FIELD PERFORMANCE OF VARIOUS TYPES OF RESIDENTIAL MECHANICAL VENTILATION SYSTEMS

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SUMMARY

Tracer gas tests and air distribution measurements were conducted in three new, energy efficient houses to evaluate the performance of their mechanical ventilation systems and to determine their compliance with the major ventilation requirements of CSA Standard F326 "Residential Mechanical Ventilation Systems". By adjusting the configuration and/or operation of the mechanical systems, five types of systems were studied:

a) Forced air heating system with exhaust-only ventilation
b) Forced air heating system with partially balanced ventilation
c) Baseboard heating system with exhaust-only ventilation
d) Baseboard heating systems with partially balanced ventilation
e) Baseboard heating system with supply-only ventilation

Each system was tested for compliance with the three major ventilation air flow rate requirements of CSA F326: i) the Minimum Ventilation Capacity for Dwelling Units, ii) the Minimum Ventilation Capacity for Rooms and iii) the Exhaust from Kitchens and Bathrooms.

The field tests confirmed that all five types of systems were able to satisfy the Minimum Ventilation Capacity for Dwelling Units requirement. The two systems intended for houses with forced air heating (a and b) were also able to meet the Minimum Ventilation Capacity for Rooms requirement because of the high air recirculation rates produced by the furnace blowers. In contrast, the three systems intended for baseboard heated houses (c, d and e) were unable to meet the room air flow rate requirement, despite having sufficient system capacity. This was viewed as a significant finding which supported the argument that houses using baseboard or radiant heating systems require dedicated ventilation ductwork systems, or equivalent, to meet the distribution requirements of CSA F326.

The systems' ability to meet the Exhaust from Kitchens and Bathrooms requirement was evaluated for four of the systems described above. Only one was able to meet the criteria with the others failing due to a combination of duct leakage and incorrect flow distribution. However, it was felt that this deficiency could have been corrected by better balancing of the exhaust air from the kitchen and bathroom.

Using data from the baseboard heating system with supply-only ventilation, comparisons were made between the measured and design ventilation system flow rates to individual rooms. In general, the agreement was found to be poor. Main floor rooms were inadequately ventilated while the basement received excessive air flow. Attempts to rectify the problem through careful sealing of the ductwork (located in the basement) were unsuccessful.

The magnitude of air leakage from the ventilation system ductwork was measured and found to range up to 35% of the total flow when the ductwork was sealed to "contractor standards". An experiment was carried out in one house to determine the effects of high quality sealing of the HRV ductwork; this reduced the leakage on the supply side from 22% to 13% and from 35% to 23% on the exhaust side.

The position of the interior doors was not found to have a significant impact on ventilation system performance for either the forced air heating systems (which were also equipped with return grilles in each room) or the systems intended for baseboard heated houses.

Tests were conducted on one of the exhaust-only ventilation systems, which was equipped with a make-up air duct connected to the low static end of the return air plenum. These revealed that roughly half the ventilation air was provided by envelope leakage with the remainder entering through the duct. Air flow rates through the make-up air duct, for this configuration, were unaffected by operation of the furnace blower.

This work was performed as part of the Flair Homes Energy Demo/ Canadian Home Builders Association Flair Mark XIV Project.

RÉSUMÉ

On a mené des essais de dépistage au gaz et effectué des mesures de la distribution de l'air dans trois (3) maisons à haut rendement énergétique neuves afin d'évaluer le rendement de leurs installations de ventilation mécanique et de déterminer leur degré de conformité aux exigences générales de ventilation de la norme CSA F326 («Ventilation des habitations»). On a étudié cinq (5) types d'installation de chauffage en modifiant leur configuration et/ou leur mode d'exploitation:

a) à air chaud pulsé, avec ventilation d'extraction seulement;
b) à air chaud pulsé, avec ventilation partiellement équilibrée;
c) à plinthes chauffantes, avec ventilation d'extraction seulement;
d) à plinthes chauffantes, avec ventilation partiellement équilibrée;
e) à plinthes chauffantes, avec ventilation d'air fourni seulement.

On a mis à l'essai chaque installation pour en vérifier la conformité aux trois principales exigences en termes de débit d'air de ventilation de la norme CSA F326: i) le débit unitaire de base pour l'unité d'habitation, ii) le débit unitaire de base pour les pièces habitables, et iii) l'extraction de l'air des cuisines et des salles de bain.

Les essais sur le terrain ont confirmé que les cinq types d'installation pouvaient répondre aux exigences de débit unitaire de base pour l'unité de logement. Les deux installations conçues pour des habitations avec chauffage à air chaud pulsé (a et b) étaient également en mesure de répondre aux exigences relatives au débit unitaire de base pour les pièces, grâce aux taux élevés de reprise d'air produits par les ventilateurs d'appareil de chauffage. Par contre, les trois installations conçues pour des habitations avec chauffage par plinthes chauffantes (c, d et e) ne pouvaient répondre aux exigences de débit d'air des pièces, malgré que leur puissance était suffisante. Ces résultats furent jugés significatifs et viennent étayer l'argument selon lequel les maisons avec installations de chauffage à plinthes chauffantes ou par rayonnement doivent être dotées de réseaux de conduits de ventilation réservés, ou l'équivalent, pour pouvoir répondre aux exigences de la norme CSA F326 relatives à la distribution de l'air.

On a évalué la capacité de quatre (4) des installations ci-dessus à répondre aux exigences relatives à l'extraction de l'air des cuisines et des salles de bain. Seulement une (1) de ces installations a pu satisfaire à la norme, les autres ayant échoué à cause de fuites de conduit alliées à une distribution inappropriée du débit. Cependant, on a estimé que cette carence aurait pu être corrigée par un meilleur équilibrage de l'air d'extraction provenant de la cuisine et de la salle de bain.

À l'aide de données issues des installations à plinthes chauffantes avec ventilation de type à extraction seulement, on a établi des comparaisons entre les débits d'air, mesurés et de calcul, des installations de ventilation selon les pièces individuelles. En général, l'argument s'est avéré insuffisant. Les pièces du rez-de-chaussée étaient ventilées de façon inappropriée tandis que le sous-sol recevait un débit d'air excessif. Les tentatives apportées en vue de remédier au problème en scellant avec soins le réseau de conduits (situé dans le sous-sol) se sont révélées infructueuses.

