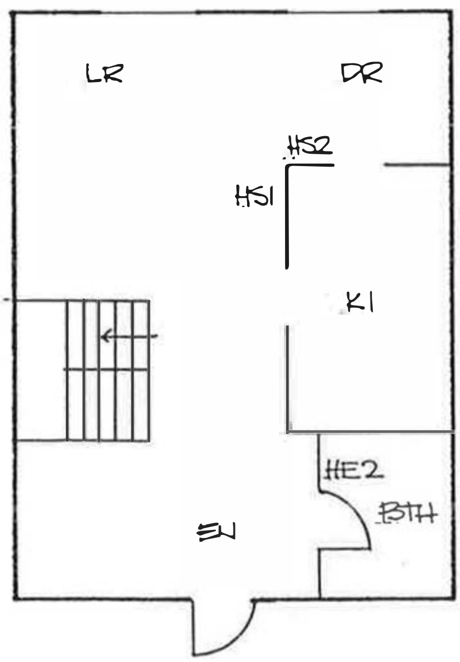
HRV Balance During Testing (l/s) 34

House ID Number: CF2-4
House Volume: $394 m^3$

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



BASEMENT



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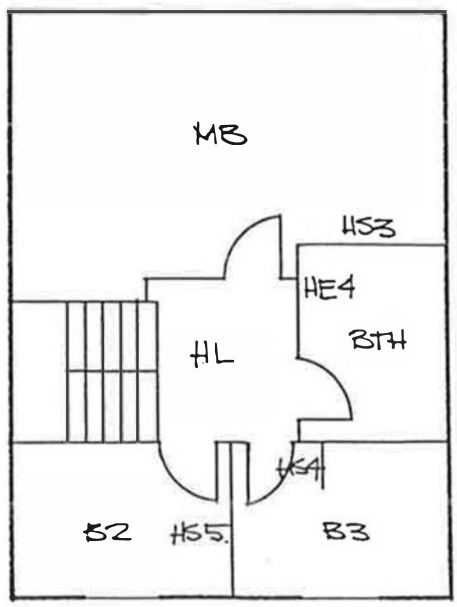


SECOND FLOOR

House ID: CF2-4

HRV Supply

Loc. ID	Location	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)	Expected ACH (no acct for losses)
S1	Living Room	7.0	13%	7.0	0.70
S2	Dining Room	9.0	16%	9.0	1.44
S3	M. Bed	11.0	20%	11.0	0.69
S4	3rd Bed	14.0	25%	14.0	2.48
S5	2nd Bed	14.0	25%	14.0	2.30
Total		55.0	100%	55.0	0.51

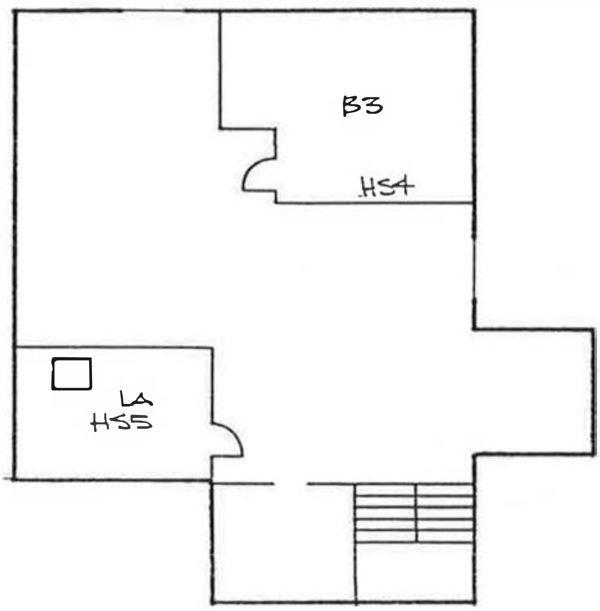
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
E1	Basement	20.0
E2	Main Bath	16.0
E3	Kitchen	24.0
E4	Upst. Bath	16.0
Total		76.0

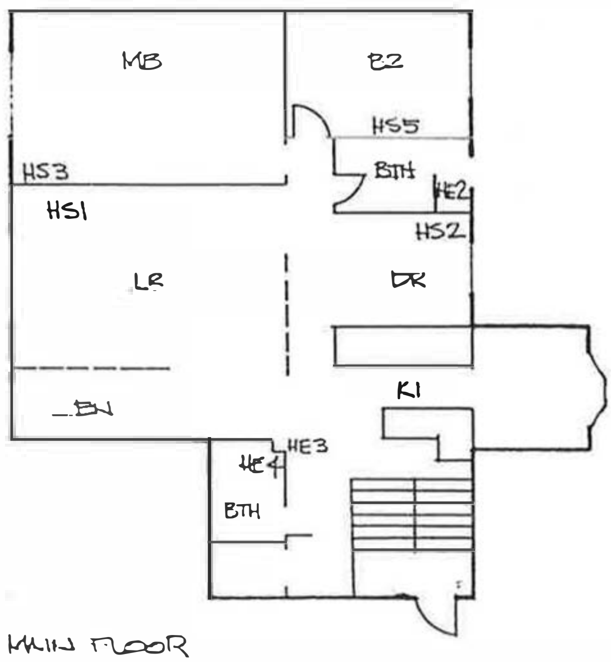
HRV Balance During Testing (l/s 55

House ID Number: CE2-5
House Volume: 621 m^3

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



BASEMENT



MAIN FLOOR

House ID: CF2-5

HRV Supply

Loc. ID	Location	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
BS1	Master Bed	9.4	29%	15.2
BS2	2nd Bed	5.4	17%	8.7
DS3	Dining Room	5.4	17%	8.7
BS4	Basement	7.5	23%	12.1
LS5	Living Room	4.5	14%	7.3
Total		32.2	100%	52.0

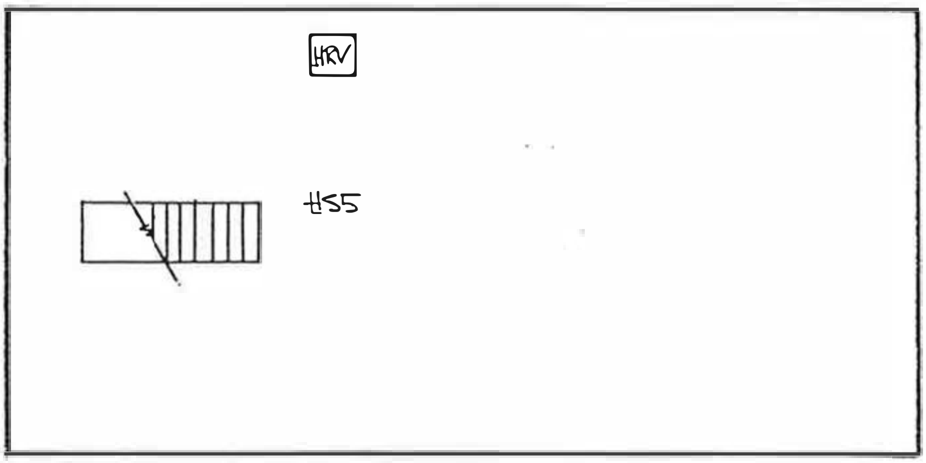
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
BE1	Main Bath	35.3
KE2	Kitchen	21.0
BE3	Entrance Bath	18.8
Total		75.1

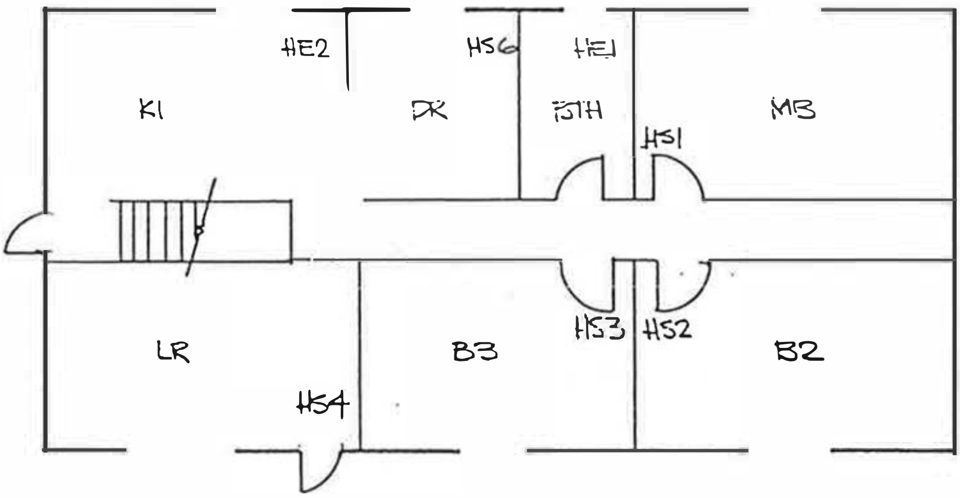
HRV Balance During Testing (l/s) 52

House ID Number: CF2-6
House Volume: 425 m³

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



BASEMENT



MAIN FLOOR

House ID: CF2-6

HRV Supply

Loc. ID	Location	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
MS1	M. Bed	6.6	18%	7.9
BS2	2nd Bed	5.0	13%	6.0
BS3	3rd Bed	5.0	13%	6.0
LS4	Living Room	5.0	13%	6.0
BS5	Basement	8.3	22%	10.0
ES6	Eating Area	7.5	20%	9.0
Total		37.4	100%	45.0

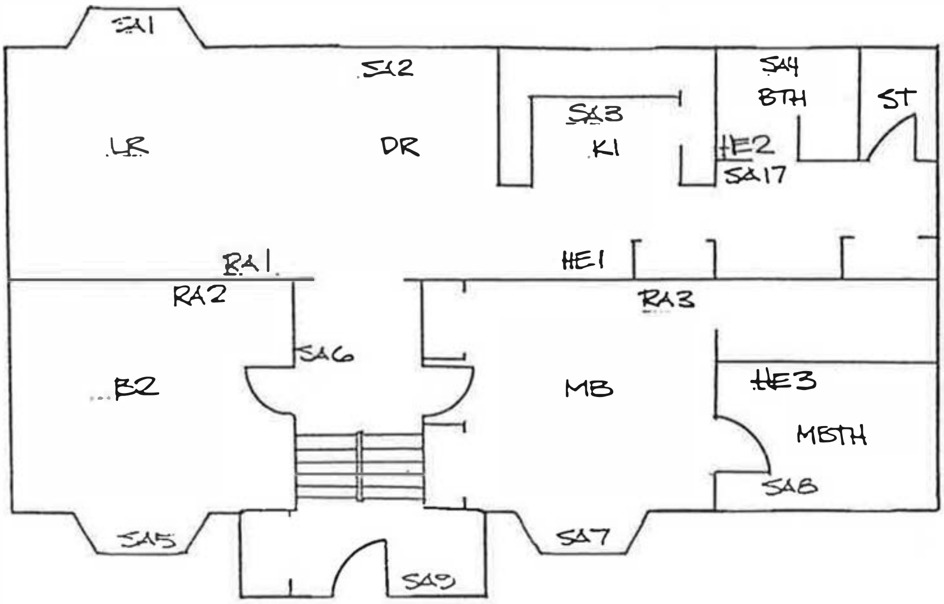
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
BE1	Bathroom	25.4
KE2	Kitchen	21.0
Total		46.4

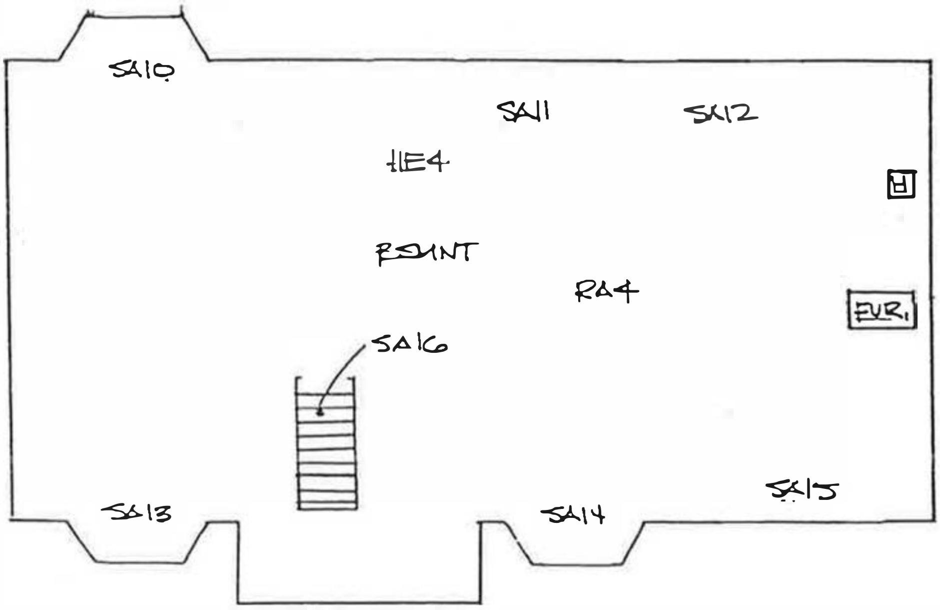
HRV Balance During Testing (l/s) 45

House ID Number: CEO-1
House Volume: 679 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



MAIN FLOOR



BASEMENT

House ID: CE0-1

FURNACE

Supply Air

Loc. ID	Location	Duct Test Rig Air Flow (l/s)	Percent (%)	Fresh Air Supply (l/s)
Total				52.0
SL1	Living Rm	37.4	9%	4.7
SD2	Dining Rm	32.6	8%	4.1
SK3	Kitchen	24.6	6%	3.1
SW4	Bathrm	18.5	4%	2.3
SB5	Bedrm 2	36.4	9%	4.5
SH6	Hallway	28.5	7%	3.5
SB7	M. Bedrm	21.8	5%	2.7
SW8	M. Bath	24.2	6%	3.0
	Walk-in Closet		0%	0.0
SE9	Entrance	18.5	4%	2.3
SC17	Laundry	25.4	6%	3.2
SX10	Basement	22.2	36%	18.7
SX11	Basement	19.2		
SX12	Basement	24.0		
SX13	Basement	24.0		
SX14	Basement	19.2		
SX15	Basement	22.2		
SX16	Basement	19.2		
Total		417.9	100%	52.0

Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
RL1	Living Rm	58.2
RB2	Bedrm 2	58.8
RB3	M. Bedrm	84.8
RX4	Basement	24.0
RX5	Basement	35.0
Total		**260.8**

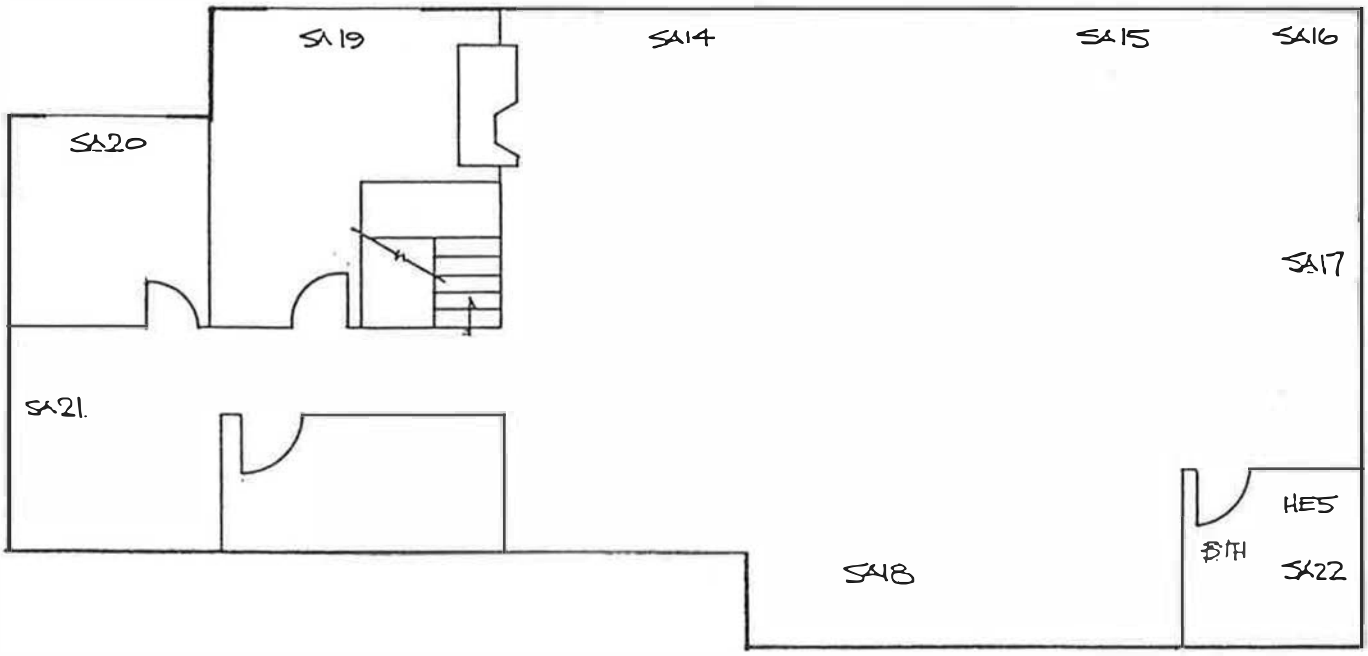
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
HE1	Kitchen	26.7
HE2	Bathroom	16.3
HE3	Ensuite	13.0
Total		56.1

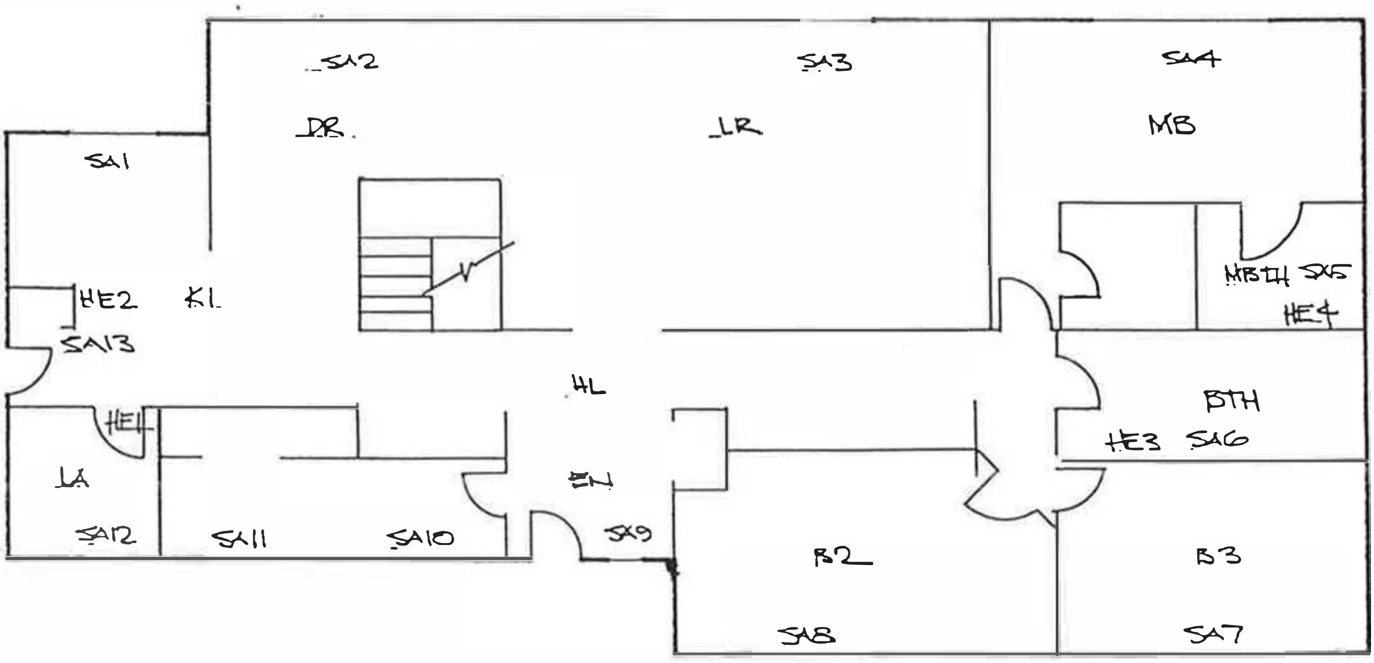
HRV Balance During Testing (l/s) 52

House ID Number: CE2-3
House Volume: 1060m³

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



BASEMENT



MAIN FLOOR

House ID: CE2-3

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)
ES1	Eating Area	21.0	6%	3.5
DS2	Dining Room	13.0	3%	2.2
LS3	Living Room	26.0	7%	4.4
MS4	Master Bed	26.0	7%	4.4
BS5	Ensuite	18.0	5%	3.0
BS6	Main Bath	23.0	6%	3.9
BS7	3rd Bed	26.0	7%	4.4
BS8	2nd Bed	26.0	7%	4.4
FS9	Foyer	16.0	4%	2.7
SS10	Sunroom	15.0	11%	6.9
SS11	Sunroom	26.0		
LS12	Laundry	20.0	5%	3.4
KS13	Kitchen	24.0	6%	4.1
B14	Basement	11.0	26%	16.7
B15	Basement	11.0		
B16	Basement	11.0		
B17	Basement	11.0		
B18	Basement	11.0		
B19	Basement	11.0		
B20	Basement	11.0		
B21	Basement	11.0		
B22	Basement	11.0		
Total		379.0	100%	64.0

FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
SR1	Sunroom	46.0
SR2	Sunroom	46.0
BR3	2nd Bed	39.0
BR4	3rd Bed	29.0
MR5	Master Bed	23.0
LR6	Living Room	43.0
BR7	Basement	96.0
Total		322.0

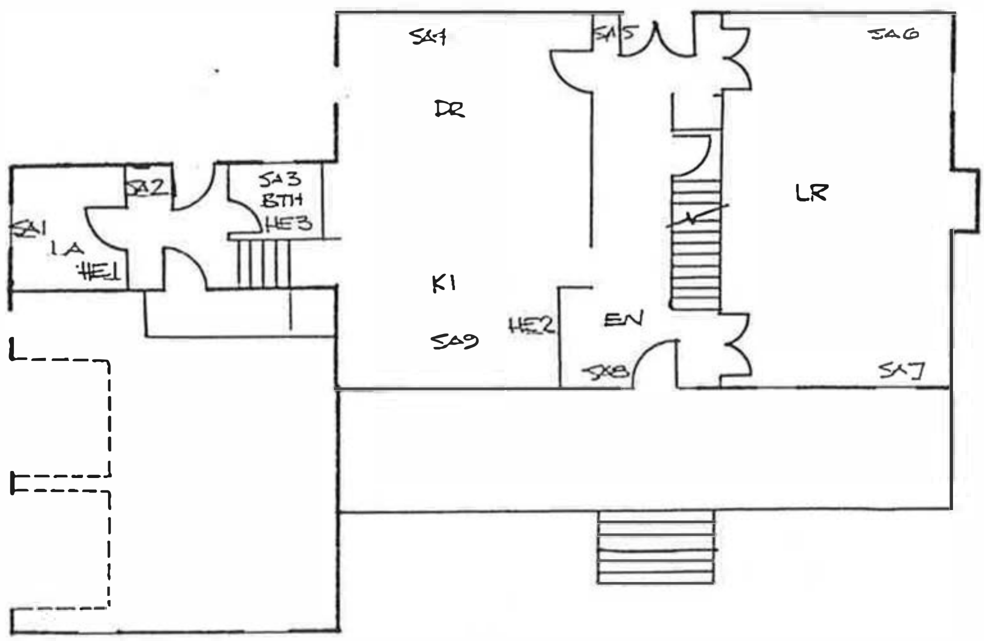
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
LE1	Laundry	18.0
KE2	Kitchen	20.0
BE3	Main Bath	14.0
ME4	Master Bath	14.0
BE4	Base Bath	16.0
Total		82.0

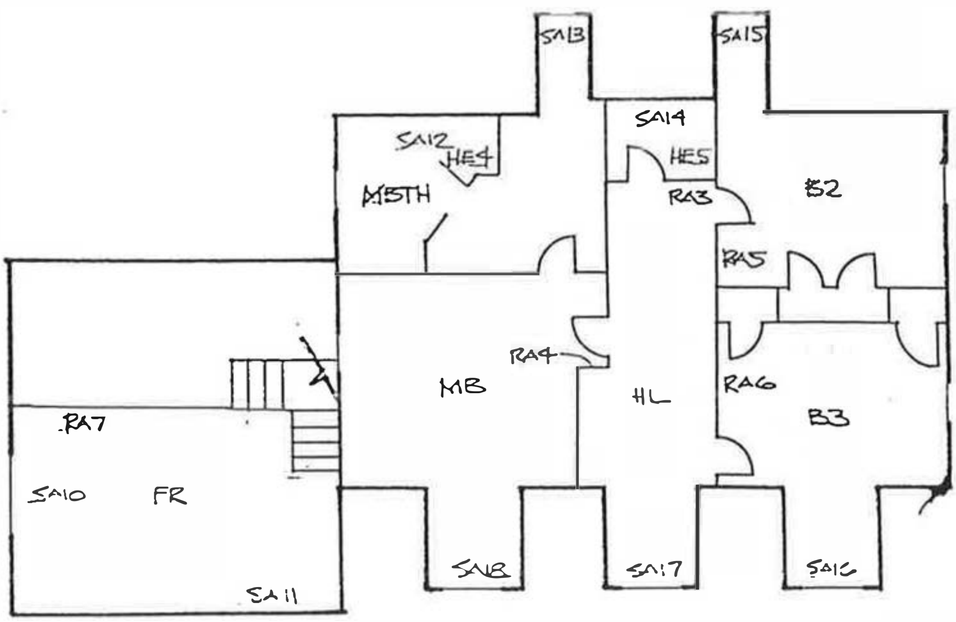
HRV Balance During Testing (l/s) 64

House ID Number: GE2-5
House Volume: 924 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



MAIN FLOOR



House ID: CE2-5

FURNACE

Supply Air

Loc. ID	Location	Duct Test Rig Air Flow (l/s)	Percent (%)	Fresh Air Supply (l/s)
BS1	Basement	3.0	7%	4.7
BS2	Basement	3.0		
BS3	Basement	3.0		
BS4	Basement	3.0		
LS1	Laundry	3.0	2%	1.2
ES2	Garage Ent.	12.0	7%	4.7
BS3	Entry Bath	10.0	6%	3.9
ES4	Eating Area	10.0	6%	3.9
FS5	Rear Foyer	10.0	6%	3.9
LS6	Living Room	14.0	13%	8.5
LS7	Living Room	8.0		
LS8	Front Foyer	10.0	6%	3.9
KS9	Kitchen	10.0	6%	3.9
FS10	Family Room	9.0	10%	6.6
FS11	Family Room	8.0		
BS12	Master Bath	8.0	5%	3.1
CS13	Master Closet	6.0	4%	2.3
BS14	Main Bath	4.0	2%	1.6
BS15	2nd Bed	8.0	5%	3.1
BS16	1st Bed	10.0	6%	3.9
HS17	Hallway	9.0	5%	3.5
BS18	Master Bed	9.0	5%	3.5
Total		170.0	100%	66.0

Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
LR1	Living Room	50
ER2	Entrance	4
HR3	Hall(near bath)	35
BR4	Master Bed	23
BR5	2nd Bed	*20*
BR6	1st Bed	*17*
FR7	Family Room	*16*
Total		165

**italicized values are from bag method*

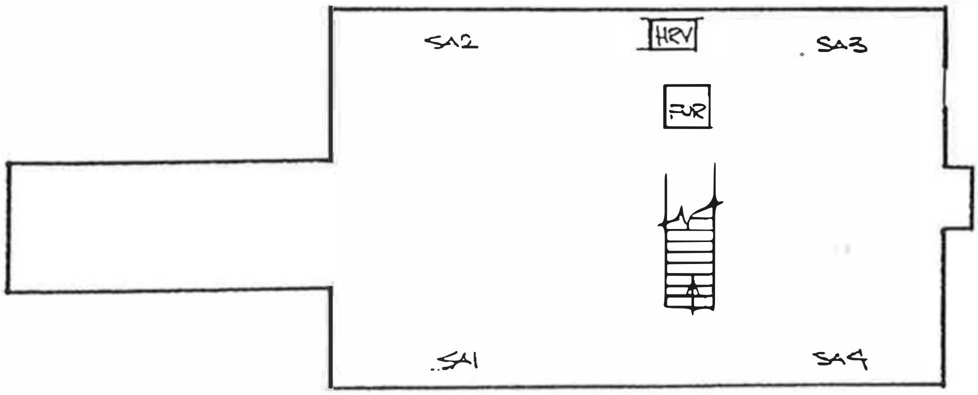
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
LE1	Laundry	17
KE2	Kitchen	39
BE3	Main Floor Bath	20
BE4	M. Bath	22
BE5	Main Bath	22
Total		120

HRV Balance During Testing (l/s) 66

House ID Number: CE2-5
House Volume: 924 m³

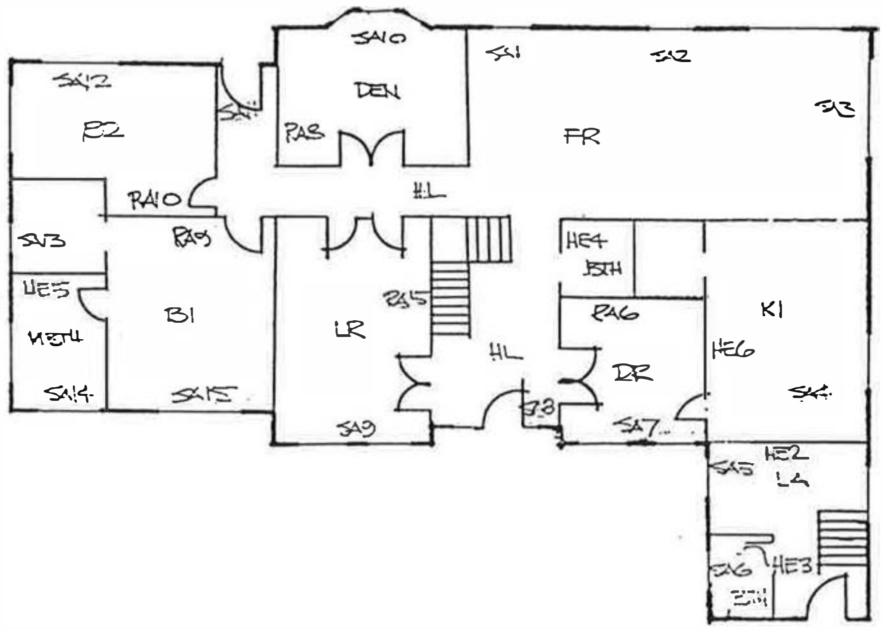
Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



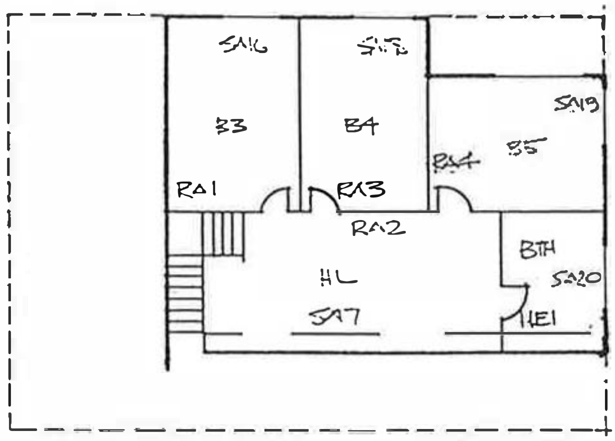
BASEMENT

House ID Number: GE2-7
House Volume: 1635 m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



MAIN FLOOR



SECOND FLOOR

House ID: CE2-7

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent (%)	Fresh Air Supply (l/s)
SF1	Family Room	8.0	5%	3.3
SD2	Dinette	8.0	9%	6.3
SD3	Dinette	7.0		
SK4	Kitchen	7.0	4%	2.9
SL5	Laundry	6.0	4%	2.5
SB6	Main Floor Bath	5.0	3%	2.1
SD7	Dining	6.0	4%	2.5
SH8	Hall/Entrance	7.0	4%	2.9
SL9	Living Room	9.0	6%	3.8
SD10	Den	9.0	6%	3.8
SH11	Hall (back dr)	8.0	5%	3.3
SH12	2nd Bed Main	10.0	6%	4.2
SC13	1st Bed Closet	9.0	6%	3.8
SE14	Ensuite	8.0	5%	3.3
SB15	1st Bed	9.0	6%	3.8
SB16	3rd Bed	6.0	4%	2.5
SH17	Hallway	6.0	4%	2.5
SB18	4th Bed	6.0	4%	2.5
SB19	5th Bed	6.0	4%	2.5
SB20	Bathroom	5.0	3%	2.1
SB21	Basement	2.0	8%	5.4
SB22	Basement	*3.0*		
SB23	Basement	*3.0*		
SB24	Basement	*0.0*		
SB25	Basement	*1.0*		
SB26	Basement	*3.0*		
SB27	Basement	*1.0*		
Total		158.0	100%	66.0

FURNACE
Return Air

Loc. ID	Location	Air Flow Bag Method (l/s)	
EB1	3rd Bed	14.0	
EB2	Hallway	20.0	
EB3	4th Bed	13.0	
EB4	Bed 5	18.0	
EL5	Living Room	*8.0*	**Italicized values are*
EL6	Dining Room	20.0	*values from bag method*
EL8	Den	*20.0*	
EL9	1st Bed	*32.0*	
EL10	2nd Bed	32.0	
Total		177.0	

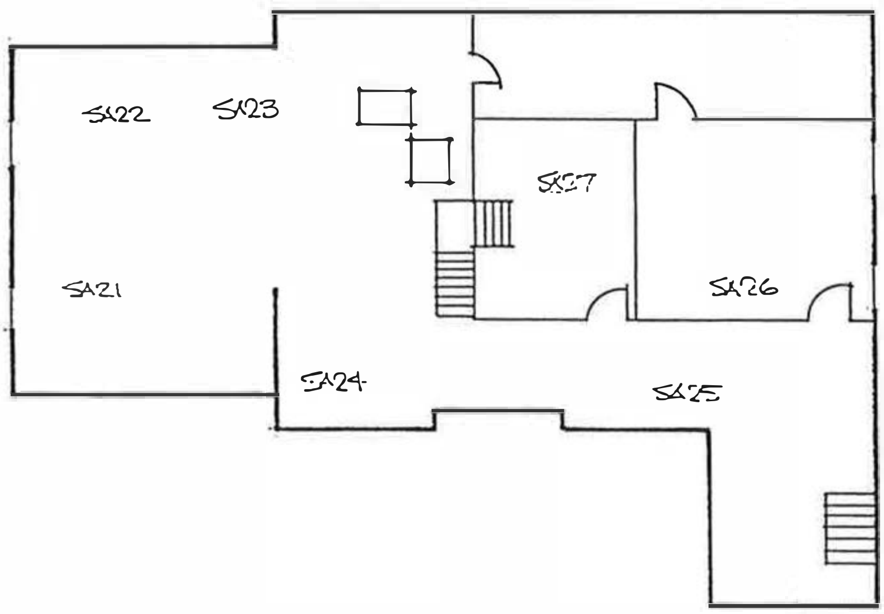
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)	
HB1	2nd FLoor Bath	18.0	
HE2	Laundry	14.0	
HE3	Bath (Laundry)	18.0	
HE4	Powder	28.0	
HE5	Ensuite	24.0	
HE6	Kitchen	*20.0*	*Estimate*
Total		122.0	

HRV Balance During Testing (l/s) 66

House ID Number: CE4-1
House Volume: 1635 m^3

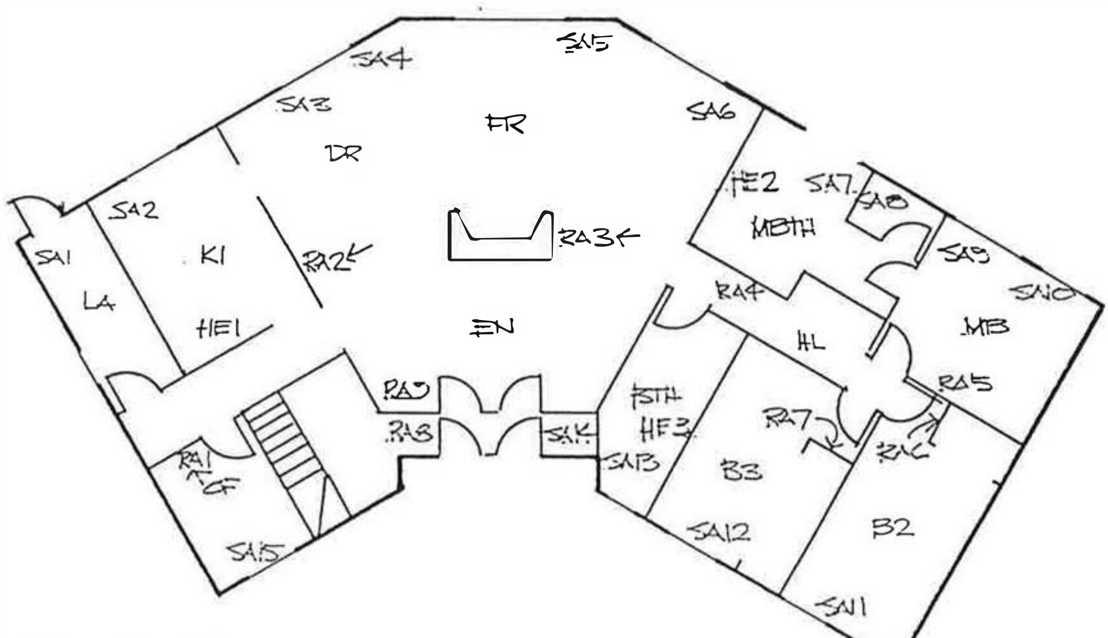
Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



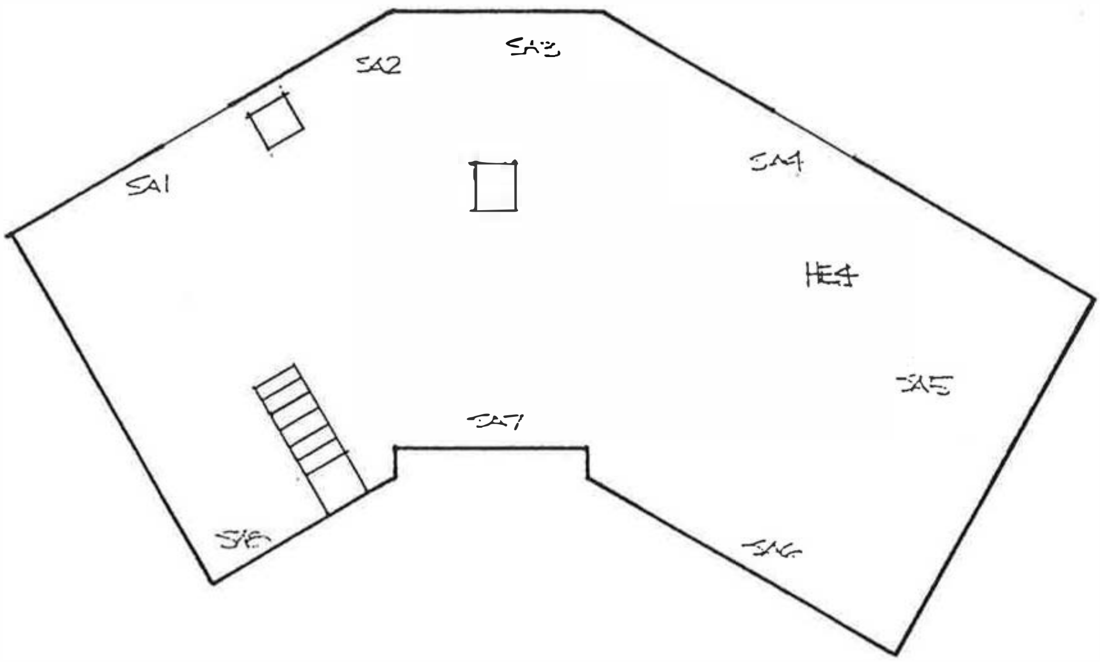
BASEMENT

House ID Number: CE2-8
House Volume: 1022 m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