On a mesuré l'ampleur du taux de fuite d'air du réseau de conduits des installations de ventilation, qui se sont élevées à 35 % du débit total, lorsque le réseau était scellé selon les «normes de l'entrepreneur». On a mené une expérience dans une maison en vue de déterminer l'incidence d'un scellement de haute qualité du réseau de conduits des ventilateurs extracteurs de chaleur; le taux de fuite a ainsi été réduit de 22 % à 13 %, du côté alimentation, et de 35 % à 23 %, du côté évacuation.

On a constaté que l'emplacement des portes intérieurs ne semblait pas avoir d'incidence significative sur le rendement des installations de ventilation des systèmes à air chaud pulsé (qui étaient également dotés de grilles de reprise pour chaque pièce) comme des systèmes conçus pour des maisons chauffées par plinthes.

On a mené des essais sur une des installations de ventilation d'extraction seulement, qui était munie d'un réseau de conduits d'air de compensation relié à l'extrémité basse pression statique du plénum de reprise d'air. Selon les résultats de ces essais, environ la moitié de l'air de ventilation était fourni par les fuites au niveau de l'enveloppe du bâtiment, l'autre moitié étant constituée de l'air qui pénètre par le réseau de conduits. Pour cette configuration, les taux de débit d'air par les conduits d'air de compensation n'étaient pas modifiés par le fonctionnement du ventilateur de l'appareil de chauffage.

Ces travaux ont été menés dan le cadre du Projet de démonstration de la maison à haut rendement énergétique/Mark XIV de l'ACCH, de Flair Homes.

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SECTION 1

INTRODUCTION

1.1 HISTORICAL PERSPECTIVE

Although residential mechanical ventilation systems have been in common use for many years, most early systems suffered from inadequate capacity, poor air distribution and a limited capability for continuous operation. In addition, design procedures were often poorly applied and, in some cases, not applied at all resulting in systems which were "installed but not designed". Fortunately, significant strides have been made in the development of ventilation products, systems and design procedures.

This trend has also been reflected in the development of better standards for residential ventilation systems. The 1980 National Building Code of Canada required that ventilation air (i.e outdoor air) be supplied to each dwelling unit by natural or mechanical means for houses heated with fuel-fired equipment (NBC 1980). This requirement could be met through the use of operating windows or by exhaust fans in rooms without windows. Implicit in the code requirement was the assumption that a significant portion of the ventilation air would be supplied by natural infiltration through the building envelope. However, during the 1980's it was recognized that Canadian housing was becoming increasingly airtight and that natural leakage was unable to supply ventilation needs. As a result, the next edition of the NBC, published in 1985, required all dwelling units to have a mechanical ventilation system capable of providing 0.5 ac/hr (air changes per hour) of outdoor air (NBC 1985). The current edition of the NBC, published in 1990, was modified slightly to reduce the ventilation capacity to 0.3 ac/hr (NBC 1990). One criticism of the 1990 NBC has been the absence of provisions for distribution of the ventilation air.

A major force in the development of ventilation standards has been the R-2000 Program which introduced ventilation requirements based on ASHRAE 62-81, "Ventilation for Acceptable Indoor Air Quality" (ASHRAE 1981). The R-2000 requirements also included provisions for air distribution and set limits upon the degree of positive and negative pressurization which the ventilation system could impose upon the building envelope (EMR 1986).

The most recent development has been the release of CSA Standard F326, "Residential Mechanical Ventilation Systems" (CSA 1991) which contains requirements for system capacity, air distribution, house pressurization/depressurization and details appropriate methods for the installation of ventilation systems and for verifying compliance. Experience is now being acquired with the application of this document.

Against this background of evolving technology and standards rests a need for a better understanding of the true performance of residential mechanical ventilation systems under real-world conditions. The work described in this report was carried out to add to that knowledge base.

1.2 PROJECT OBJECTIVES

The objectives of this study were to evaluate the performance of various types of mechanical ventilation systems under actual field conditions and to evaluate their compliance with three of the major ventilation requirements of CSA F326.

1.3 SCOPE

The study was restricted to a field analysis of ventilation system performance; it did not consider homeowner interaction with the systems nor did it deal with the impact of ventilation upon indoor air quality. These subjects are dealt with in two separate reports (Proskiw 1992).

1.4 THE FLAIR HOMES ENERGY DEMO/CHBA FLAIR MARK XIV PROJECT

The work described in this report was conducted as part of the Flair Homes Energy Demo/CHBA Flair Mark XIV Project. This project was created in 1985 to provide a demonstration of various energy conservation technologies, products and systems which might be suitable for the Canadian home building industry. The specific objectives of the project were:

1. To demonstrate and evaluate the performance of various low energy building envelope systems.

2. To demonstrate and evaluate the performance of various space heating, hot water heating and mechanical ventilation systems.

3. To transfer the knowledge gained in the project to the Canadian home building industry.

Support for the project was provided by Energy, Mines and Resources Canada under the Energy Demo Program and by Manitoba Energy and Mines under the Manitoba/Canada Conservation and Renewable Energy Demonstration Agreement (CREDA). Project management was the responsibility of Flair Homes (Manitoba) Ltd. Project monitoring and reporting were performed by UNIES Ltd., consulting engineers, of Winnipeg.

The project was also designed to provide technical support to the R-2000 Home Program, which is funded by Energy, Mines and Resources Canada and administered by the Canadian Home Builders Association (CHBA). The CHBA's "Mark XIV" designation was acquired when a major portion of the research priorities identified by the CHBA's Technical Research Committee was incorporated into the work plan.

To meet the project's objectives, 24 houses were constructed in Winnipeg by Flair Homes Ltd. and independently monitored for periods of up to three years. Their energy conservation levels ranged from those of conventional houses to those which met or exceeded the R-2000 Standard.