MAIN FLOOR



BASEMENT

House ID: CE2-8

FURNACE

Supply Air

Loc. ID	Location	ECM Motor Speed	Duct Test Rig Air Flow (l/s)	Percent (%)	Fresh Air. Supply (l/s)	Bag Method Air Flow (l/s)	Percent (%)	Fresh Air Supply (l/s)	Expected ACH
Total					63.0			63.0	
BS1	Basement		4.6	27%	17.0	8.0	27%	17.0	0.12
BS2	Basement		4.6			8.0			
BS3	Basement		4.0			7.0			
BS4	Basement		4.0			7.0			
BS5	Basement		5.2			9.0			
BS6	Basement		4.6			8.0			
BS7	Basement	*Factor for*	5.2			9.0			
BS8	Basement	*Basement DTR*	4.0			7.0			
LS1	Laundry	*0.58*	5.0	4%	2.3	9.0	4%	2.4	0.32
KS2	Kitchen		10.0	7%	4.7	10.0	4%	2.7	0.24
DS3	Dining		6.0	11%	7.0	9.0	10%	6.2	0.22
DS4	Dining		9.0			14.0			
FS5	Living		9.0	7%	4.2	14.0	6%	3.8	0.13
FS6	Living		6.0			9.0			
WS7	Ensuite		5.0	4%	2.3	9.0	4%	2.4	0.40
CS8	Master Closet		5.0	4%	2.3	11.0	5%	3.0	0.74
MS9	Master Bed		6.0	10%	6.6	11.0	11%	7.0	0.66
MS10	Master Bed		8.0			15.0			
BS11	Bed 2		7.0	5%	3.3	11.0	5%	3.0	0.30
BS12	Bed 3		7.0	5%	3.3	16.0	7%	4.3	0.53
BS13	Main Bath		6.0	4%	2.8	14.0	6%	3.8	1.00
BS14	Entrance		3.0	2%	1.4	9.0	4%	2.4	0.17
BS15	Office		6.0	4%	2.8	9.0	4%	2.4	0.39
Total		329.0	134.3	96%	60.2	233.0	96%	60.6	

Return Air

Loc. ID	Location	Air Flow (l/s)	Air Flow D.T.R. (l/s)	Air Flow Bag Method (l/s)
OR1	Office	has an 1/2 hp	17.0	23.0
DR2	Dining	ECM motor	13.3	23.0
FR3	Family	speed setting	21.9	38.0
NR4	Hallway	for 700 cfm	28.0	36.0
MR5	Master Bd		14.4	25.0
BR6	Bed 2		13.3	23.0
BR7	Bed 3		11.0	23.0
BR8	Entrance		22.0	38.0
BR9	Entrance		18.0	28.0
Total		329.0	158.8	257.0

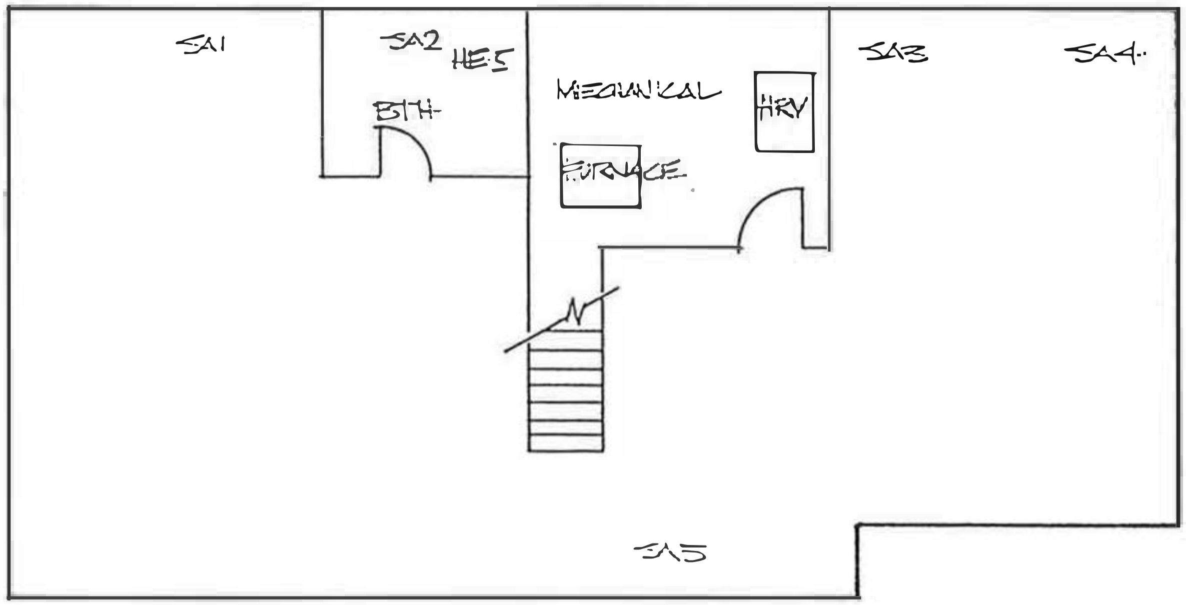
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
KE1	Kitchen	20
ME2	Master Bath	13
BE3	Main Bath	12
DE4	Bmnt. Darkrm.	16
Total		61

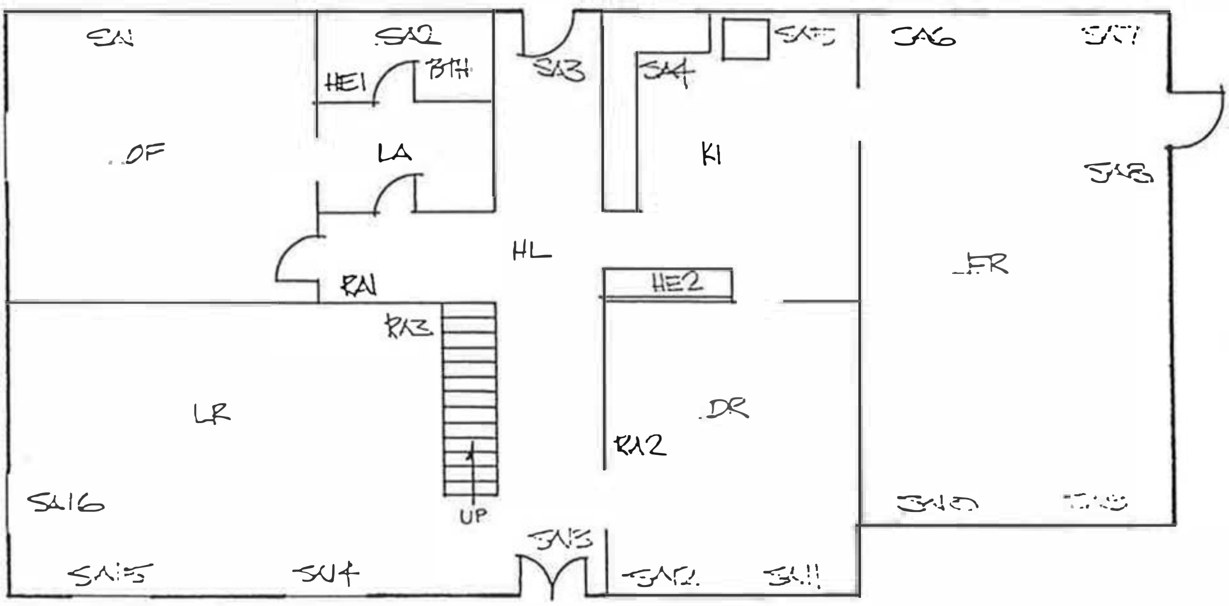
HRV Balance During Testing (l/s) 64

House ID Number: EE2-9
House Volume: 1320m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



BASEMENT



House ID: CE2-9

FURNACE
Supply Air

Loc. ID	Location	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
OS1	Main Fl. Office	8.0	3%	1.6
BS2	Main Fl. Bath	11.0	4%	2.2
HS3	Rear Hall	8.0	3%	1.6
KS4	Kitchen	7.0	3%	1.4
ES5	Eating Area	7.0	3%	1.4
FS6	Family Room	6.0	15%	8.0
FS7	Family Room	6.0		
FS8	Family Room	9.0		
FS9	Family Room	7.0		
FS10	Family Room	11.0		
DS11	Dining Room	11.0	7%	3.9
DS12	Dining Room	8.0		
ES13	Front Entry	8.0	3%	1.6
LS14	Living Room	6.0	10%	5.5
LS15	Living Room	8.0		
LS16	Living Room	13.0		
BS17	M. Bath	8.0	3%	1.6
BS18	Main Bath	8.0	3%	1.6
BS19	3rd Bed	9.0	3%	1.8
BS20		9.0	3%	1.8
BS21	4th Bed	9.0	3%	1.8
BS22	5th Bed	6.0	5%	2.9
BS23	5th Bed	8.0		
HS24	Hallway	9.0	3%	1.8
LS25	Loft Area	0.0	0%	0.0
LS26	Loft Area	0.0		
LS27	Loft Area	0.0		
LS28	Loft Area	0.0		
LS29	Loft Area	0.0		
LS30	Loft Area	0.0		
BS1	Basement	0.0	0%	0.0
BS2	Base Bath	9.0	3%	1.8
BS3	Basement	11.0	20%	10.4
BS4	Basement	16.0		
BS5	Basement	24.0		
Total		260.0	100%	53.0

FURNACE
Return Air

Loc. ID	Location	Air Flow Bag Method (l/s)
HR1	Hallway	71.0
DR2	Dining Room	71.0
LR3	Living Room	47.0
BR4	Master Bed	47.0
HR5	Hallway	47.0
BR6	3rd Bed	47.0
BR7	4th Bed	14.0
BR8	5th Bed	20.0
Total		364.0

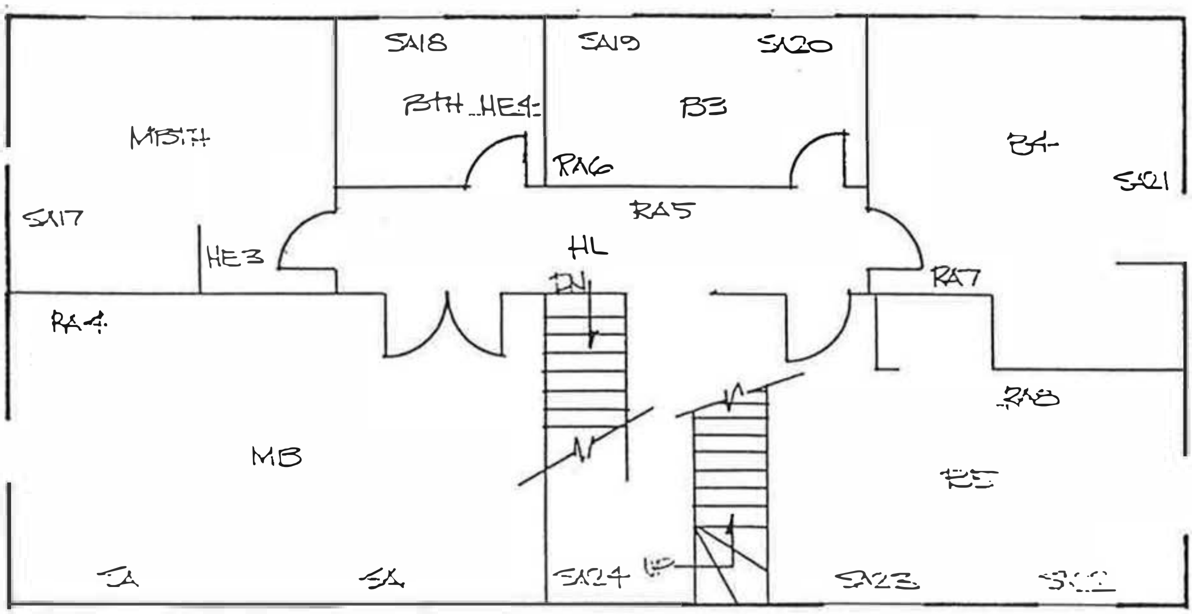
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
BE1	Bath	14.0
KE2	Kitchen	14.0
BE3	Master Bath	13.0
BE4	Main Bath	13.0
BE5	Base Bath	14.0
Total		68.0

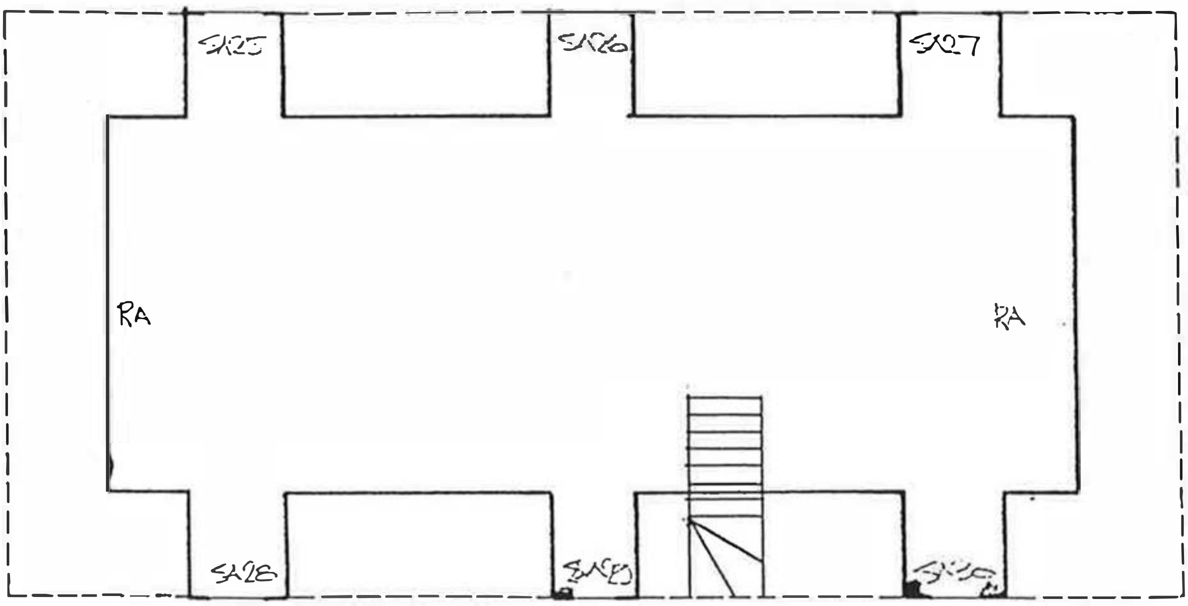
HVR Balance During Testing (l/s) 53

House ID Number: GE2-9
House Volume: 1022 m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



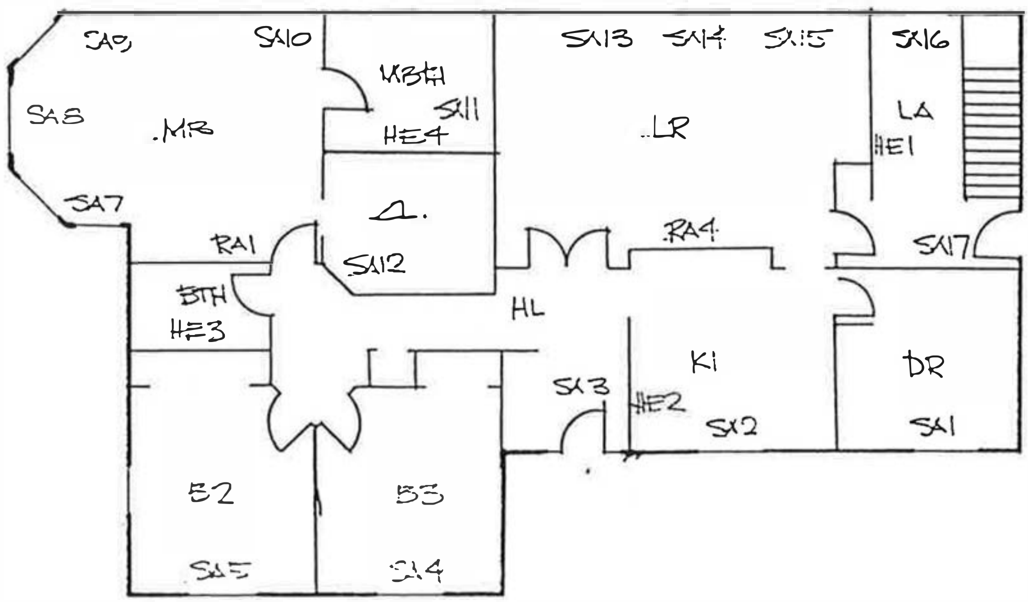
SECOND FLOOR



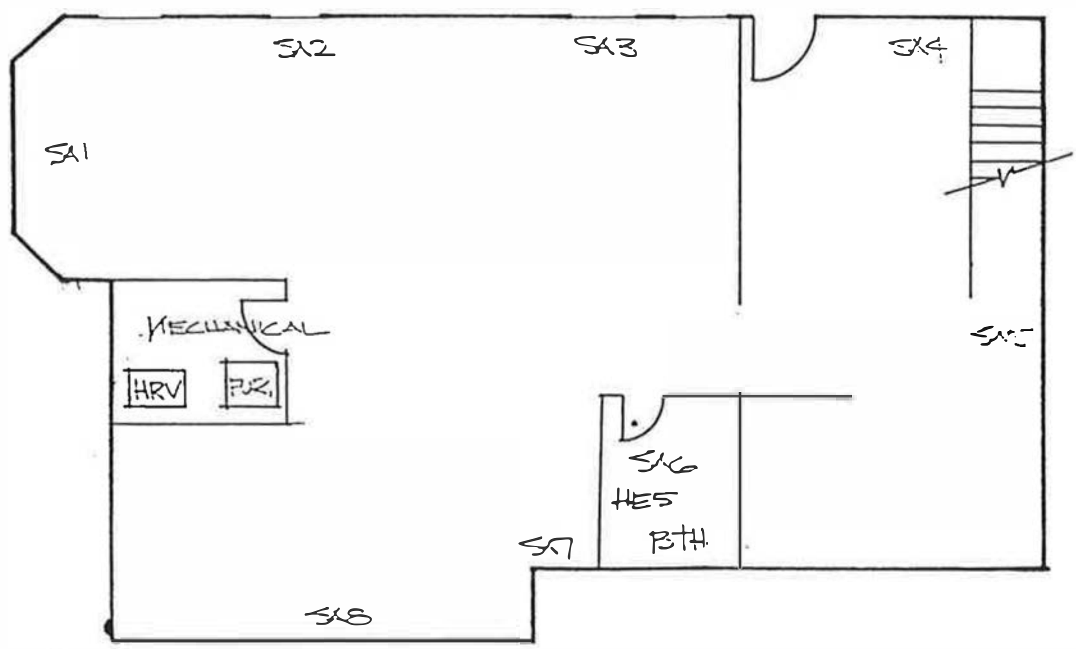
THIRD FLOOR

House ID Number: CE2-10
House Volume: 871m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