SECTION 2

HOUSE DESCRIPTIONS

2.1 HOUSES

The field trials were conducted in Flair project Houses #22, #23 and #24. These were new, unoccupied single-family bungalows with similar floor plans, full depth basements, main floor areas of 91 m^2 (979 ft^2) and internal volumes of about 450 m^3 (15,900 ft^3). The building envelopes incorporated various design details to minimize natural infiltration and airtightness tests were performed to verify the success of these measures. Electric space and DHW heating systems were used in all three houses. During the field trials the houses were about 95% complete, with only the carpets, plumbing and (for the tracer gas testing, discussed in Section 3) the stucco missing.

2.2 VENTILATION SYSTEMS

2.2.1 System Types

Each of the three houses was constructed with a different type of ventilation system. However, by adjusting the configuration and/or operation of the mechanical systems, it was possible to simulate and evaluate five different types of ventilation systems. These are summarized below and system layouts are shown in Figs. 1 to 5.

a) Forced Air Heating System with Exhaust-Only Ventilation
- o Tests conducted in House #22.
- o Central blower exhausting from the kitchen and bathroom.
- o Make-up air duct (127 mm or 5") connected to the return air plenum through an indirect connection.
- o Forced air furnace with a single speed blower.
- o Individual room return air grilles on the forced air system.
- o House operated under negative pressure differential.

b) Forced Air Heating System with Partially Balanced Ventilation
- o Tests conducted in House #23.
- o Balanced HRV exhausting from the bathroom and supplying into the return air plenum of the heating system through an indirect connection.
- o Kitchen range hood exhausting directly outside.
- o Forced air furnace with a multi-speed blower.
- o Individual room return air grilles on the forced air system.
- o House operated under negative pressure differential.

c) Baseboard Heating System with Exhaust-Only Ventilation
- o Tests conducted in House #22 with the furnace blower off.
- o Otherwise same as system a).

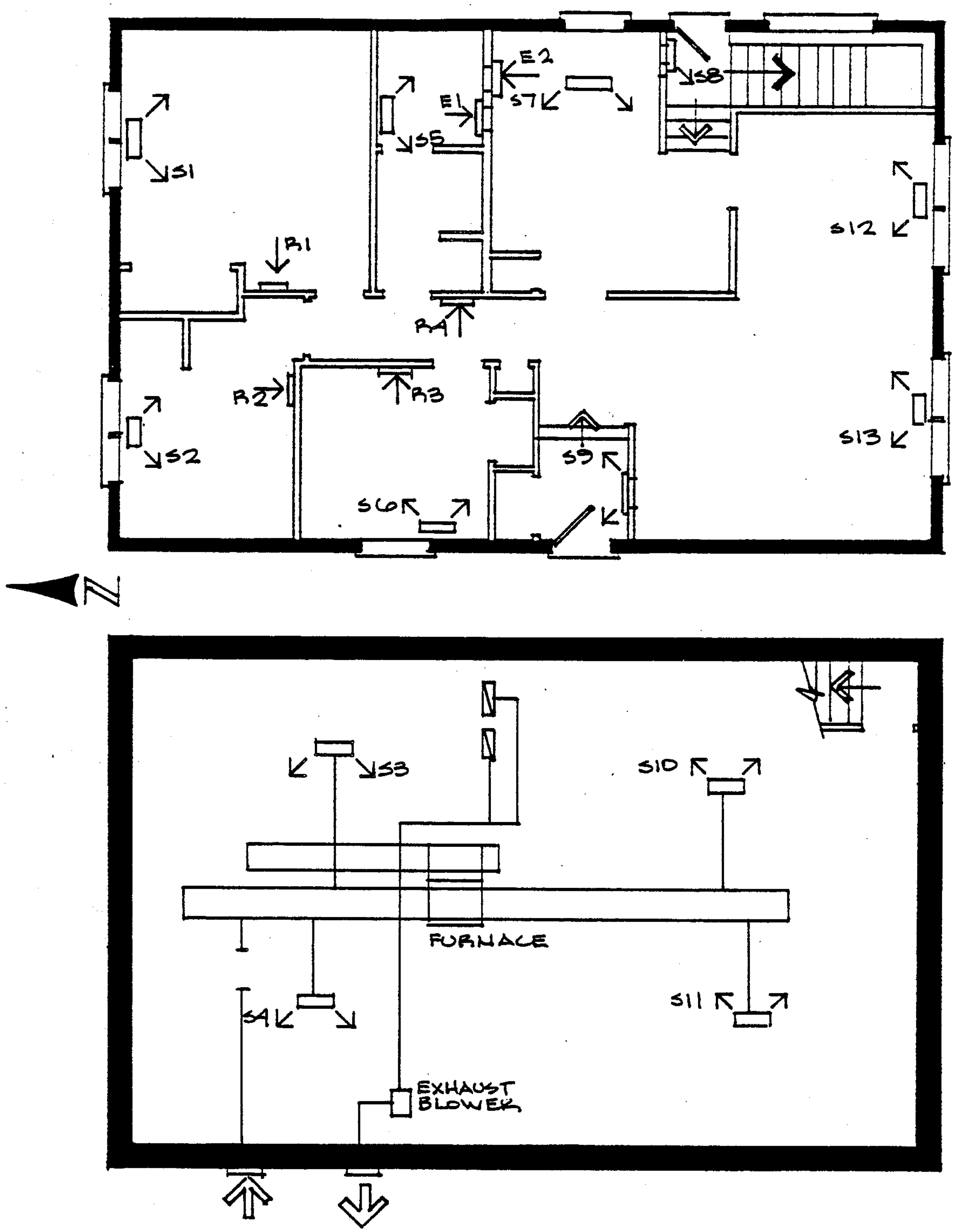
d) Baseboard Heating System with Partially Balanced Ventilation
- o Tests conducted in House #24.
- o Balanced HRV exhausting from the kitchen and supplying the main floor rooms and basement through ventilation-only ductwork.
- o Bathroom fan exhausting directly outside.
- o Electric baseboard heating.
- o House operated under negative pressure differential.

e) Baseboard Heating System with Supply-Only Ventilation
- o Tests conducted in House #24.
- o Unbalanced HRV (no exhaust) supplying main floor rooms and basement through ventilation-only ductwork.
- o Electric baseboard heating.
- o House operated under positive pressure differential.

2.2.2 Ventilation System Design

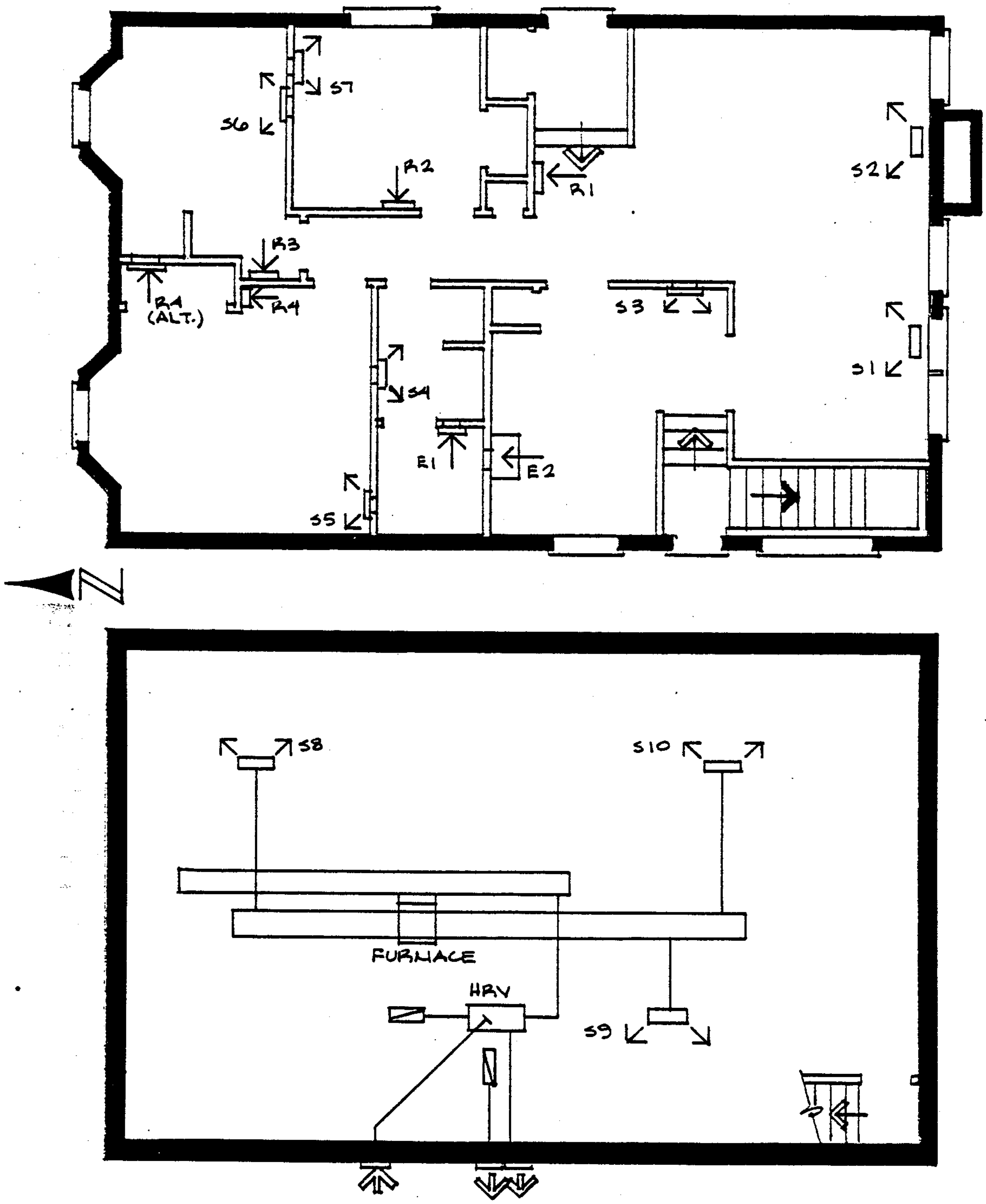
The ventilation systems were designed using the Equal Friction method to satisfy the ventilation requirements of CSA F326. This is probably the most common procedure used for residential ductwork design and is employed, in a simplified format, in the "Design and Installation Manual for Residential Mechanical Ventilation Systems" published by the Heating, Refrigerating and Air Conditioning Institute of Canada" (HRAI 1990).

The ductwork for the forced air heating systems in Houses #22 and #23 was designed by the mechanical contractor using unknown procedures. Following installation, all of the ventilation systems were commissioned by personnel from UNIES Ltd.