MAIN FLOOR



House ID: CE2-10

FURNACE
Supply Air

Loc. ID	Location	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
BS1	Basement	9.0	25%	17.7
BS2	Basement	4.0		
BS3	Basement	6.0		
BS4	Basement	14.0		
BS5	Basement	24.0		
BS6	Basement	7.0		
BS7	Basement	7.0		
BS8	Basement	7.0		
DS1	Eating Area	11.0	4%	2.5
KS2	Kitchen	*10.0*	3%	2.3
FS3	Foyer	7.0	2%	1.6
BS4	2nd Bed	20.0	6%	4.5
BS5	1st Bed	*20.0*	6%	4.5
BS6	Bath	20.0	6%	4.5
MS7	Master Bed	18.0	25%	17.7
MS8	Master Bed	18.0		
MS9	Master Bed	18.0		
MS10	Master Bed	24.0		
BS11	Ensuite Bath	10.0	3%	2.3
CS12	Master Closet	*8.0*	3%	1.8
LS13	Living Room	12.0	11%	7.5
LS14	Living Room	12.0		
LS15	Living Room	9.0		
LS16	Laundry	7.0	2%	1.6
ES17	Entrance	11.0	4%	2.5
Total		313.0	100%	71.0

FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
MR1	Master Bed	53
BR2	1st Bed	37
BR3	3rd Bed	Dobermans
LR4	Living Room	Heavy Furnishings
Total		Incomplete

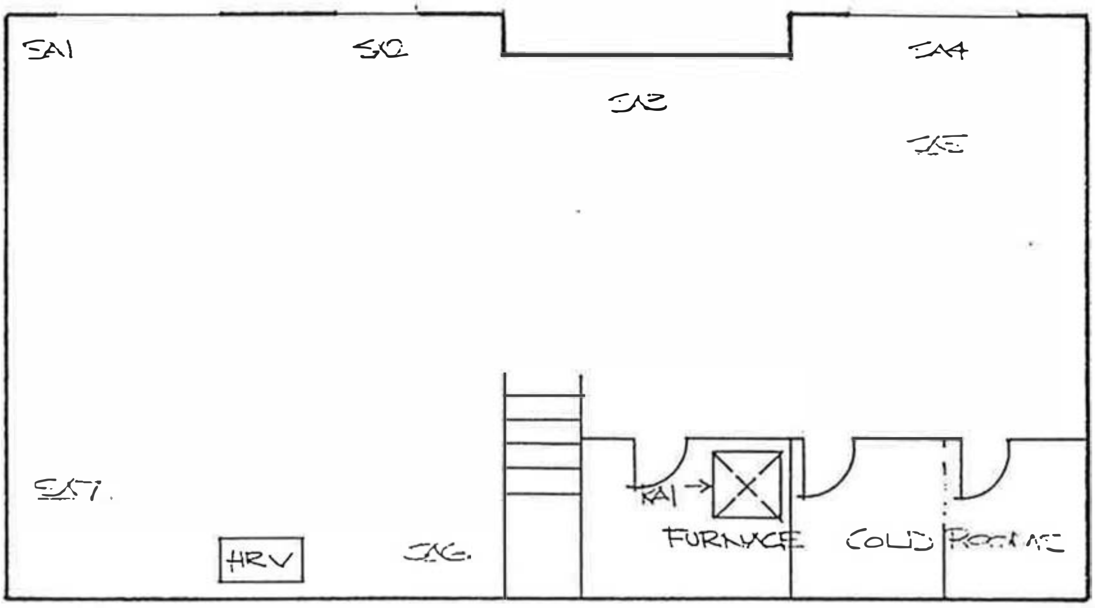
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
LR1	Laundry	6.6
KE2	Kitchen	24.6
BE3	Main Bath	19.7
BE4	Master Bath	19.4
BE5	Base Bath	8.2
Total		78.5

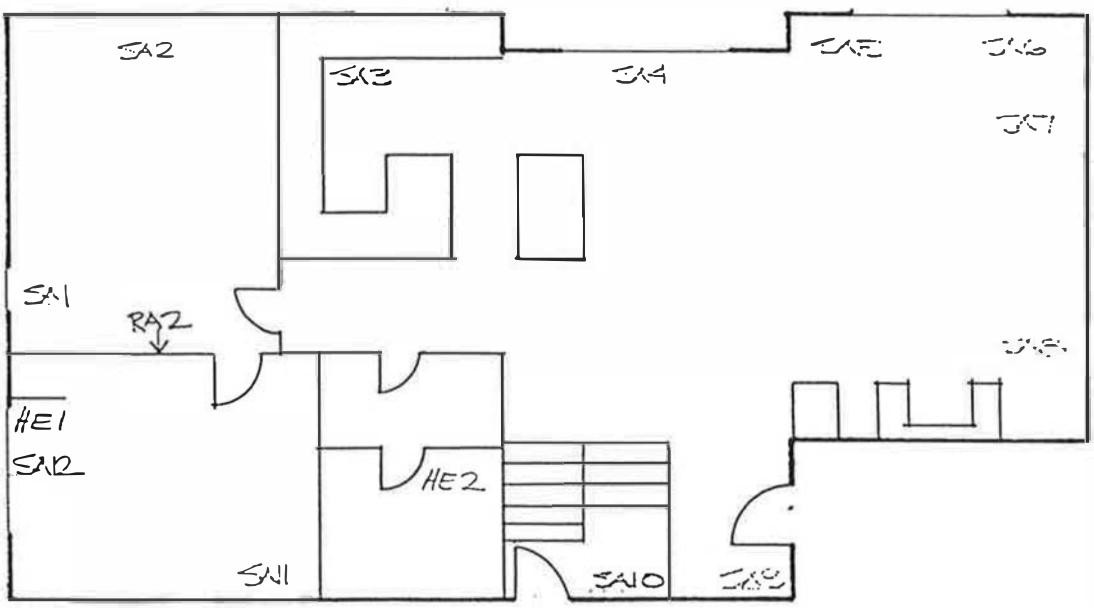
HRV Balance During Testing (l/s) 71

House ID Number: CE8-1
House Volume: 1027 m^3

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



BASEMENT



MAIN FLOOR

House ID: CE8-1

FURNACE
Supply Air

Loc. ID	Location	Air Flow* Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)
BS1	Basement	*3.0*	11%	6.9
BS2	Basement	*3.5*		
BS3	Basement	*6.5*	*Italicized D.T.R air flows	
BS4	Basement	*3.0*	based on bag method*	
BS5	Basement	*2.8*		
BS7	Basement	*2.5*		
MS1	Master Bed	16.0	13%	8.1
MS2	Master Bed	9.0		
KS3	Kitchen	10.0	5%	3.2
DS4	Dining Room	10.0	5%	3.2
LS5	Living Room	40.0	29%	17.6
LS6	Living Room	9.0		
LS7	Living Room	2.5		
LS8	Living Room	2.7		
ES9	Entrance	2.3	1%	0.7
SS10	Stairwell	4.3	2%	1.4
MBS11	Master Bath	10.0	10%	6.2
MBS12	Master Bath	9.0		
BS13	Bedroom	6.0	3%	1.9
LS14	2nd Fl. Loft	8.0	4%	2.6
SS15	2nd Fl. Storage	6.0	3%	1.9
OS16	2nd Fl. Office	6.0	9%	5.2
OS17	2nd Fl. Office	10.0		
BS18	2nd Fl. Bath	6.0	3%	1.9
Total		188.1	100%	61.0

FURNACE
Return Air

Loc. ID	Location	Air Flow Bag Method (l/s)
BR1	Basement	142.0
MR2	Master Bed	*Not measurable*
BR3	Master Bed	*Not measurable*
LR4	Liv. Rm (High)	*Not measurable*
OR5	Office (Low)	28.3
Total		**Incomplete**

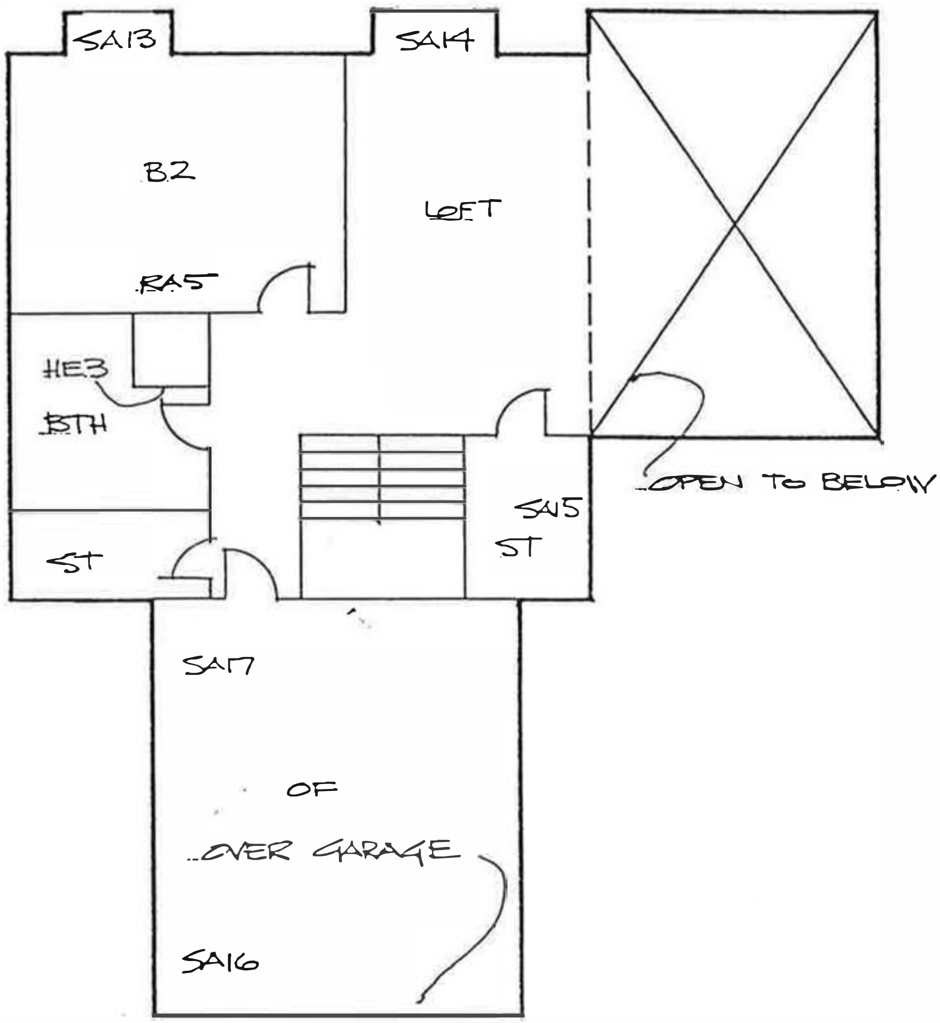
HRV Exhaust

Loc. ID	Location	Air Flow Bag Method (l/s)
ME1	Master Bath	28.3
LE2	Laundry	28.3
BE3	2nd Fl. Bath	20.2
Total		76.8

HRV Balance During Testing (l/s) 61

House ID Number: CEE-1
House Volume: 1027 m³

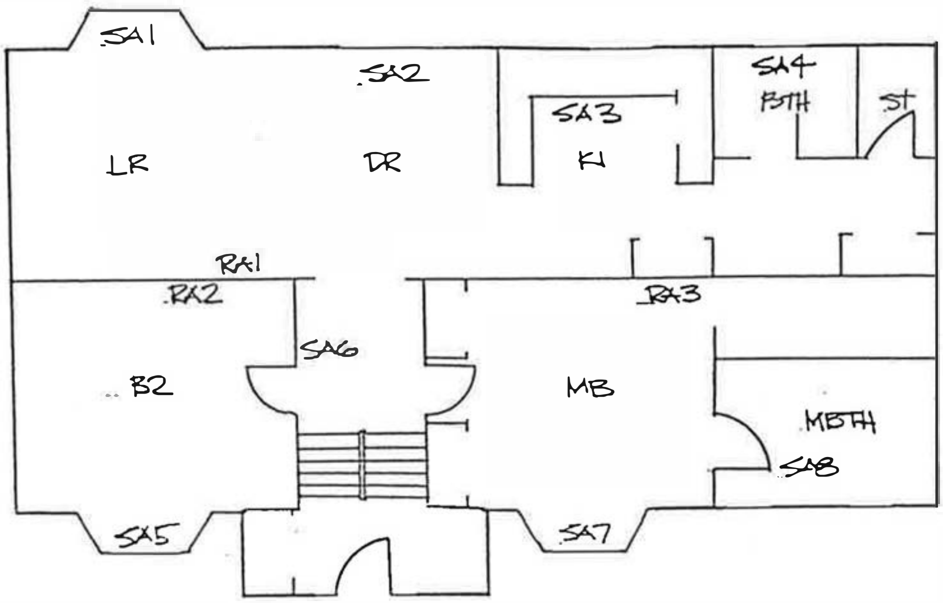
Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



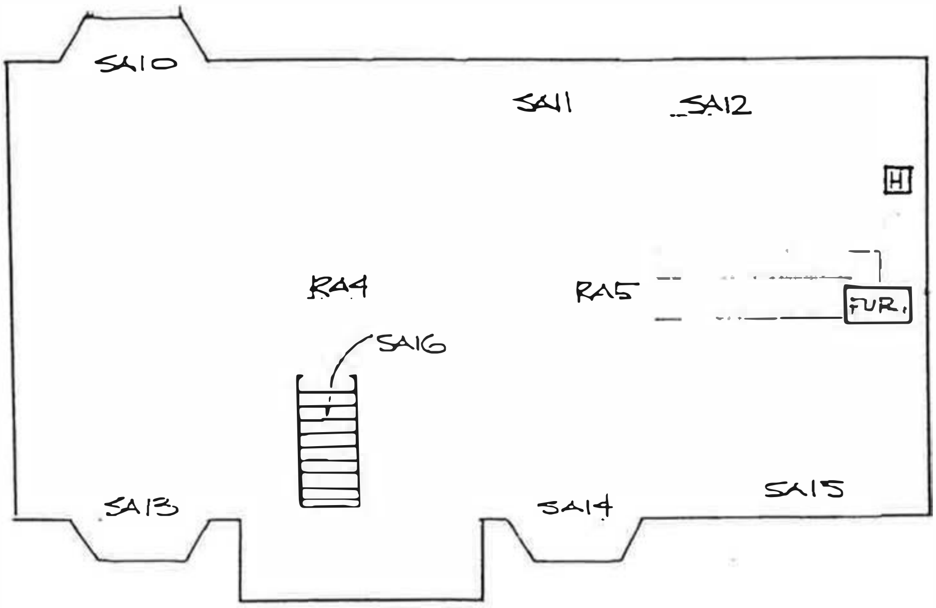
SECOND FLOOR

House ID Number: CSO-1
House Volume: 679 m³

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



MAIN FLOOR



BASEMENT

House ID: CS0-1

FURNACE

Supply Air

Loc. ID	Location	Duct Test Rig Air Flow (l/s)	Percent (%)	Fresh Air Supply (l/s)	Expected ACH
Total				52.0	
SL1	Living Rm	37.4	9%	4.7	0.38
SD2	Dining Rm	32.6	8%	4.1	0.38
SK3	Kitchen	24.6	6%	3.1	0.28
SW4	Bathrm	18.5	4%	2.3	0.76
SB5	Bedrm 2	36.4	9%	4.5	0.32
SH6	Hallway	28.5	7%	3.5	0.75
SB7	M. Bedrm	21.8	5%	2.7	0.19
SW8	M. Bath	24.2	6%	3.0	0.48
	Walk-in C		0%	0.0	0.00
SE9	Entrance	18.5	4%	2.3	0.23
SC17	Laundry	25.4	6%	3.2	0.50
SX10	Basement	22.2	36%	18.7	0.20
SX11	Basement	19.2			
SX12	Basement	24.0			
SX13	Basement	24.0			
SX14	Basement	19.2			
SX15	Basement	22.2			
SX16	Basement	19.2			
Total		**417.9**	**100%**	**52.0**	**0.27**

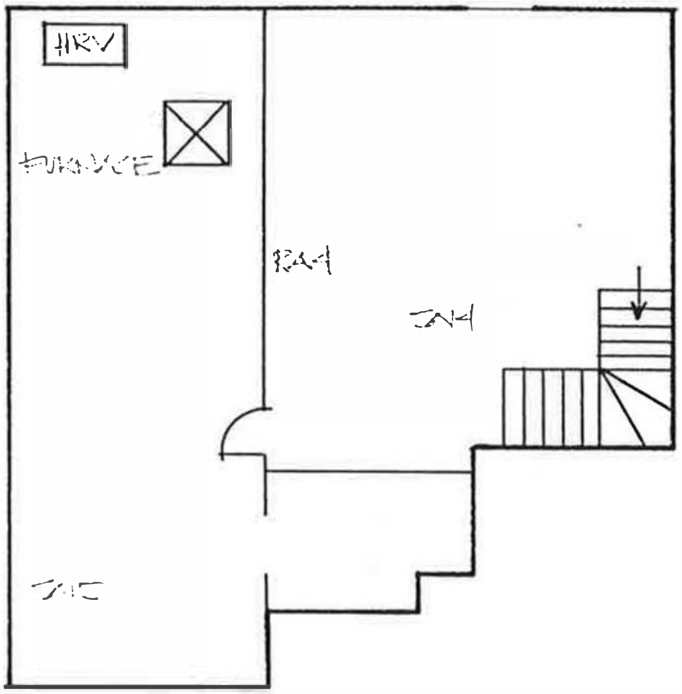
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
RL1	Living Rm	58
RB2	Bedrm 2	59
RB3	M. Bedrm	85
RX4	Basement	24
RX5	Basement	35
Total		**261**

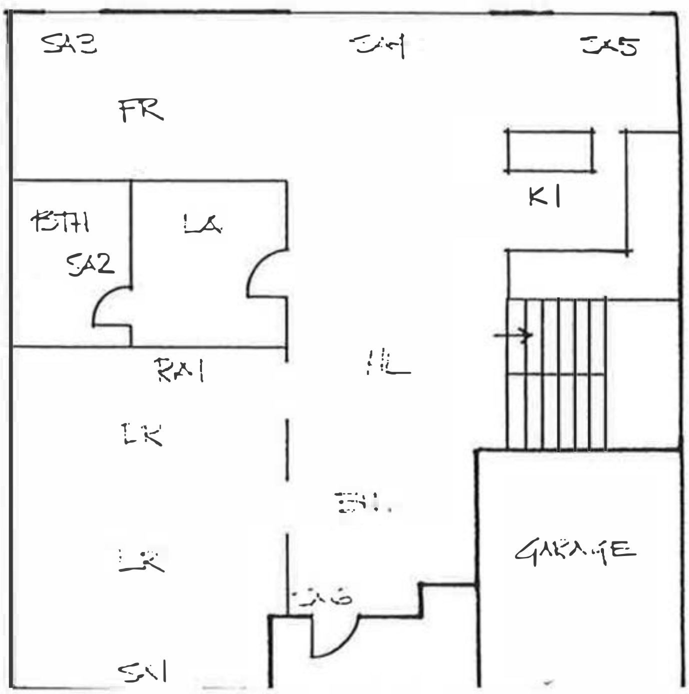
HRV Balance During Testing (l/s) **52**

House ID Number: CS2-1
House Volume: 550m³

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



BASEMENT



House ID: CS2-1

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)
SA1	Living	9.0	4%	1.7
SA2	Main Fl. Bath	16.0	6%	3.1
SA3	Family Room	27.0	11%	5.2
SA4	Family-Slider	29.0	11%	5.6
SA5	Kitchen	19.0	7%	3.7
SA6	Entry	22.0	9%	4.2
SA7	Master Bed	13.0	10%	5.0
SA8	Master Bed	13.0		
SA9	Ensuite	18.0	7%	3.5
SA10	Closet Walk-In	9.0	4%	1.7
SA11	Bathroom	9.0	4%	1.7
SA12	2nd Bedroom	6.0	2%	1.2
SA13	3rd Bedroom	6.0	2%	1.2
SA14	Basement	32.0	23%	11.3
SA15	Basement	27.0		
Total		**255.0**	100%	49.0