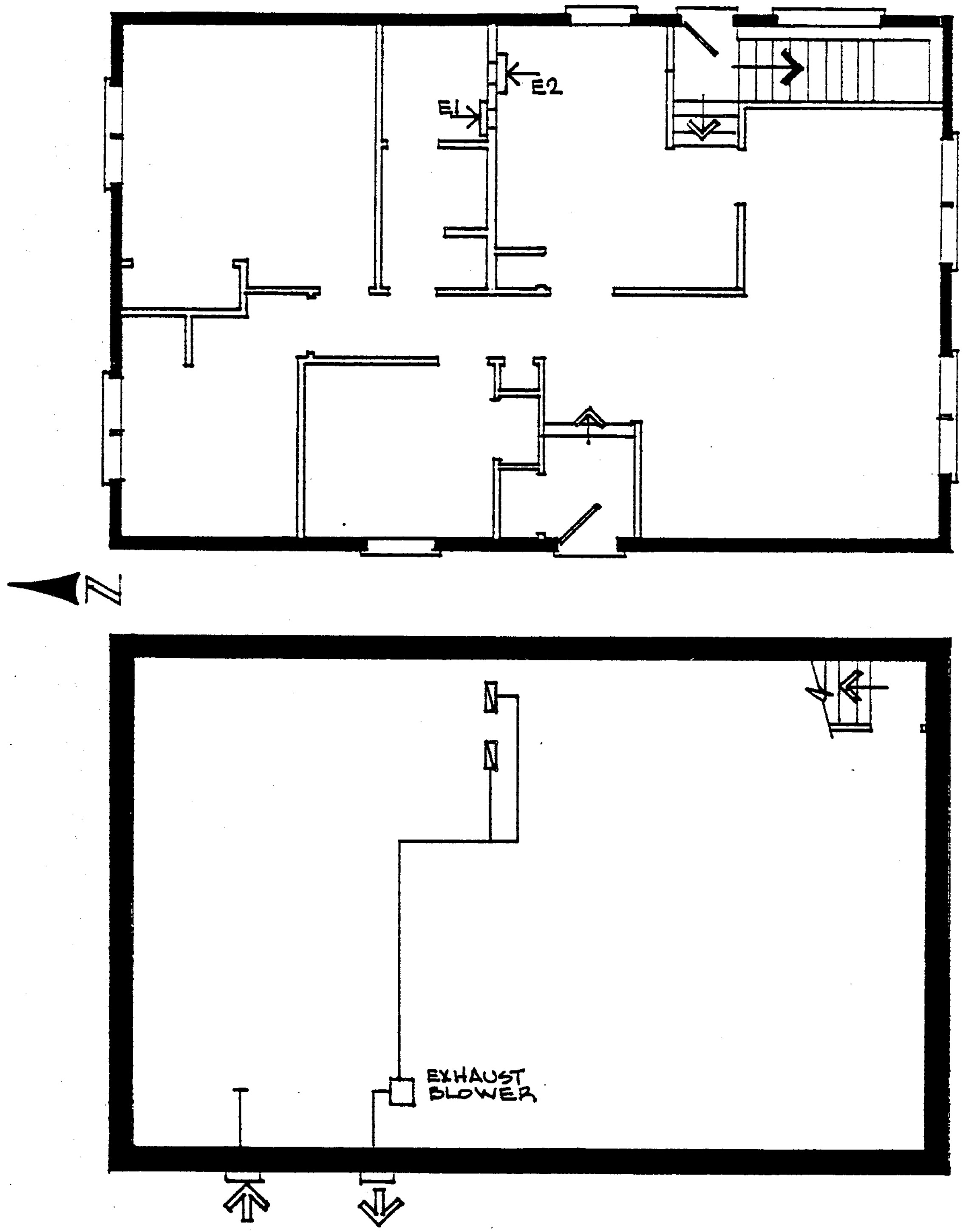
FORCED AIR HEATING SYSTEM WITH EXHAUST-ONLY VENTILATION
(HOUSE #22)

FIGURE 1



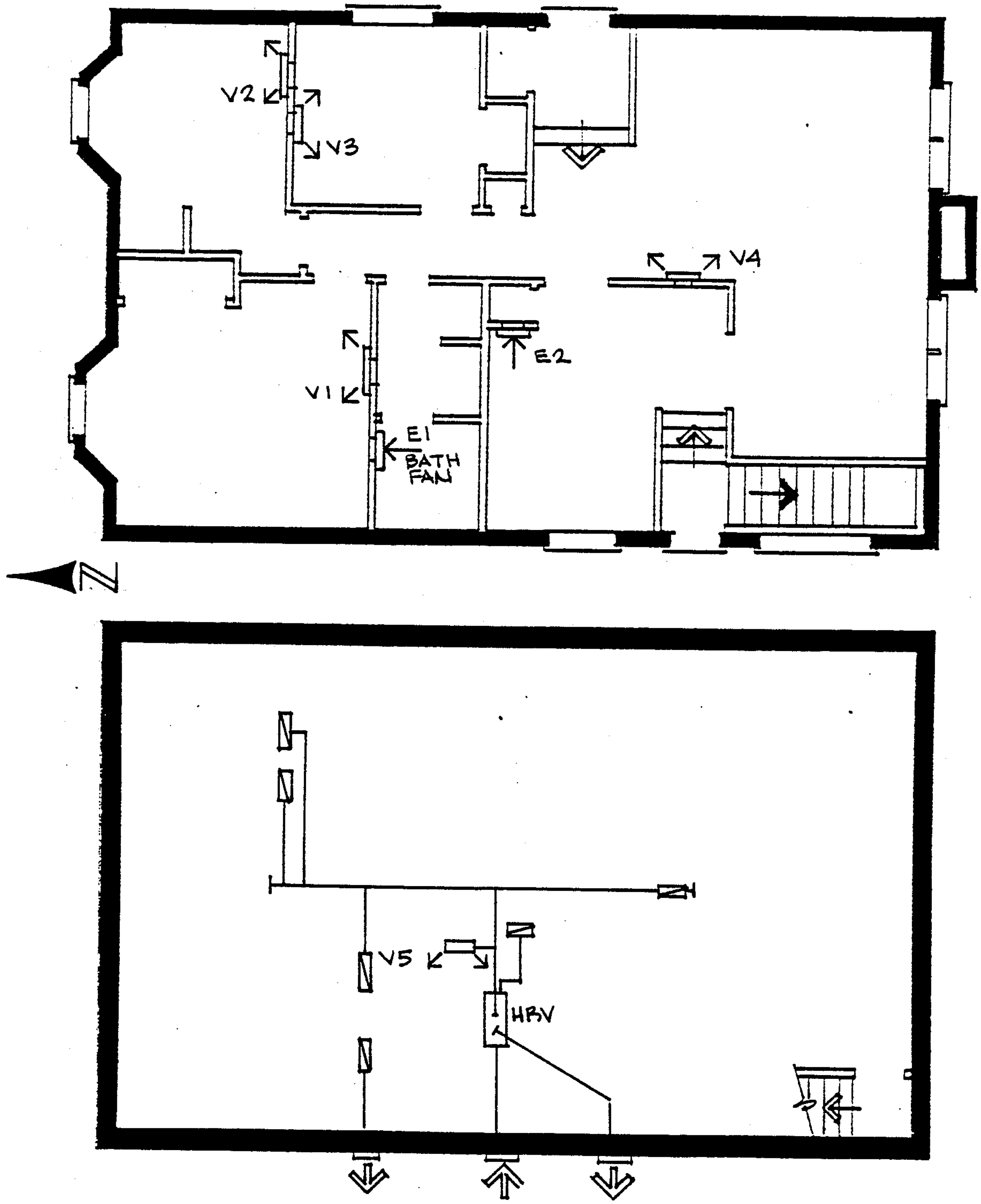
FORCED AIR HEATING SYSTEM WITH PARTIALLY BALANCED VENTILATION
(HOUSE #23)