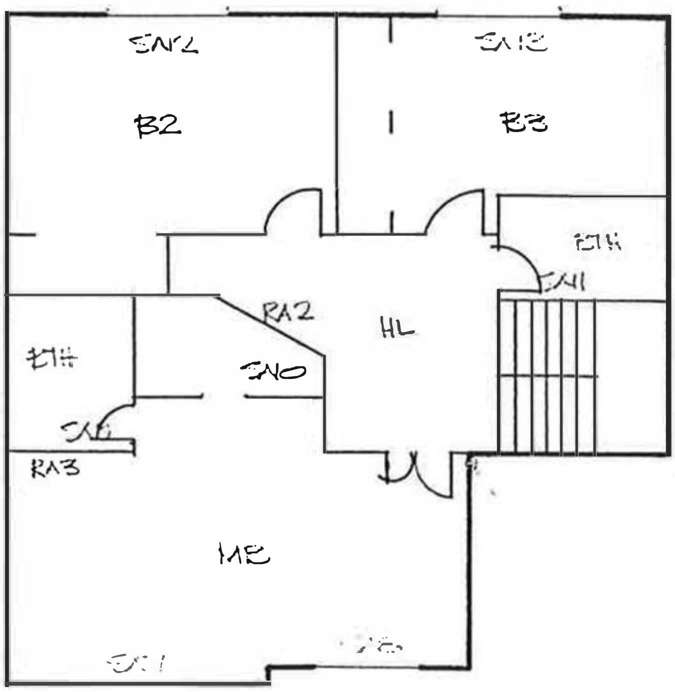
FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)
RA1	Dining Room	73.0
RA2	Upst. Hallway	5.0
RA3	Master Bed	5.0
RA4	Basement	36.0
Total		**119.0**

HRV Balance During Testing (l/s) **49**

House ID Number: CS2-1
House Volume: 550 m³

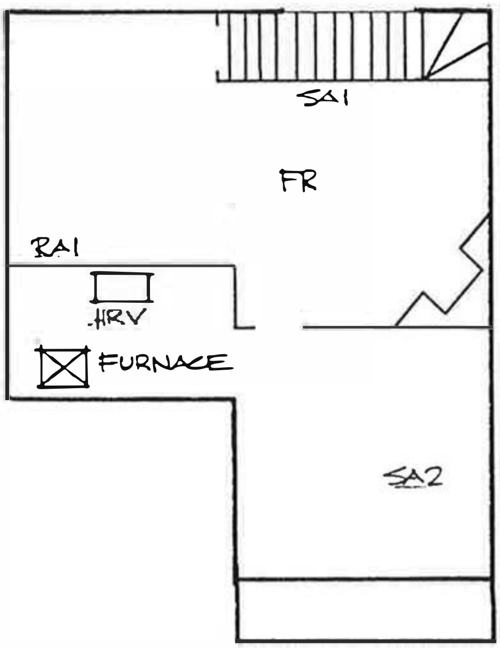
Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



SECOND FLOOR

House ID Number: CS2-3
House Volume: 491 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



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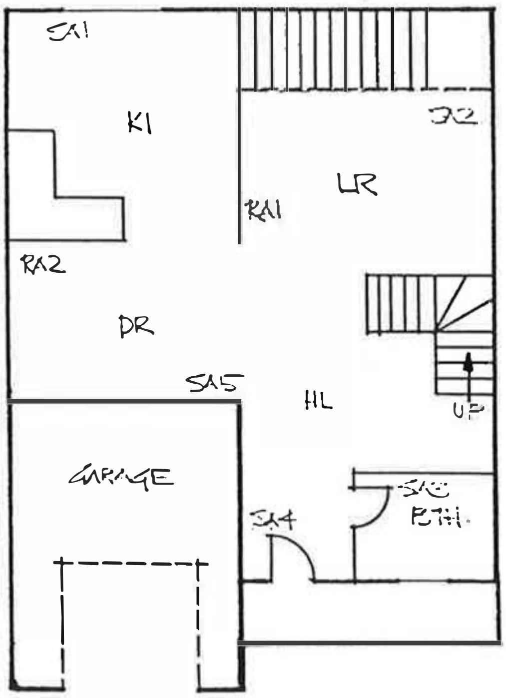


House ID: CS2-3

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
KS1	Kitchen	24.0	9%	4.9	39.0	9%	5.0
LS2	Living Room	24.0	9%	4.9	31.0	7%	4.0
BS3	Entry Bath	18.0	7%	3.7	26.0	6%	3.3
ES4	Entrance	18.0	7%	3.7	31.0	7%	4.0
DS5	Dining Room	20.0	8%	4.1	26.0	6%	3.3
CS1	Master Closet	11.0	4%	2.3	16.0	4%	2.0
MS2	Master Bed	20.0	8%	4.1	39.0	9%	5.0
BS3	2nd Bed	14.0	5%	2.9	26.0	6%	3.3
BS4	3rd Bed	13.0	5%	2.7	26.0	6%	3.3
BS5	Main Bath	13.0	5%	2.7	26.0	6%	3.3
BS6	Master Bath	12.0	5%	2.5	26.0	6%	3.3
SA1	Fam Rm Ceilin	*19.6*	20%	10.7	28.0	7%	3.6
SA2	Fam Rm Ceilin	*32.9*			47.0	11%	6.0
SA3	Mech Ceiling	*19.6*	8%	4.0	28.0	7%	3.6
Total		**259.1**	**100%**	**53.0**	**415.0**	**100%**	**53.0**

**Italicized are estimates*

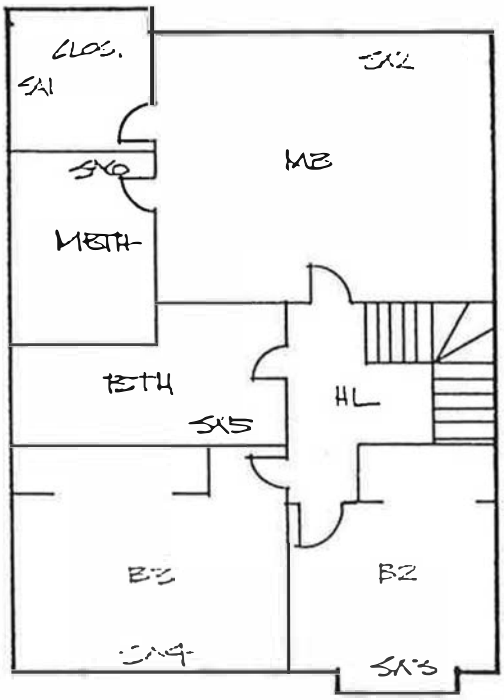
FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Air Flow Bag Method (l/s)
LR1	Living Room	25.0	78.0
DR2	Dining Room	63.0	78.0
MR1	Master Bed	37.0	71.0
BR2	3rd Bed	25.0	35.0
BR1	Basement	37.0	47.0
Total		**187.0**	**309.0**

HRV Balance During Testing (l/s) **53**

House ID Number: [illegible]
House Volume: 491 m^3

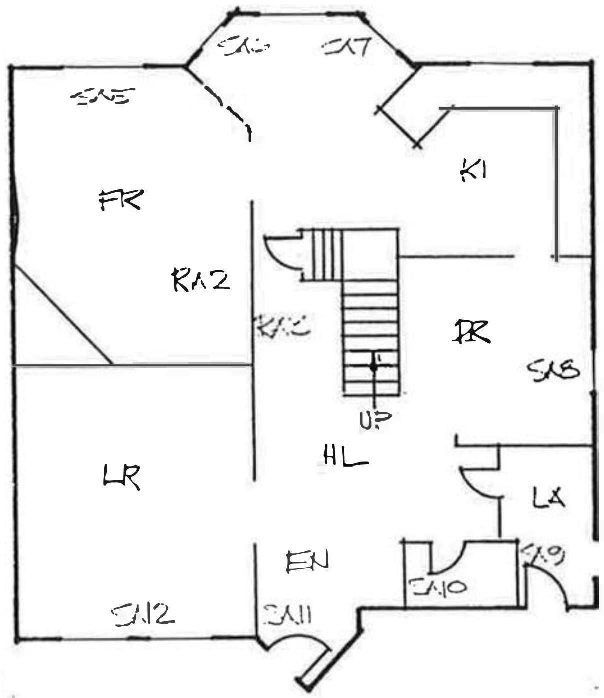
Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



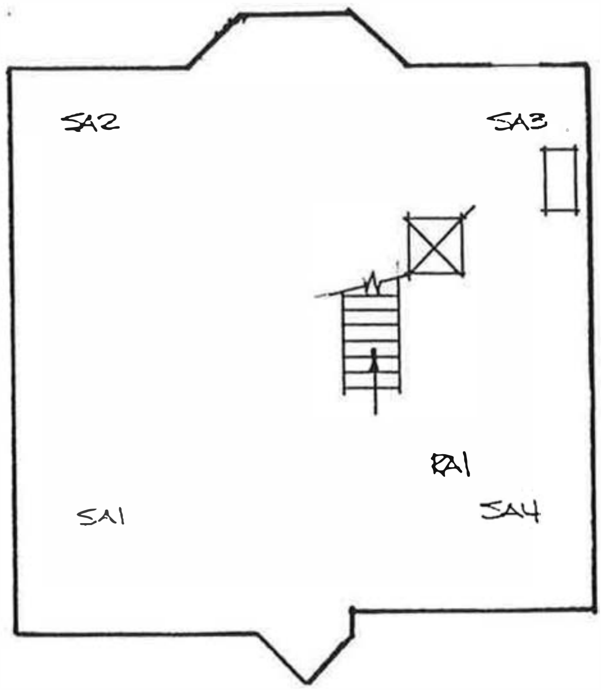
SECOND FLOOR

House ID Number: CS2-5
House Volume: 914 m³

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



MAIN FLOOR



House ID: CS2-5

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)
SB1	Basement	13.0	22%	11.0
SB2	Basement	10.0		
SB3	Basement	14.0		
SB4	Basement	13.0		
SF5	Family Room	12.0	5%	2.6
SK6	Kitch/Breakfas	16.0	16%	8.2
SK7	Kitch/Breakfas	21.0		
SD8	Dining Room	16.0	7%	3.5
SL9	Laundry	11.0	5%	2.4
SB10	Bathroom	15.0	6%	3.3
SF11	Foyer	10.0	4%	2.2
SL12	Living Room	11.0	5%	2.4
SM13	Master Bed	10.0	9%	4.4
SM14	Master Bed	10.0		
SE15	Ensuite	11.0	5%	2.4
SB16	4th Bed	10.0	4%	2.2
SB17	3rd Bed	10.0	4%	2.2
SB18	2nd Bed	8.0	3%	1.8
SB19	Bathroom	10.0	4%	2.2
Total		**231.0**	**100%**	**51.0**

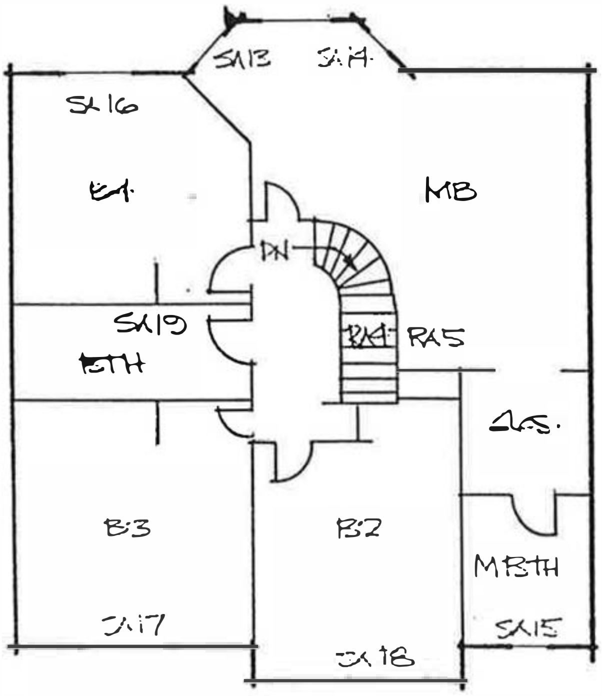
FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	
RB1	Basement	40.0	
RF2	Family	80.0	
RF3	Corridor	32.0	
RS4	Stairs	*40.0*	**Italicized values from*
RM5	Master Bed	*52.0*	*Bag Method*
Total		**244.0**	

HRV Balance During Testing (l/s) 51

House ID Number: [illegible]
House Volume: 914 m^3

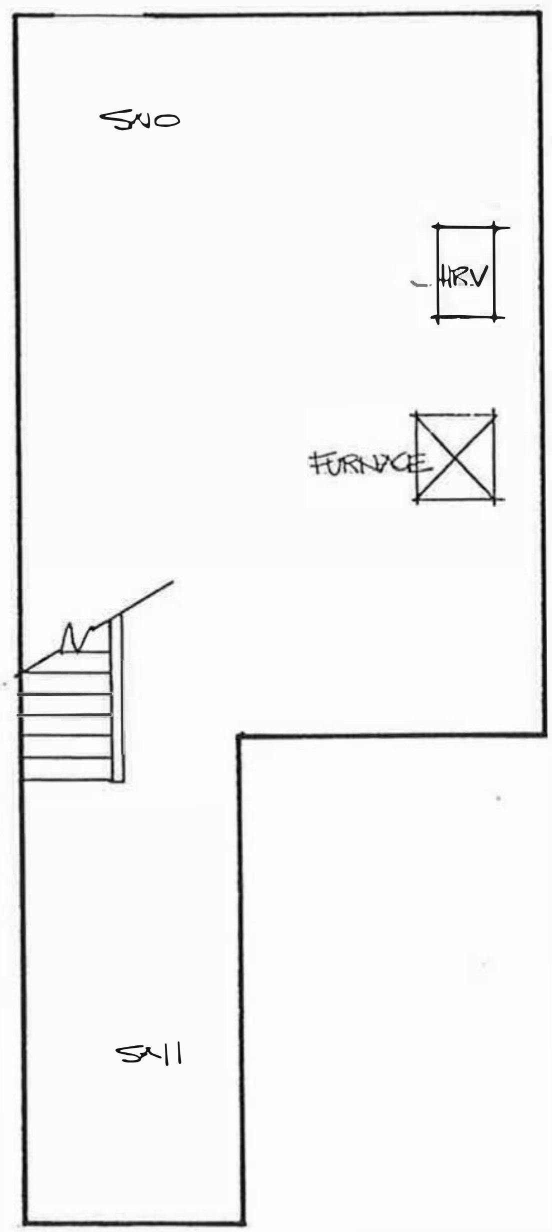
Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



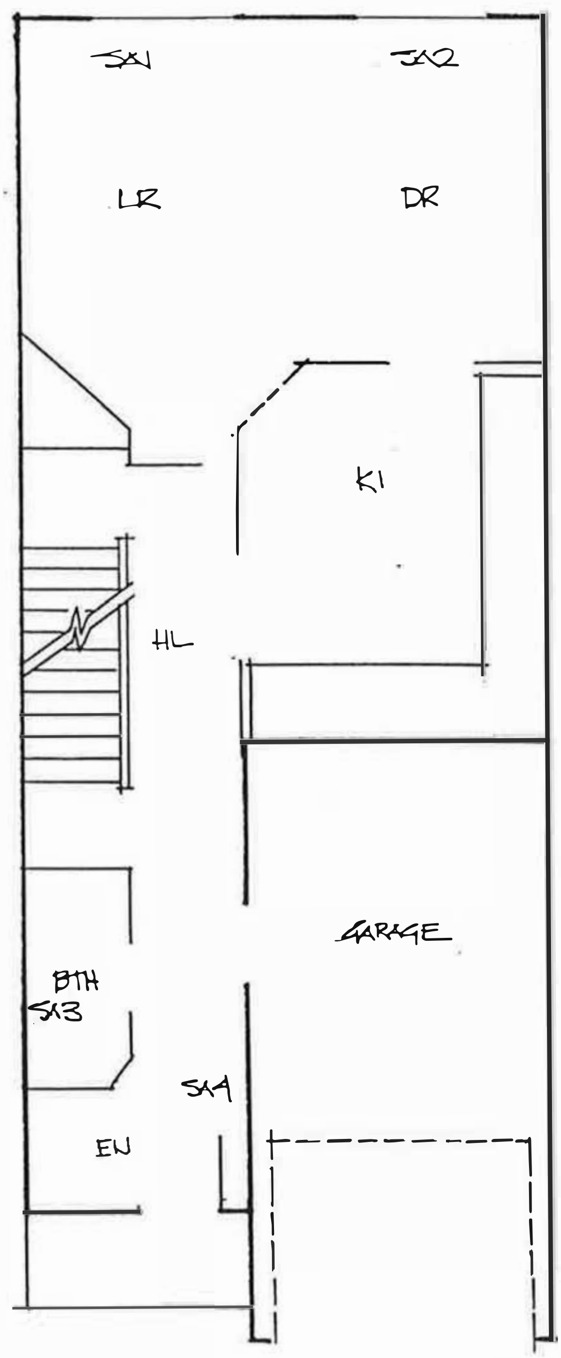
SECOND FLOOR

House ID Number: [illegible]
House Volume: 404 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



BASEMENT



MAIN FLOOR

House ID: CS2-7

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
LS1	Living Room	42.0	9%	4.9	39.0	9%	5.0
DS2	Dining Room	62.0	13%	7.2	52.0	12%	6.7
BS3	Powder Room	42.0	9%	4.9	52.0	12%	6.7
ES4	Entrance	37.0	8%	4.3	31.0	7%	4.0
BS5	2nd Bed	25.0	5%	2.9	*28.0*	7%	3.6
BS6	3rd Bed	15.0	3%	1.8	26.0	6%	3.3
BS7	Main Bath	31.0	7%	3.6	31.0	7%	4.0
MS8	Master Bed	77.0	17%	9.0	39.0	9%	5.0
BS9	Master Bath	42.0	9%	4.9	31.0	7%	4.0
BS10	Basement	50.0	19%	10.4	52.0	22%	11.7
BS11	Basement	39.0			39.0		
Total		462	100%	54.0	420.0	100%	54.0

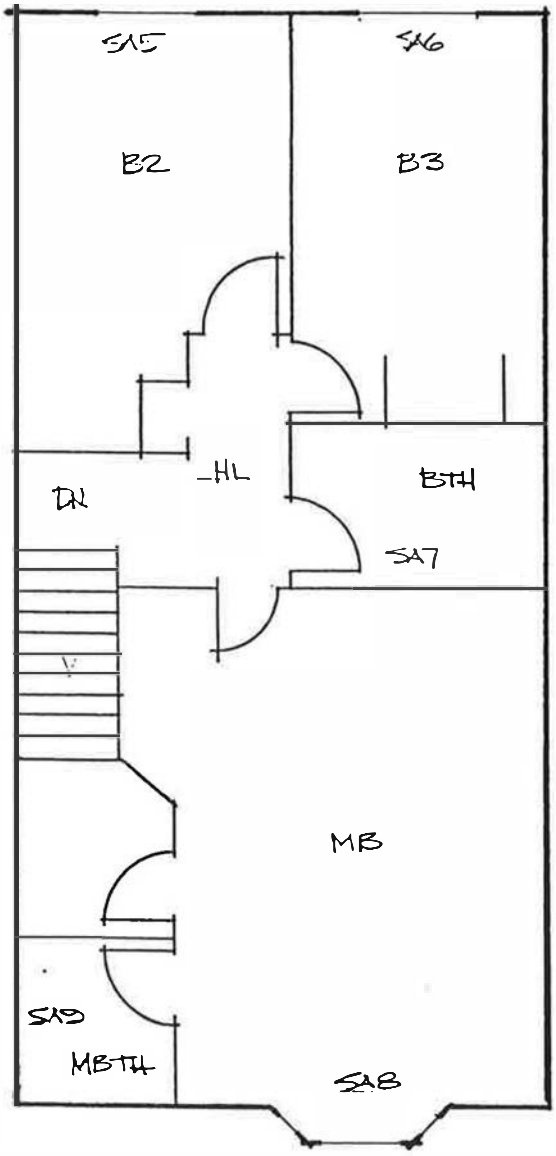
FURNACE
Return Air

Loc. ID	Location	Air Flow Bag Method (l/s)	
LR1	Living Room	*150.0*	**reading from*
HR2	Hallway	52.0	*duct test rig*
BR3	3rd Bed	39.0	
Total		241.0	