FIGURE 2



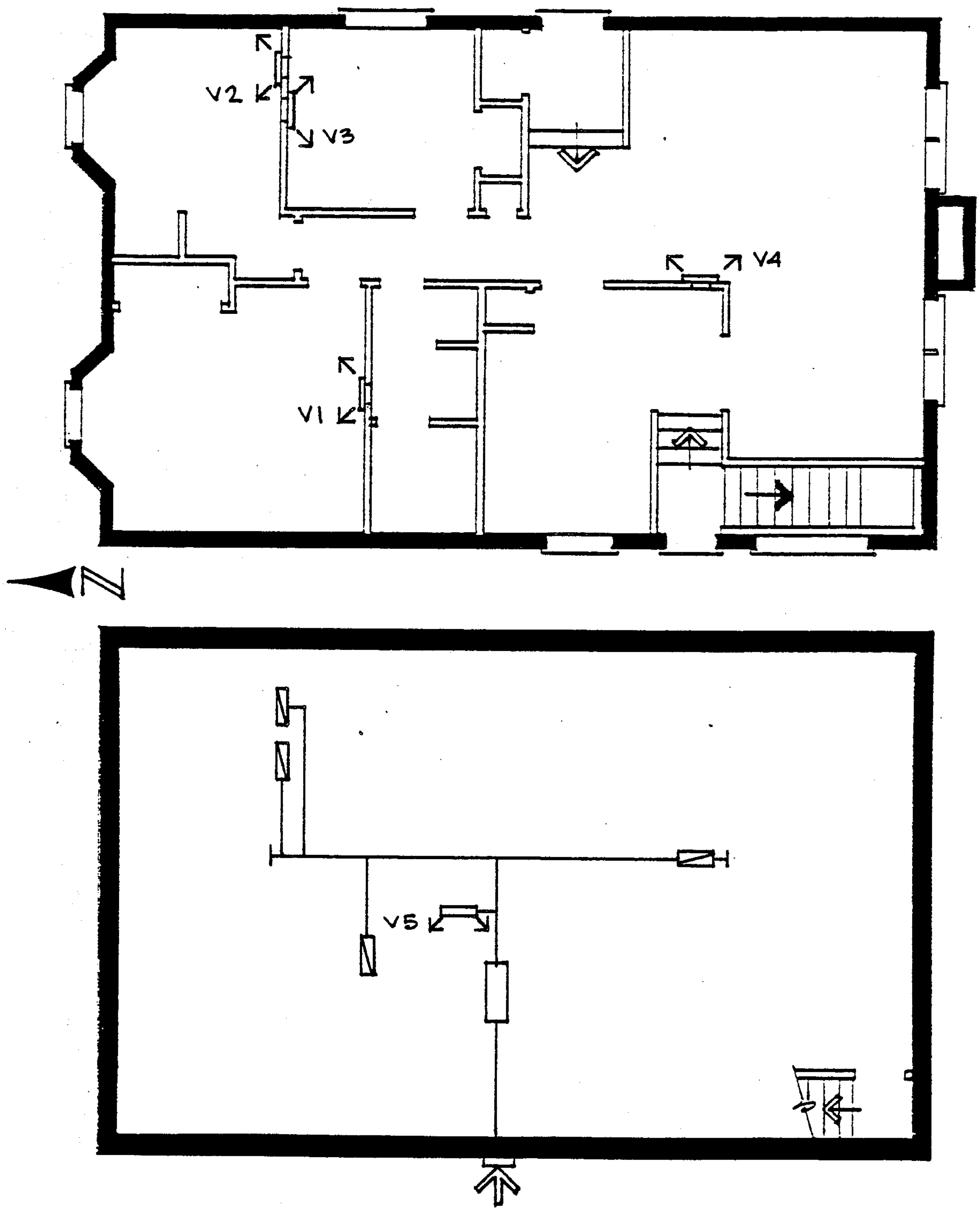
BASEBOARD HEATING SYSTEM WITH EXHAUST-ONLY VENTILATION
(HOUSE #22)

FIGURE 3



BASEBOARD HEATING SYSTEM WITH PARTIALLY BALANCED VENTILATION
(HOUSE #24)

FIGURE 4



BASEBOARD HEATING SYSTEM WITH SUPPLY ONLY VENTILATION
(HOUSE #24)

FIGURE 5

SECTION 3

MONITORING PROCEDURES

3.1 OVERVIEW

Tracer gas tests were carried out in Houses #22 and #23 while measurements of grille air flow rates were made on Houses #22 to #24. Additional flow rate data was collected using Flow Measuring Stations (FMS) installed at various locations in the ventilation ductwork. For the tests, the houses were operated in a wide range of operating configurations, i.e. with different combinations of furnace blower and exhaust fan operation, interior door position and levels of ductwork sealing.

3.2 TRACER GAS TESTING

The tracer gas decay technique with grab bag sampling was used to determine total air change rates, i.e. the combination of mechanical ventilation and natural infiltration. The field work was performed by personnel from the Institute for Research in Construction (IRC) in Saskatoon (Figley 1988). With this procedure, a volume of N_2O gas was manually injected into the house, while all the interior doors were open, until an initial concentration of roughly 100 parts per million (ppm) was attained. Approximately 15 minutes later, a one litre sample of air was collected from each of four zones (master bedroom, 2nd bedroom, remainder of the main floor, and the basement) using a hand pump and a mylar sample bag. Three additional grab samples were then taken in each zone at approximately 12 minute intervals. The interior doors were then closed and, after 15 minutes, a further four grab samples were collected at roughly 12 minute intervals. Each sample was then analyzed to determine its N_2O concentration.