HRV Balance During Testing (l/s) 54

House ID Number: C32-7
House Volume: 404 m^3

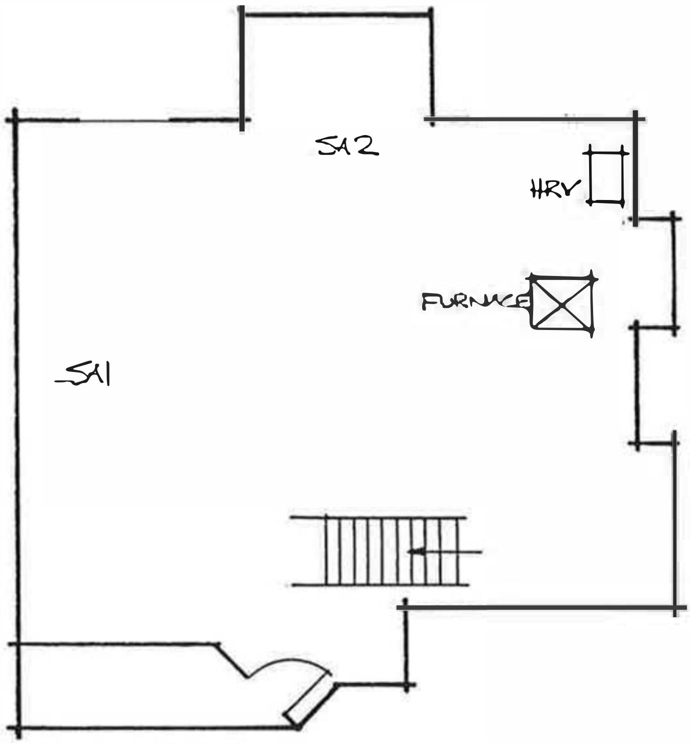
Register Code		*Room Code*			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



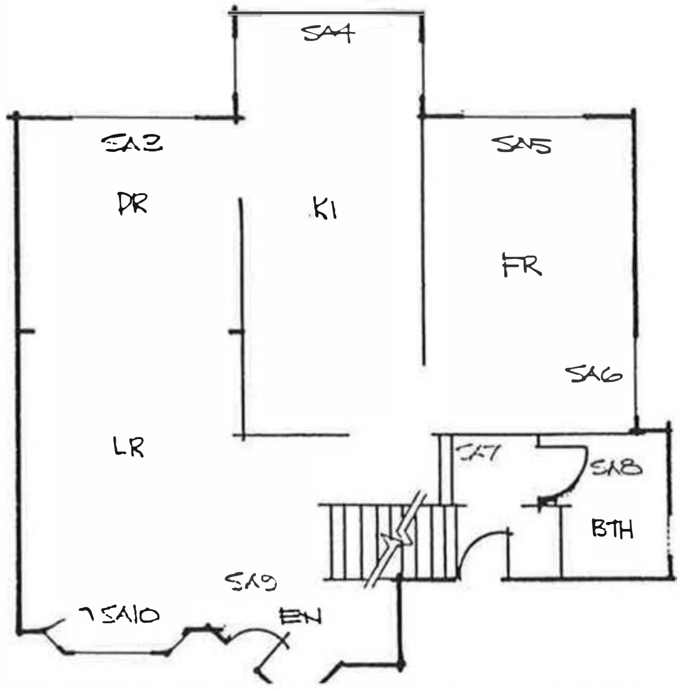
SECOND FLOOR

House ID Number: 112-3
House Volume: 567 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



BASEMENT 1



House ID: CC2-3

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)
BS1	Basement	18.0	14%	8.4
BS2	Basement	26.0		
DS3	Dining Room	5.0	2%	1.0
NS4	Breakfast Nook	30.0	9%	5.7
FS5	Family Room	*30.0*	19%	11.4
FS6	Family Room	*30.0*		
HS7	Stair to Base	10.0	3%	1.9
PS8	Main Fl. Bath	5.0	2%	1.0
ES9	Main Entrance	18.0	6%	3.4
LS10	Living Room	28.0	9%	5.3
BS11	Master Bath	26.0	8%	4.9
BS12	2nd Bed	17.0	5%	3.2
BS13	3rd Bed	19.0	6%	3.6
MS14	Main Bath	24.0	7%	4.6
BS15	Master Bed	35.0	11%	6.7
Total		321.0	100%	61.0

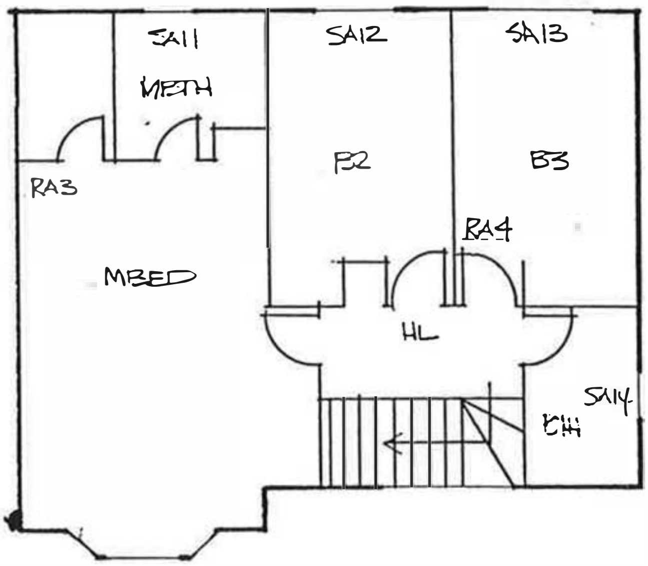
FURNACE
Return Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	
R1	Family Room	95.0	
R2	Living Room	76.0	
R3	Master Bed	*40.0*	**Italicized values from*
R4	3rd Bed	*80.0*	*bag method*
Total		291.0	

HRV Balance During Testing (l/s) 61

House ID Number: 112-3
House Volume: 567 m³

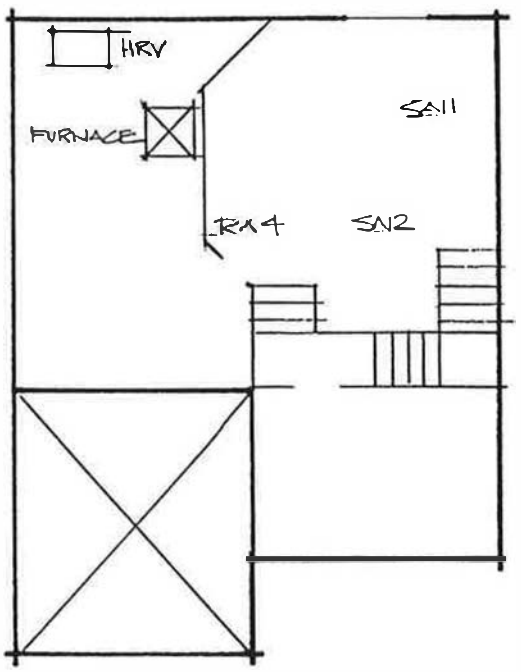
Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



SECOND FLOOR

House ID Number: CCZ-5
House Volume: 515 m^3

Register Code		Room Code			
		MB	Master Bedroom	*FR*	Family Room
SA	Furnace Supply Air	*B1*	1st Bedroom	*DR*	Dining Room
RA	Furnace Return Air	*B2*	2nd Bedroom	*LR*	Living Room
HS	HRV Supply	*B3*	3rd Bedroom	*LA*	Laundry
HE	HRV Exhaust	*BTH*	Bathroom	*EN*	Entrance
		MBTH	Master Bathroom	*OF*	Office
		BSMNT	Basement	*ST*	Storage
		KI	Kitchen	*HL*	Hallway



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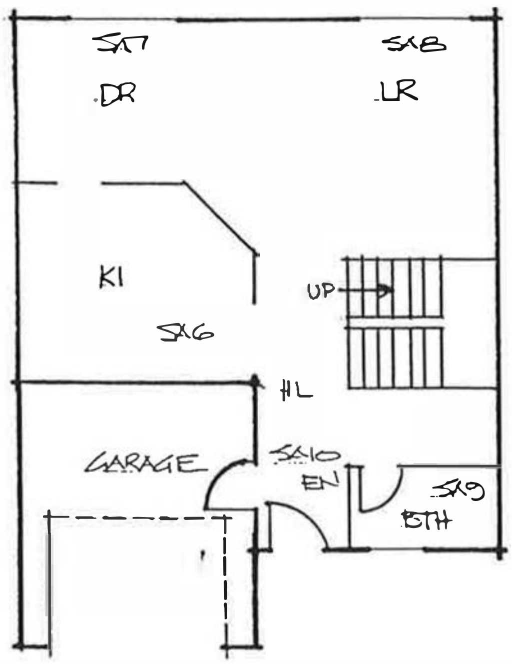


MAIN FLOOR

House ID: CC2-5

FURNACE
Supply Air

Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Percent	Fresh Air Supply (l/s)	Air Flow Bag Method (l/s)	Percent	Fresh Air Supply (l/s)
B1	Master Bed	8.5	9%	5.6	15.7	8%	5.3
B2	2nd Bed	7.7	8%	5.1	14.0	7%	4.7
B3	3rd Bed	6.9	7%	4.5	12.8	7%	4.3
E4	Ensuite	8.7	9%	5.7	15.7	8%	5.3
BA5	Bathroom	5.7	6%	3.7	12.8	7%	4.3
K6	Kitchen	10.0	10%	6.6	18.0	10%	6.1
K7	Dining Room	13.1	13%	8.6	28.0	15%	9.5
L8	Living Room	10.6	11%	7.0	20.0	11%	6.8
BA9	Bathroom	6.3	6%	4.1	12.8	7%	4.3
E10	Entry	8.7	9%	5.7	17.6	9%	5.9
B11	Base Family	5.7	12%	7.4	11.0	12%	7.4
B12	Base Family	5.7			11.0		
Total		97.5	100%	64.0	189.4	100%	64.0

FURNACE
Return Air

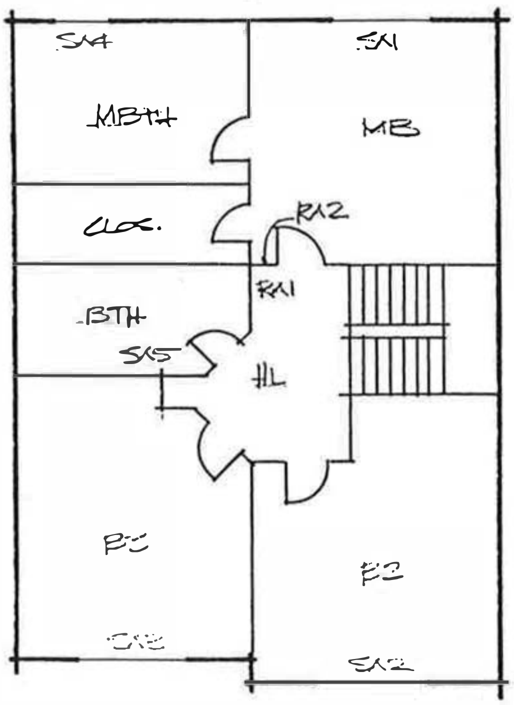
Loc. ID	Location	Air Flow Duct Test Rig (l/s)	Air Flow Bag Method (l/s)
RA1	Hallway (High)	*32.9*	47.0
RA2	Master Bed	*32.9*	47.0
RA3	Dining Room	40.0	*57.1*
RA4	Basement	35.0	*50.0*
Total		140.8	201.1

**Italicized are estimates*

HRV Balance During Testing (l/s) 64

House ID Number: 162-5
House Volume: 515 m^3

Register Code		Room Code			
		MB	Master Bedroom	FR	Family Room
SA	Furnace Supply Air	B1	1st Bedroom	DR	Dining Room
RA	Furnace Return Air	B2	2nd Bedroom	LR	Living Room
HS	HRV Supply	B3	3rd Bedroom	LA	Laundry
HE	HRV Exhaust	BTH	Bathroom	EN	Entrance
		MBTH	Master Bathroom	OF	Office
		BSMNT	Basement	ST	Storage
		KI	Kitchen	HL	Hallway



SECOND FLOOR

Appendix E

Alternative Ventilation Systems - Ventilation Effectiveness Results

Contents

E.1 Introduction

The Efficiency and Alternative Energy Technology Branch (CANMET) of Natural Resources Canada (NRCan) commissioned a study to develop and evaluate various alternative, low-cost ventilation systems intended to meet CAN/CSA-F326-M91, *Residential Mechanical Ventilation Systems*. The systems developed were evaluated in terms of both initial cost and operating cost using HOT2000. The report on this work is titled, *Energy impact of Ventilation Air Distribution*. The report recommended that the ventilation effectiveness of the more promising systems be tested. This appendix details the installation of these systems, the testing carried out, and the conclusions than can be drawn based upon the results.

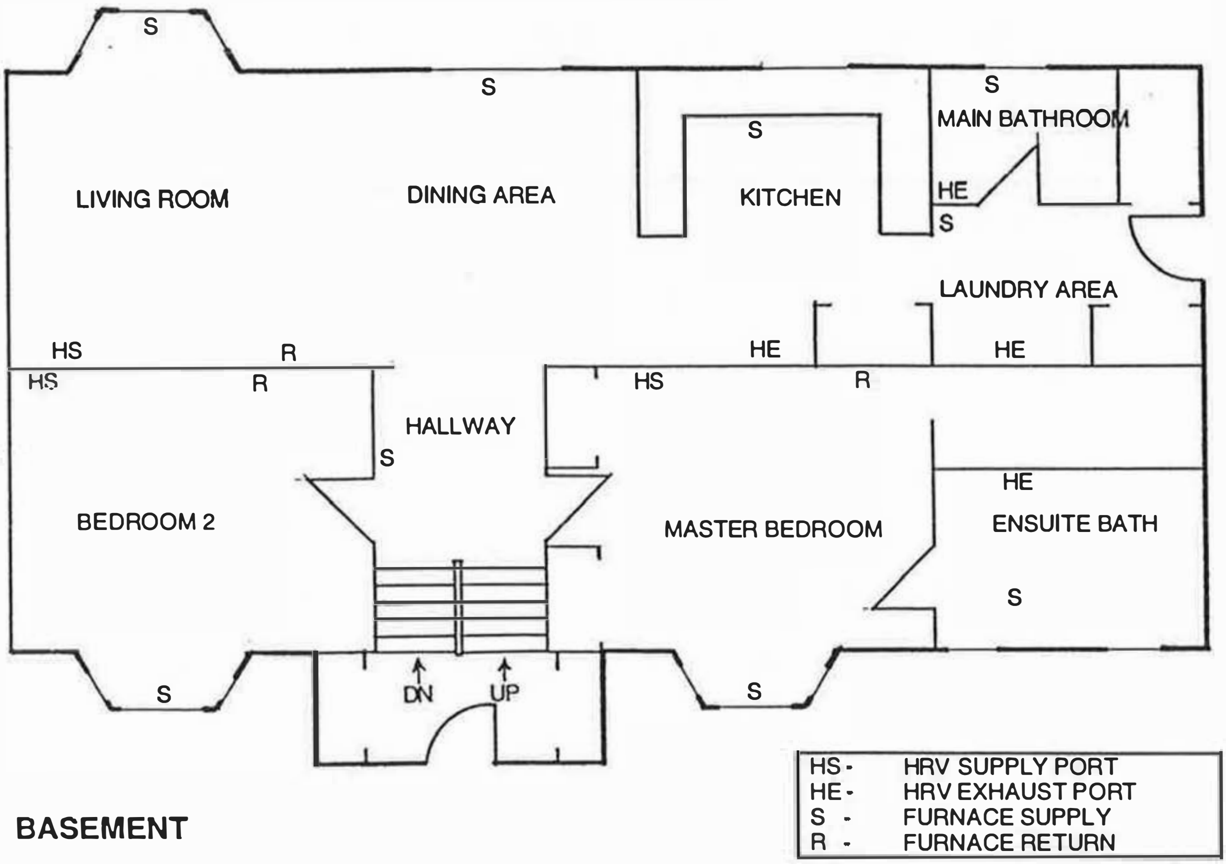
An agreement was made with a builder for the use of a bungalow that was almost ready for occupancy, but had not yet had the HRV component of the ventilation system installed. Alternative ventilation systems, based upon NRCan's conceptual systems, were designed and installed. The HRV warm-side ductwork was configured in such a way that, with minimal effort, the ventilation system could be rearranged from one alternative ventilation strategy to another. Conventional fully ducted, extended, and simplified systems were also configured and tested in this house.

The house layout is shown in Figure E.1. This figure also shows the furnace circulation system and HRV system. To consider the relevance of the results from the test home for similar installations at other houses, the relatively modest size and open plan of the test home should be considered.

Fan depressurization testing indicated that the test house met the air leakage requirements of the R-2000 Program. This served to reduce the effect of varying environmental conditions outside on natural air infiltration rates during testing. However, it should be noted that, due to the short timeframe available to do the work at this home, some testing was carried out during high wind conditions. This may have the varied natural infiltration rates during testing, ultimately increasing the error in the results.

The testing methodology employed for the alternative and conventional ventilation systems at this house was identical to that used for the conventional systems installed at all other test houses in this study. Section 3.2 provides an explanation of the methodology.

MAIN FLOOR



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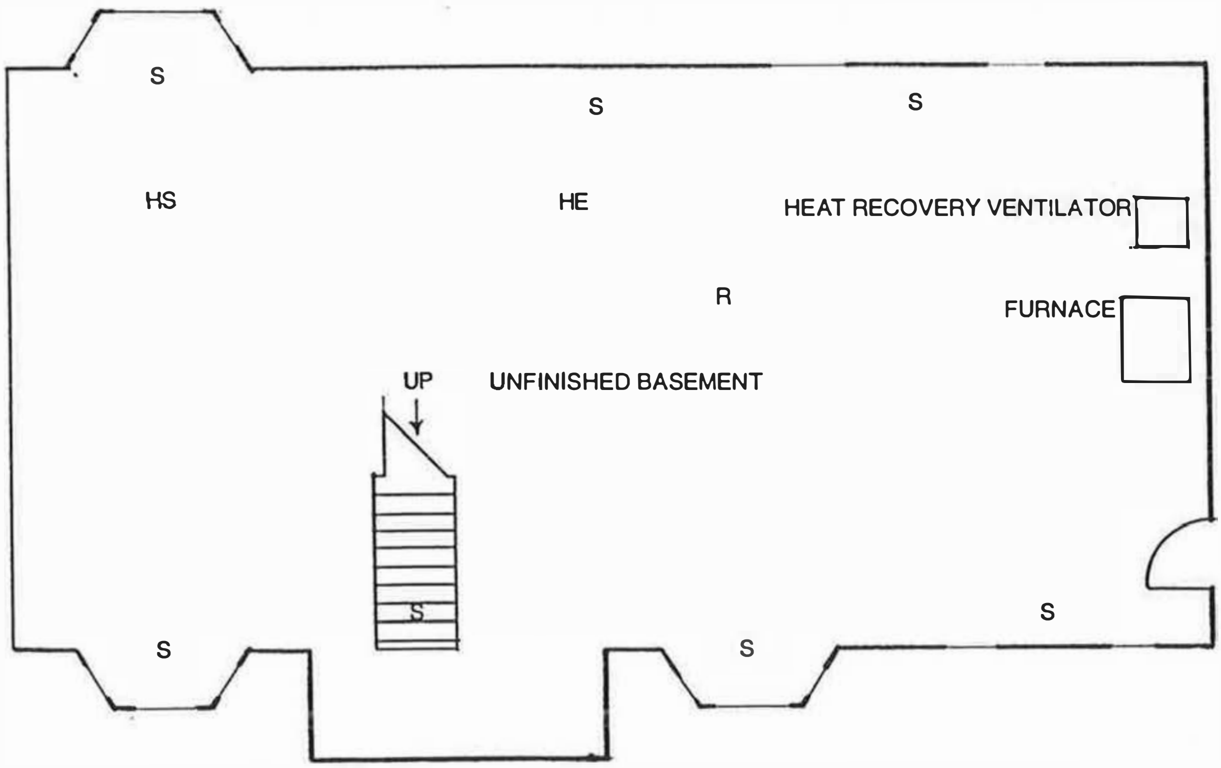

Figure E.1: Plan of Test House

E.2 Alternative Ventilation Systems

E.2.1 System 1 – Simplified System with Backdraft Damper

This simplified system was installed with the HRV drawing exhaust air from the furnace return and supplying fresh air to the supply plenum. A backdraft damper was located in the vertical section of the furnace supply air plenum between the furnace and the point where the HRV fresh-air supply was connected. It opened due to air pressure when the furnace fan was operating and closed due to gravity when the fan was not operating.

The damper, therefore, prevented fresh air delivered by the HRV from flowing through the furnace and return air system when the furnace was not operating. Dampers were installed to simulate low system air flow rates provided by an electronically commutated (ECM) DC motor.

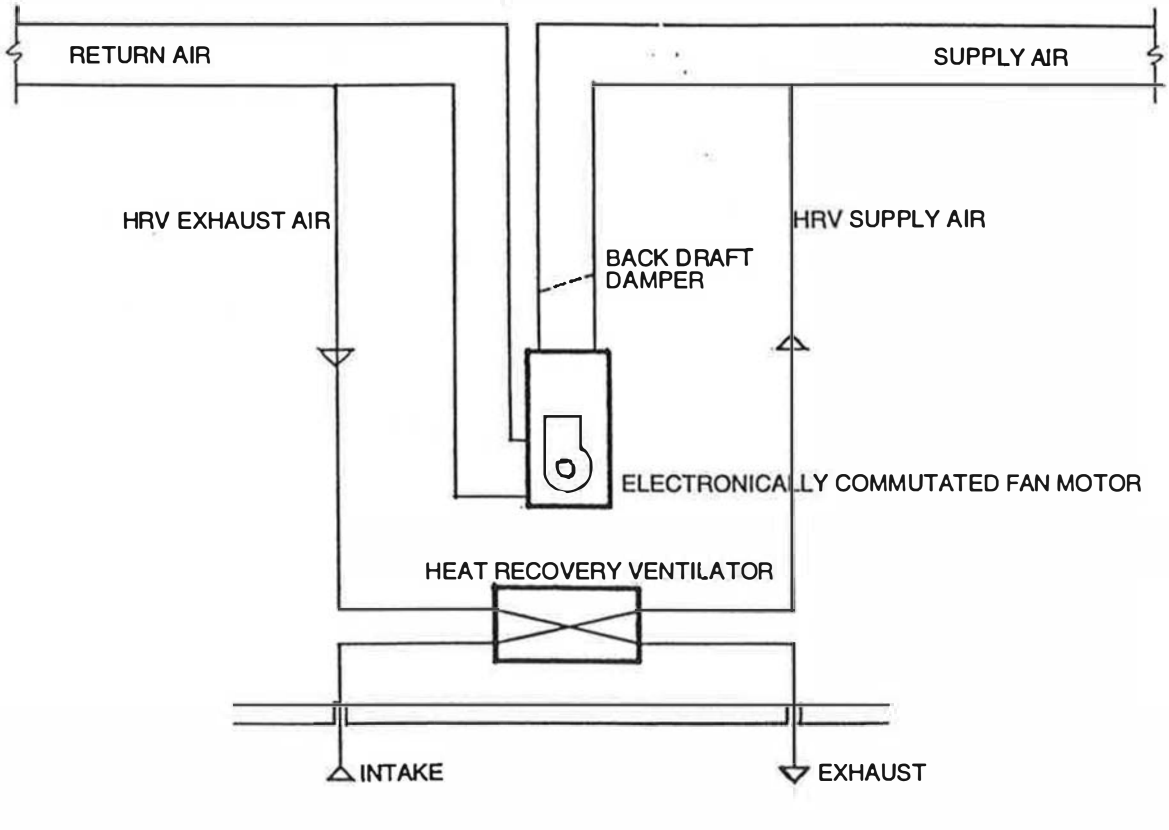

Figure E.2: Schematic Drawing of System 1

This system was designed to test two configurations that could become common installation practice. The first was the use of an ECM motor with a simplified system. Particularly with the electronically commutated (ECM motors now available for furnace fans, the low speed continuous air-flow rate can be a much smaller fraction of the higher speed settings for heating and cooling. The intention was to determine whether the advantages of low-speed operation, low-noise generation, and low-energy use were offset by reductions in distribution effectiveness. Testing was carried out to determine the effect of low-speed operation on the distribution of ventilation air via a ductwork system designed for higher air flow rate operation.

The system was also designed to test the distribution of ventilation air when the furnace fan was not operating. It was clear than many people were not operating their furnace fan when their HRV was operating because they were unaware that they should; they found it noisy; or they were concerned about operating costs. The typical simplified ventilation system provided the ventilation air from the HRV to the furnace return. When the furnace was not operating, this air either flowed through the furnace and supply ductwork or through the return ductwork. Resistance is usually far less on the return side, so it would be expected that most of the air flows out of the closest return air registers and leaks in the return air ductwork. Some air enters living space close to the location where it was provided by the HRV via cracks in the leaky return air ductwork and return air registers. Most of the fresh air was exhausted outsidc again due to suction from the HRV exhaust pickup that was also connected to the furnace return.

To distribute the fresh air without the furnace fan operating, the HRV supply was connected to the most airtight side of the distribution ductwork with smaller registers. This increased air flow within the supply ductwork, ultimately causing more air to move further through the system than it would in a return system with leaky ductwork and large registers. Also, the supply system typically has a register in all rooms, whereas the return system does not. For these reasons, the fresh air from the HRV was provided to the supply plenum instead of the return plenum.

E.2.2 System 2 – Extended System with Backdraft damper

This system was identical to System1 with the exception that the exhaust air for the HRV was taken from the kitchen and bathrooms instead of the return air plenum. The purposes of testing this alternative system installation were the same as those for System 1. The intent was to compare the effect of drawing stale air from the bathrooms and kitchens on the apparent net mechanical AC/H rates in living areas when the circulation system was not operating.

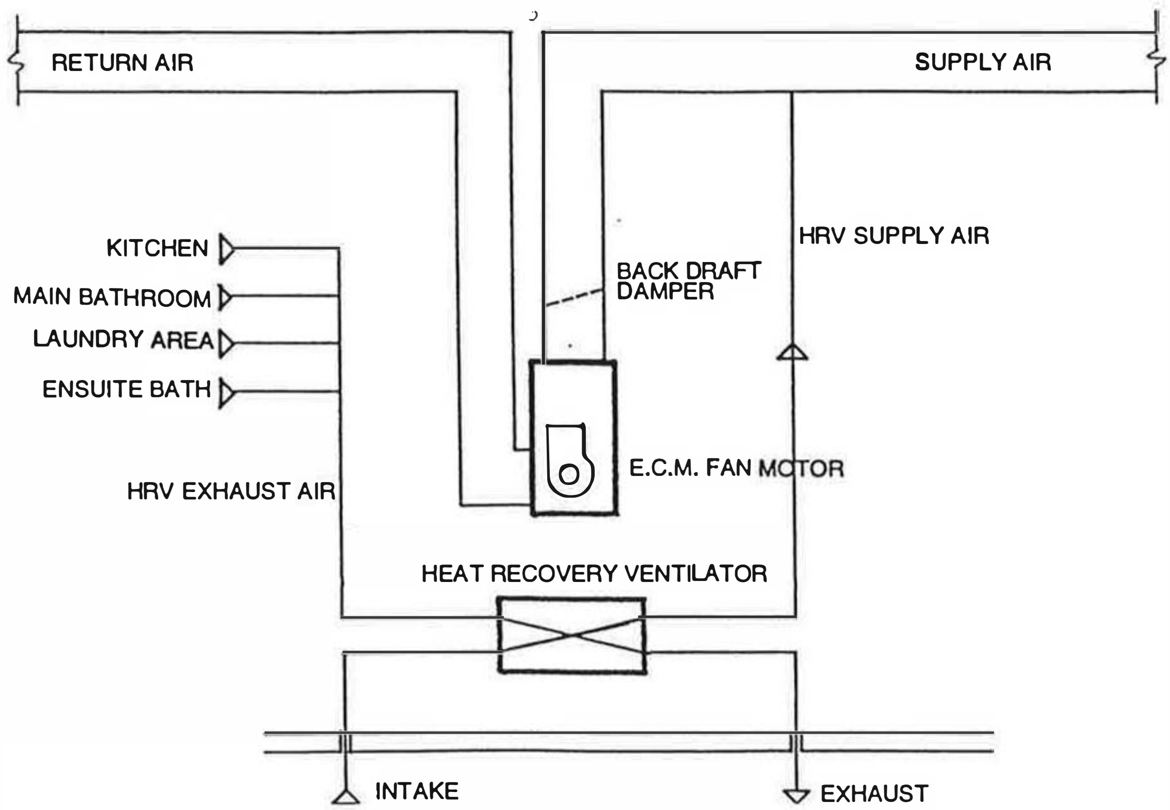

Figure E.3: Schematic Drawing of System 2

E.2.3 System 3 – Supply to Central Location, Exhaust Fans in Bedroom Doors

The installation of fans in/or above bedroom doors was perceived, in the *Energy Impact of Ventilation Air Distribution* report, to be a ventilation option with low installation and operating costs. The premise was that supply-side HRV ductwork in houses without forced-air heating systems could be reduced by the use of small fans above bedroom doorways to aid in distribution and circulation. The intent was to use small, efficient axial fan motor sets installed and operated at the rates required by CAN/CSA-F326-M91 for rooms not directly supplied by ventilation air during the testing. Thus, the exhaust air rates from the master bedroom wcrc 20 L/s and 10 L/s respectively.

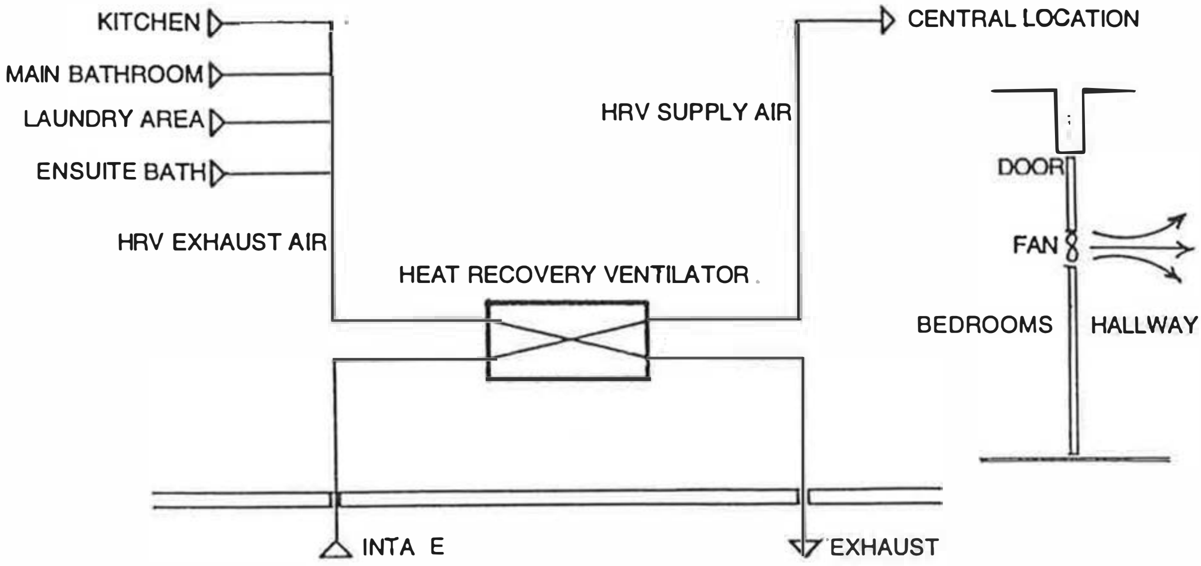

Figure E.4: Schematic Drawing of System 3

The HRV exhausted from the kitchen and the bathrooms during all testing. An ensuite bath for the master bedroom also exhausted air during testing.

During one test, the HRV central air supply location was in the living room of the first storey. In the other test, the central supply was placed in the basement to simulate a typical, two-storey house with a ventilation air supply in the first storey living area only and bedrooms located on the second storey.

E.2.4 System 4 – Supply to Central Location, Exhaust Fans in Bedroom Closets

System 4 was based on the same premise as System 3. The difference from system 3 was the small fans exhausted stale air from bedroom closets to the floor below instead of exhausting air from the bedrooms into the hallway on the same floor.

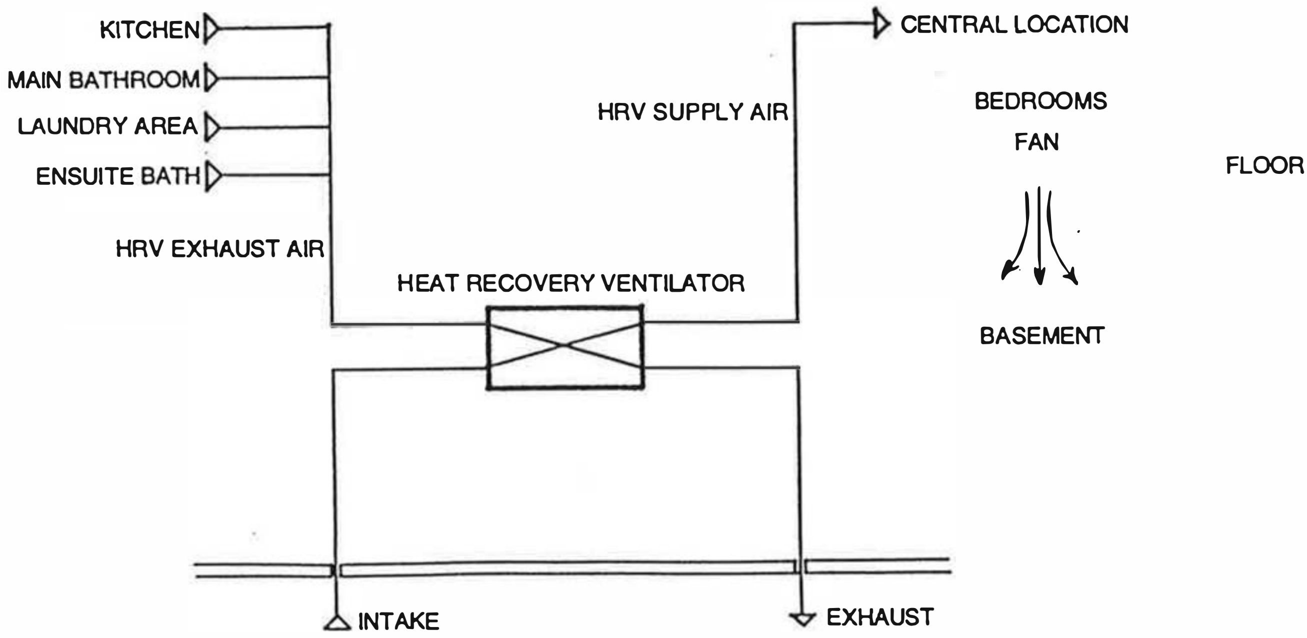

Figure E.5: Schematic Drawing of System 4

E.2.5 Comparative Traditional Systems

Standard fully ducted, extended, and simplified systems were also tested in this house to provide a comparison to the results of the alternative system testing. These system types are discussed in Section E.1, the introduction to this appendix.

E.3 Results

The average apparent natural air change rate within the house was subtracted from the apparent total air change rates to determine the apparent mechanical AC/H rates for the five sample rooms discussed throughout this report. The results, therefore, relate directly to each mechanical system.

Table E.1 summarizes the system configurations tested:

Table E.1: Summary of Test Configurations

System	***HRV Operation***	***Furnace Fan Operation***	***Bedrm Doors***	***Comments***
System 1-1	MVC (1)	Off	Open	Backdraft damper open
System 1-2	MVC	Off	Open	Backdraft damper closed
System 1-3	MVC	ECM low	Open	
System 1-4	MVC	Low	Open	
System 1-5	MVC	High	Open	
System 2-1	MVC	Off	Open	Backdraft damper open
System 2-2	MVC	Off	Open	Backdraft damper closed
System 2-3	MVC	ECM low	Open	
System 2-4	MVC	Low	Open	
System 2-5	MVC	High	Open	
System 3-1	MVC	Off	Closed(2)	HRV supply to main floor
System 3-2	MVC	Off	Closed(3)	HRV supply to basement
System 4-1	MVC	Off	Closed(2)	HRV supply to main floor
System 4-2	MVC	Off	Closed(3)	HRV supply to basement
Fully Ducted	MVC	Low	Open	
Extended	MVC	Low	Open	
Simplified	MVC	Low	Open	

Notes:

1. **HRV balanced at CAN/CSA-F326-M91 Minimum Ventilation Capacity (MVC) air flow rate**
2. **Bedroom doors closed only – ensuite door open**
3. **Bedroom doors closed only – ensuite door closed**
4. **Supply side furnace system air flow measurements show that low-speed setting, total air flow rate is approximately 20% less than the total air flow rate on high speed.**

Table E.2 provides a listing of the air flow rates for each setting of the furnace and HRV during testing.