Using the resulting concentration data, an exponential decay equation was produced for each zone using a linear regression analysis from which the tracer gas decay rate was calculated to give the Zone Ventilation Rate (ZVR). The ZVR was defined as the net flow of outdoor (i.e. ventilation) air delivered to each zone divided by the zone's volume:

$$ZVR = \frac{Q_z}{V_z} \qquad (1)$$

where:
Q_z = Net outdoor air flow rate to the zone (m^3/hr)
V_z = Zone volume (m^3).

The Total Ventilation Rate (TVR) of the house was then calculated by combining the four measured zone ventilation rates on a volume-weighted basis:

$$TVR = \frac{Q_t}{V_t} \qquad (2)$$

where:

Q_t = Net outdoor air flow rate to the building (m^3/hr)
V_t = Total building volume (m^3).

This technique is only capable of determining the true Zone Ventilation Rate when no inter-zone mixing takes place. For example, with a forced air heating system, tracer removed from one zone can be recirculated back to the same zone to produce a false indication of the ZVR. In this report, this quantity is termed the "apparent" ZVR. When no mixing occurs, the calculated ventilation rate can be accepted as a reasonable estimate of the true ZVR. For example, the apparent ZVR for a room without an exhaust grille, in a house equipped with a baseboard heating system and an exhaust-only ventilation system, would equal the true ZVR since all of the air entering the zone would come directly from outdoors. In such cases, this quantity is termed the "true" ZVR.

The TVR represents an explicit measure of the total indoor-to-outdoor air exchange since it is based on the total mass balance of the tracer in the building. However, it does assume perfect mixing of the tracer within the zones. In houses with high air recirculation rates, such as those with forced air heating systems, this can be regarded as a reasonable assumption. For systems without mechanical recirculation, such as with exhaust-only ventilation, mixing will be less pronounced and the tracer gas results are less reflective of actual ventilation rates.

A summary of the tracer gas results for Houses #22 and #23 is shown in Table 1 along with house airtightness results measured in accordance with CAN/CGSB Standard 149.10-M86 (1986).

3.3 GRILLE AIR FLOW RATE MEASUREMENTS

Measurements of the air flow rates were made at the supply, return and exhaust grilles using an ACIN type 153 pressure-compensated flow hood. This device uses a built-in blower to negate the internal flow resistance of the unit thereby permitting accurate flow measurements, even under low flow conditions. The measurements were made for various modes of operation of the ventilation and heating systems, with interior doors opened and closed and with the ductwork sealed to varying degrees. Summaries of the grille flow rate measurements, FMS-measured duct flow rates and the airtightness data are given in Tables 2, 3 and 4.

TABLE 1
N_2O TRACER GAS RESULTS

HOUSE #22

TEST	FURNACE BLOWER	EXHAUST FAN	INTERIOR DOORS	MAKE-UP AIR DUCT CONNECTION	ZVR MASTER BDRM. (l/s)	ZVR BDRM. #2 (l/s)	ZVR REST OF MAIN FLOOR (l/s)	ZVR BSMT. (l/s)	APPARENT OR TRUE ZVR	TVR (l/s)	TVR (ac/hr)
1	ON	ON	OPEN	INDIRECT	6.0	3.7	34.6	39.6	APPARENT	83.7	0.67
2	ON	ON	CLOSED	INDIRECT	6.4	2.1	23.4	27.5	APPARENT	59.9	0.48
3	ON	OFF	OPEN	INDIRECT	7.5	2.1	6.6	-5.2	APPARENT	11.2	0.09
4	ON	OFF	CLOSED	INDIRECT	0.3	0.1	5.1	4.6	APPARENT	10.0	0.08
5	OFF	ON	OPEN	INDIRECT	4.6	1.9	11.2	58.5	TRUE	76.2	0.61
6	OFF	ON	CLOSED	INDIRECT	2.9	2.3	24.4	44.2	TRUE	73.7	0.59
7	ON	ON	CLOSED	DIRECT	4.0	3.5	37.3	30.5	APPARENT	74.9	0.60
8	OFF	ON	CLOSED	DIRECT	2.0	1.2	22.5	57.0	TRUE	82.4	0.66

NOTES:
1. TVR and ZVR values include natural infiltration.
2. House #22 airtightness during tracer gas testing: air change rate at 50 Pascals: 1.59 ac/hr.

HOUSE #23

TEST	FURNACE BLOWER	EXHAUST FAN	INTERIOR DOORS	AIR DISTRIBUTION	ZVR MASTER BDRM. (l/s)	ZVR BDRM. #2 (l/s)	ZVR REST OF MAIN FLOOR (l/s)	ZVR BSMT. (l/s)	APPARENT OR TRUE ZVR	TVR (l/s)	TVR (ac/hr)
1	ON	OFF	OPEN	BALANCED	4.9	2.2	20.1	17.4	APPARENT	45.2	0.37
2	ON	OFF	CLOSED	BALANCED	3.0	1.8	12.3	15.2	APPARENT	31.8	0.26
3	ON	OFF	OPEN	SEE NOTE #2	4.8	2.8	24.0	10.7	APPARENT	42.8	0.35
4	ON	OFF	CLOSED	SEE NOTE #2	4.0	2.3	10.8	19.1	APPARENT	36.7	0.30
5	ON	OFF	OPEN	SEE NOTE #3	2.9	1.6	10.8	26.9	APPARENT	42.8	0.35
6	ON	OFF	CLOSED	SEE NOTE #3	3.1	1.9	16.2	16.8	APPARENT	37.9	0.31
7	OFF	OFF	OPEN	BALANCED	4.1	2.1	9.3	24.7	TRUE	40.4	0.33
8	OFF	OFF	CLOSED	BALANCED	2.0	0.8	13.2	21.9	TRUE	37.9	0.31
9	ON	OFF	OPEN	SEE NOTE #4	5.5	2.8	25.0	22.4	APPARENT	56.3	0.46
10	ON	OFF	CLOSED	SEE NOTE #4	3.5	2.2	17.6	18.0	APPARENT	41.6	0.34

NOTES:
1. TVR and ZVR values include natural infiltration.
2. Forced air system grossly unbalanced (living room and dining room supply and return grille dampers closed).
3. Return air grille in master bedroom covered and alternate return grille in closet used.
4. Air distribution balanced but all heating and ventilation ductwork in basement sealed.
5. House #23 airtightness during tracer gas testing: air change rate at 50 Pascals: 1.92 ac/hr.