Table E.2: Listing of Air Flow Rates

FURNACE Fan Setting Air Location	High Total (l/s)	High Outdoor Air (l/s)	Medium Total (l/s)	Medium Outdoor Air (l/s)	Low Total (l/s)	Low Outdoor Air (l/s)	ECM Motor Simulated Low Total (l/s)	ECM Motor Simulated Low Outdoor Air (l/s)
Supply								
Living Rm	44.6	4.6	41.3	4.9	37.4	4.7	15.0	4.6
Dining Rm	39.6	4.1	36.1	4.3	32.6	4.1	14.1	4.3
Kitchen	28.5	3.0	25.7	3.0	24.6	3.1	12.8	3.9
Bathroom	20.4	2.1	19.5	2.3	18.5	2.3	6.2	1.9
Bedrm #2	53.8	5.6	39.9	4.7	36.4	4.5	11.5	3.5
Hallway	31.7	3.3	25.3	3.0	28.5	3.5	9.7	3.0
Master Bedrm	24.2	2.5	22.1	2.6	21.8	2.7	7.5	2.3
Master Bath	26.8	2.8	24.6	2.9	24.2	3.0	10.3	3.2
Entrance	21.8	2.3	19.9	2.4	18.5	2.3	5.0	1.5
Laundry	30.5	3.2	26.5	3.1	25.4	3.2	9.6	2.9
Basement	180.0	18.6	157.5	18.7	150.0	18.7	67.0	20.7
Total Supply	501.9	52.0	438.4	52.0	417.9	52.0	168.7	52.0
Return								
Living Rm	53.0		50.9		58.2		7.7	
Den	58.7		55.0		58.8		7.9	
Master Bedrm	94.8		98.6		84.8		9.3	
Basement	28.8		25.2		24.0		9.1	
Basement	42.0		36.8		35.0		13.3	
Total Return	277.3		266.5		260.8		47.3	

HRV Location	Air Flow (l/s)	Percent
Supply		
M. Bedrm	12.8	25%
Den	5.0	10%
Living Rm	16.6	32%
Basement	17.7	34%
Total Supply	52.0	100%
Exhaust		
Kitchen	26.7	48%
Bathroom	16.3	29%
Ensuite	13.0	23%
Total Exhaust	56.1	100%

Notes

1. *For a discussion of air flow measurement results, see Appendix D*
2. *Flow measuring station used to balance HRV at 52 l/s for all tests when HRV was running. F326 requires 47 l/s - used 52 l/s to ensure flows were high enough at various intakes and outlets*
3. *HRV flow measurements at grilles taken with bag method*
4. *HRV exhausts were taped in future laundry and future bathroom in basement for all testing*
5. *Furnace air flow measurements taken at registers with CMHC duct test rig*
6. *Direct outdoor air to each room values assume fresh air proportion of supply air flow rate equal in all cases. Air lost via leaky ductwork is not considered in determining these values*

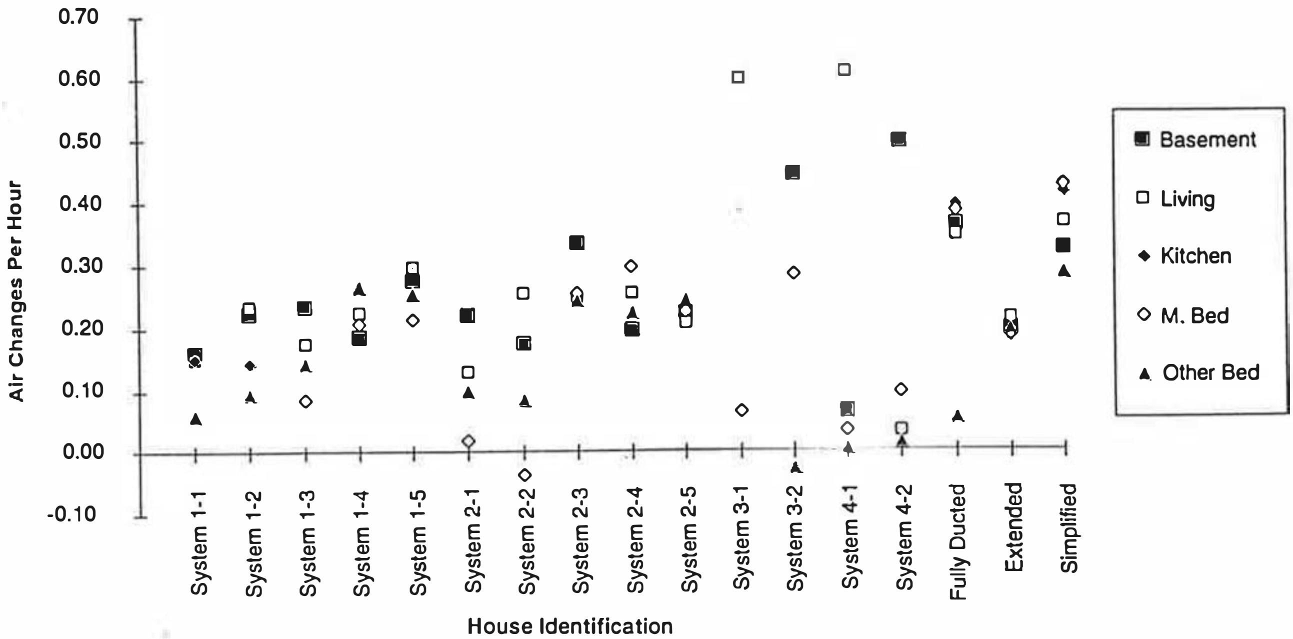

Figure E.6: Summary of Net Mechanical AC/H Rates by Ventilation System Type and Operation

E.3.1 Systems 1 and 2

The first two options for the first two systems: systems 1-1,1-2, 2-1, and 2-2 in the previous table are all options where the furnace fan was off. In the latter option of each pair, the backdraft damper was closed forcing all ventilation air to flow through the supply system. The table shows that, when the damper was closed, there was a marginal increase in the net mechanical AC/H in the living room – a room far from the furnace. The AC/H in a second room equally far from the furnace (the second bedroom) stayed relatively constant with the damper open and shut.

For both modified simplified and the modified extended systems, there was little difference between the results with the furnace fan operating at the three different speed settings –high speed, low speed and ECM low speed. The lowest net mechanical AC/H values in this testing were recorded in the master bedroom in system 1-3 (the simplified system on CM low speed). Note that the ensuite exhaust would induce air into this room in the extended system configuration.

The distributions of net mechanical AC/H rates with the furnace fan operating were similar to those found for standard fully ducted, extended, and simplified systems.

E.3.2 Systems 3 and 4

The two systems where the HRV supplied a central location and exhaust fans in bedrooms were used to induce ventilation elsewhere both produced negligible net mechanical AC/H values in all rooms monitored with the exception of the room supplied directly.

The lone exception to this was the relatively high net mechanical AC/H value in the master bedroom in the test where fresh air was only supplied to the basement. In this test, the door between the master bedroom and the ensuite was open. The combined effect of the 20 L/s exhaust from the master bedroom and the 14 L/s exhaust from the ensuite may have drawn air into the master bedroom from the basement below through the open return air ductwork for the furnace.

In system 3.1, the opening in the return air system was such that it is likely that most of the air being induced into the bedrooms was coming from unventilated areas. Hence, further testing in houses without forces air systems may be advisable.

Appendix F

Inspection Form

Coding Number: ________

HRV System Inspection

Field Survey of Heat Recovery Systems

NOTE:

In order for the house to qualify as a host house, the HRV must be capable of meeting the CAN/CSA F326-M91 ventilation rate. Please check the installed unit to ensure it has been properly sized for this house.

A. HOUSE IDENTIFICATION

Name: ________________

Street Address: ________________

City: ________ Province: ________ Postal Code: ________

Phone: home: ________ work: ________

Investigator: ________________

Date of construction of house: ________________

Type of home: (bungalow, split level, 2 storey, 3 storey)

____

B. TYPE OF HRV INSTALLATION

1. Date of HRV installation: ________________

2. Configuration of the HRV ducting system:

   A. ❑ Fully Ducted
   B. ❑ Partially Ducted
   C. ❑ Simplified

C. DUCT LAYOUT DIAGRAM

The Duct Layout Diagram should include the location of the furnace and HRV and the layout of the ductwork.

Label the following items on the diagram:

Furnace Supply Air:	SA
Furnace Return Air:	RA
HRV Supply:	S
HRV Exhaust:	E

D. CONDITION OF HRV

3. **HRV** manufacturer: ____________________

model: ____________________

4. Is the dehumidistat functioning properly? Yes ❑ No ❑

If no, what problems were encountered? ____________________

____

5. Timers in washrooms and or kitchen:

A. *Location*	***B.*** *Type (Push button, Crank)*	***C.*** *Functioning (Yes, No)*	
1. **A.** __________	**B.** __________	**C.** Yes ❑	No ❑
2. **A.** __________	**B.** __________	**C.** Yes ❑	No ❑
3. **A.** __________	**B.** __________	**C.** Yes ❑	No ❑

6, Have control wires been properly connected to the HRV circuit board. Yes ❑ No ❑

____

____

E. CORE AND FILTERS

7. Is the **core** properly installed in the HRV? Yes ❑ No ❑

Is the core clean? Yes ❑ No ❑

Any sign of deterioration or other noted problems ____________________

____

8. Are the **HRV filters** properly installed in the correct air flow streams Yes ❑ No ❑

Comments ____________________

____

Are the filters clean Yes ❑ No ❑

Are the filters properly fitted for this unit Yes ❑ No ❑

9. Is there a **grease filter** installed in the kitchen exhaust port? Yes ❑ No ❑

   What type of filter is installed? ____________________

   Has the filter been cleaned? Yes ❑ No ❑

10. Have bird screens been installed in the HRV supply and exhaust hoods? Yes ❑ No ❑

    Size of mesh: ____________

    Accessibility: ____________

    Removable: Yes ❑ No ❑

11. Is the condensate tube trapped? Yes ❑ No ❑

    Is there water in the trap? Yes ❑ No ❑

F. FANS AND MOTORS AND DEFROST MECHANSIM

12. **Fan:**

    Accessibility: ____________

    Condition: ____________

    Specs: ____________

13. **Motor**:

    Size of Motor: ____________

    Is it working? Yes ❑ No ❑

    Condition: ____________

    Does the motor require oiling Yes ❑ No ❑ Maybe ❑

    Notes: ____________________

    ____

13a. **Defrost Mode**:

    Describe the defrost mode: ____________________

    ____

    Is it working? Explain if not working. ____________________

    ____

    Note any spillage susceptible appliances: ____________________

F. CONDITION OF DUCT SYSTEM

14. Sizing - Is ductwork sized according to applicable Building Code? Yes ❑ No ❑

Comments: ____________________

15. Have appropriate connections been used? (Hoods, fittings, screwed together, metallic tape)

Comments: ____________________

____

16. Is the **kitchen exhaust duct** accessible for cleaning for the entire length or is a grease filter installed at the intake? Yes ❑ No ❑

Comments: ____________________

17. **Vibration Isolation**:

HRV suspended: Yes ❑ No ❑

Installed between the HRV & supply ductwork: Yes ❑ No ❑

Installed between the HRV & exhaust ductwork: Yes ❑ No ❑

Comments: ____________________

18. **Cold side ductwork:**

Ductwork insulated with vapor barrier: Yes ❑ No ❑

Do supports compress insulation excessively? Yes ❑ No ❑

Is vapor barrier sealed at header? Yes ❑ No ❑

Is ductwork excessive and or sagging? Yes ❑ No ❑

Comments: ____________________

19. **Exterior Hoods:**

Hood material: (galvanized steel, aluminum, plastic, etc.) ____________

Protected from weather Yes ❑ No ❑

Proper damper on exhaust air stream Yes ❑ No ❑

Accessible for cleaning and servicing Yes ❑ No ❑

Located where ice is not a problem Yes ❑ No ❑

Exhaust—distance above finished grade: ____________

Supply—distance above finished grade: ____________

Proximity of air intake to pollutant sources:

Item: ________________ distance from intake: ____________

Item: ________________ distance from intake: ____________

Comments: ________________________________

G. SYSTEM AIR FLOW CAPACITY

20. Flow measuring stations installed? Yes ❑ No ❑

    Accessible: Yes ❑ No ❑ ________________________

21. Balancing dampers installed in the main supply & exhaust Yes ❑ No ❑

    Appropriate locations as per CSA/F326 Yes ❑ No ❑

22. Has the HRV been balanced? Yes ❑ No ❑

    Are the measured flow rates noted on the HRV? Yes ❑ No ❑

    What are the flows indicated on the unit?

    Supply: High: ____________ Low: ____________

    Exhaust: High: ____________ Low: ____________

23. Measured flow rates as found:

    Furnace Fan ON:

    High speed: supply: ____________ exhaust: ____________

    Low speed: supply: ____________ exhaust: ____________

    Furnace Fan OFF:

    High speed: supply: ____________ exhaust: ____________

    Low speed: supply: ____________ exhaust: ____________

24. Required flow rate capacity by room count: ________________________

25. Measured flow rates as left:

Furnace Fan ON:

High speed: supply: ____________ exhaust: ____________

Low speed: supply: ____________ exhaust: ____________

Furnace Fan OFF:

High speed: supply: ____________ exhaust: ____________

Low speed: supply: ____________ exhaust: ____________

26. Has the HRV been correctly sized for this house Yes ❑ No ❑

H. COMPLIANCE WITH MANUFACTURERS & HRAI INSTALLATION INSTRUCTIONS

26. Does the installation comply with the Manufacturer's Installation instructions? Yes ❑ No ❑

Does the installation comply with the HRAI Installation instructions? Yes ❑ No ❑

Note any deficiencies:

____

____

____

____

22. Note any signs of occupant related adjustment and revision:

____

____

23. Note any deficiencies that could be a health concern and should be immediately addressed:

____

____

____

Appendix G

Occupant Survey Form and Telephone Survey Form

Coding Number: ___________

Occupant Survey
Field Survey of Heat Recovery Systems

Name: ______________________________

Street Address: ______________________________

City: ______________ Province: ____________ Postal Code: __________

Phone: home: ______________________ work: ______________________

Investigator: ______________________________

Occupant's Understanding of the Operation of their Ventilation System

1. At the time of purchase, was the operation and maintenance requirements of the heat recovery ventilator explained to you? Yes _____ No _____

2. Was literature provided with the unit? Yes _____ No _____
   Have you read it? Yes _____ No _____

3. Do you have an arrangement with a company to maintain your furnace?
   Yes _____ No _____
   If so, do they also maintain your HRV at the same time?
   Yes _____ No _____

4. Please explain your understanding of the purpose of the HRV and how it works.

   ____
   ____
   ____
   ____

5. How would you rate the air quality in your home?

   ____
   ____
   ____
   ____

6. What impact do you think your HRV has on the air quality in your home?

   ____
   ____
   ____
   ____

7. How often do you perform maintenance duties on the HRV?

- clean grease filter in kitchen	once/wk	once/month	once/yr	never
- clean HRV filters	once/wk	once/month	once/yr	never
- clean bird screens on ext. ports	once/wk	once/month	once/yr	never
- clean HRV core	once/wk	once/month	once/yr	never

8. Please state what controls you have for your HRV (eg. timer and dehumidistat). If you have a dehumidistat, please explain how it controls your HRV operation and its effect on the humidity in your home.

____

____

____

9. How is the ice build-up in the HRV core defrosted during the winter months?

____

____

HRV System Interaction with Other Systems

10. Does operating the furnace fan in conjunction with the HRV influence the effectiveness of the ventilation system? If so, how?

____

____

____

11. Could an unbalanced HRV have any negative effects, and if so what are they?
Yes _____ No _____

____

____

12. How many people interact with the HRV system? ____________________

13. Do the occupants normally use high-speed timers in the washrooms?
Yes _____ No _____

14. What do you notice about winter time humidity in your home?

Window Condensation	N/A	Most of the time	Seldom	Never
Damp Basement	N/A	Most of the time	Seldom	Never
Air Too Dry	N/A	Most of the time	Seldom	Never
Other	N/A	Most of the time	Seldom	Never

____

15. Is the HRV operated throughout the year continuously?

Spring	Continuous	Intermittent	Seldom	Never
Summer	Continuous	Intermittent	Seldom	Never
Fall	Continuous	Intermittent	Seldom	Never
Winter	Continuous	Intermittent	Seldom	Never

16. What reasons do you have for not operating the HRV on a continuous basis?

____

____

____

17. Has any component of your HRV been replaced since it was installed?

Yes _____ No _____

HRV OCCUPANT TELEPHONE SURVEY

Field Survey of Heat Recovery Ventilation Systems

HOUSE IDENTIFICATION

Name: ______
Street Address: ______
City: ______ Province: ______ Postal Code: ______
Phone: home: ______ work: ______
Investigator: ______

Date house was constructed: 19____.

Type of house:
Bungalow: ______
Split Level: ______
1-Storey: ______
2-Storey: ______

OCCUPANT'S KNOWLEDGE OF THEIR HRV SYSTEM

1. What is the purpose of your HRV?
______
______
______

2. How does you HRV work?
______
______
______

3. Can you tell if your HRV is running?
YES ______ NO ______

4. Where is your HRV located?
Floor: ______ Room: ______

5. Is your HRV connected to the furnace ductwork?
YES ______ NO ______ DON'T KNOW ______

6. Do you know if there are exhaust vents in the kitchen or washrooms that connect to the HRV?
YES ______ NO ______
______
______
______

7. Was the operation and maintenance of your HRV system ever explained and demonstrated to you?
YES ______ NO ______

8. Was an operation and maintenance manual provided with your HRV unit?
YES ______ NO ______

9. If yes, have you read it?
YES ______ NO ______

10. If no, list your reasons for not reading the manual.
______
______
______

11. If yes, were the explanations and instructions clear to you?
YES ______ NO ______

OCCUPANT'S OPERATION OF THEIR HRV SYSTEM

12. Do you operate your HRV?
YES ______ NO ______

13. If no, list your reasons for not operating your HRV.
______
______
______

14. Do you ever use different speed settings?
YES ______ NO ______

15. During the warm weather months, do you operate your HRV:
all the time ______ sometimes ______ never ______

16. If you answered "sometimes" or "never" list your reasons for not operating the HRV all the time.
______
______
______

17. During the cold weather months, do you operate your HRV?
all the time ______ sometimes ______ never ______

18. If you answered "sometimes" or "never," list your reasons for not operating the HRV all the time.
______
______
______

19. Do you have any of the following controls for the HRV in your home:

- timers or switches in washrooms?	YES ____	NO ___	DON'T KNOW____
- timers or switches in living area?	YES ____	NO ___	DON'T KNOW____
- timers or switches in kitchen?	YES ____	NO ___	DON'T KNOW____
- central dehumidistat	YES ____	NO ___	DON'T KNOW____
- dehumidistat mounted directly on the HRV	YES ____	NO ___	DON'T KNOW____

20. What purpose do the controls listed above serve?

____
____
____
____
____
____

21. Do you normally use high-speed operation timers or switches in washrooms or kitchen when required?
YES ______ NO ______

22. Do you ever adjust the dehumidistat?
YES ______ NO ______

23. Do you operate your furnace fan on:
AUTO? ______ CONTINUOUS? ______ DON'T KNOW ______

24. If "AUTO", list your reasons for not operating the fan on a continuous setting?

____
____
____
____
____
____

25. Do you know that the HRV has a defrost mechanism built in?

HRV MAINTENANCE

26. Does someone routinely perform maintenance duties on your HRV?
YES ______ NO ______

27. Is there a grease filter in the kitchen exhaust port?
YES ______ NO ______ DON'T KNOW ______

28. How often do you clean the grease filter in the kitchen exhaust port?
-every three months or more often ______
-once a year or more often ______
-never ______

29. Do you know if there are filters in your HRV?
YES ______ NO ______ DON'T KNOW ______

30. How often do you clean the filters in your HRV?
-every three months or more often ______
-once a year or more often ______
-never ______

31. Do you know where the HRV's outside intake and exhaust ports are?
YES ______ NO ______ DON'T KNOW ______

32. Do you know if the HRV ports outside are equipped with bird screens?
YES ______ NO ______ DON'T KNOW ______

33. How often do you clean the bird screens in the HRV ports outside?
-every three months or more often _____
-once a year or more often _____
-never _____

34. Do you know if there is a removable core inside the HRV?
YES _____ NO _____ DON'T KNOW _____

35. If YES, do you clean the core inside your HRV?
YES _____ NO _____

36. If YES, how often do you clean the core?
-every three months or more often _____
-once a year or more often _____
-never _____

OCCUPANT INFORMATION

37. Number of occupants: ____________________

OCCUPANT'S PERCEPTION OF INDOOR AIR QUALITY IN THEIR HOME

38. During the cold weather months, you would say the air in your home is:
very fresh? _____ acceptable? _____ stale? _____

39. During the cold weather months, you would say the humidity level in your home is:
too humid? _____ ok? _____ too dry? _____

40. During the warm weather months, you would say the air in your home is:
very fresh? _____ acceptable? _____ stale? _____

41. During the warm weather months, you would say the humidity level in your home is:
too humid? _____ ok? _____ too dry? _____

42. Do you find that excess humidity is removed at an acceptable rate from kitchen and washrooms?
YES _____ NO _____

43. Window condensation occurs:
Always _____ Sometimes _____ Never _____
When?
____
____
____

44. Do you open your windows?
YES _____ NO _____

45. If yes, why?
____
____
____

46. Have you ever noticed mould growth on your windows?
YES ______ NO ______

47. Have you ever noticed mould growth on your walls?
YES ______ NO ______

48. The basement is damp and/or musty smelling:
Always ______ Sometimes ______ Never ______
When?
____
____

49. Do you find the temperature of the air being distributed in your home
too cool? ______ comfortable? ______ too warm? ______

50. If you answered, "too cool" above, would this prompt you to turn your HRV off?
YES ______ NO ______

51. Do you find that odours generated in the home dissipate quickly?
YES ______ NO ______

52. Have you noted any other benefits from operating your HRV?
YES ______ NO ______

Please elaborate:
____
____
____