TABLE 2
GRILLE AIR FLOW RATE MEASUREMENTS - HOUSE #22

TEST	FURNACE BLOWER	EXHAUST FAN	INTERIOR DOORS	DUCTWORK	EXHAUST FAN (l/s)	MAKE-UP AIR DUCT (l/s)	SUPPLY (l/s)													
							S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	SUM(S)
1	ON	OFF	OPEN	CONT-SLD	0	0	21	21	26	24	19	22	13	16	19	29	28	25	25	287
2	ON	ON	OPEN	CONT-SLD	71	34	21	20	27	25	19	22	14	16	18	32	30	25	26	294
3	OFF	ON	OPEN	CONT-SLD	70	34														
4	ON	OFF	CLOSED	CONT-SLD	0	0	22	20	30	22	17	23	16	17	20	29	29	25	26	295
5	ON	ON	CLOSED	CONT-SLD	71	38	22	20	22	24	19	24	13	15	19	32	27	25	26	289
6	OFF	ON	CLOSED	CONT-SLD	71	37														
7	ON	OFF	OPEN	SEALED	0	0	23	20	27	25	21	24	14	19	18	32	29	25	26	300
8	ON	ON	OPEN	SEALED	70	31	22	21	30	24	20	24	14	18	19	32	30	25	26	305
9	OFF	ON	OPEN	SEALED	70	30														
10	ON	OFF	CLOSED	SEALED	0	0	24	20	27	25	20	24	14	17	21	32	28	26	27	303
11	ON	ON	CLOSED	SEALED	70	29	23	20	28	24	21	25	15	18	19	30	32	25	27	305
12	OFF	ON	CLOSED	SEALED	69	28														

TABLE 2 (continued)
GRILLE AIR FLOW RATE MEASUREMENTS - HOUSE #22

TEST	RETURN (l/s) R1	R2	R3	R4	R5	SUM(R)	EXHAUST (l/s) E1	E2	SUM (E)	DUCT LEAKAGE F/A SYSTEM (MIN) (l/s)	%	EXHAUST SYSTEM (l/s)	%	SOURCE OF VENTILATION AIR FROM MAKE-UP AIR DUCT (l/s)	%	ENVELOPE LEAKAGE (l/s)	%
1	45	18	35	66	11	175	0	0	0	112	39	0	0	0		0	
2	48	18	35	66	11	178	32	23	55	N/A	N/A	16	22	34	48	37	52
3							29	22	51	N/A	N/A	20	28	34	48	36	52
4	42	18	33	75	12	180	6	0	6	115	39	N/A	N/A	0		0	
5	42	18	34	61	10	166	29	20	49	N/A	N/A	22	31	38	53	34	47
6							27	22	49	N/A	N/A	22	31	37	52	34	48
7	46	19	37	67	12	180	5	2	7	120	40	N/A	N/A	0		0	
8	44	19	39	68	11	181	32	24	56	N/A	N/A	14	20	31	44	39	56
9							32	22	55	N/A	N/A	15	22	30	43	39	57
10	42	20	37	70	11	180	5	0	5	123	41	N/A	N/A	0		0	
11	42	20	35	69	11	176	30	23	53	N/A	N/A	18	25	29	42	41	58
12							31	24	54	N/A	N/A	14	21	28	41	40	59

NOTES:
1. House #22 airtightness during grille air flow rate measurements: air change rate at 50 Pascals: 0.96 ac/hr.
2. "CONT-SLD" = Contractor sealed.
3. "Exhaust Fan" and "Make-Up Air Duct" flow rates measured using FMS.
4. Forced air (F/A) duct leakage defined as difference between supply and return grille flow rates.
5. Exhaust system duct leakage defined as difference between FMS and grille flow rates.

TABLE 3
GRILLE AIR FLOW RATE MEASUREMENTS - HOUSE #23

TEST	HRV SPEED	FURNACE BLOWER	EXHAUST FAN	INTERIOR DOORS	DUCTWORK	HRV		SUPPLY (l/s)										
						EXHAUST (l/s)	SUPPLY (l/s)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	SUM(S)
1	MAX	ON	OFF	OPEN	CONT-SLD	28	28	26	18	35	29	34	45	23	32	42	41	323
2	MAX	ON	ON	OPEN	CONT-SLD	28	28	24	18	34	29	36	46	23	32	42	41	326
3	OFF	ON	ON	OPEN	CONT-SLD	0	0	25	20	34	29	34	45	23	34	42	41	326
4	MAX	ON	OFF	OPEN	NOTE 6	28	28											
5	MAX	ON	ON	OPEN	NOTE 6	27	28											

TABLE 3 (continued)

TEST	HRV SPEED	FURNACE BLOWER	EXHAUST FAN	INTERIOR DOORS	DUCT-WORK	HRV		RETURN (l/s)						EXHAUST (l/s)			DUCT LEAKAGE			
						EXHAUST (l/s)	SUPPLY (l/s)	R1	R2	R3	R4	R6	SUM(R)	E1	E2	SUM (E)	F/A SYSTEM (MIN) (l/s)	F/A SYSTEM (MIN) %	EXHAUST AIR (l/s)	EXHAUST AIR %
1	MAX	ON	OFF	OPEN	CONT-SLD	28	28	30	38	36	28	76	206	23	0	23	117	36	5	19
2	MAX	ON	ON	OPEN	CONT-SLD	28	28	30	36	35	28	76	205	24	69	93	121	37	5	17
3	OFF	ON	ON	OPEN	CONT-SLD	0	0	32	37	34	28	74	205	0	64	64	121	37	N/A	N/A
4	MAX	ON	OFF	OPEN	NOTE 6	28	28													
5	MAX	ON	ON	OPEN	NOTE 6	27	28								66	66				

NOTES:
1. House #23 airtightness during grille air flow rate measurements: air change rate at 50 Pascals: 1.43 ac/hr.
2. "CONT-SLD" = Contractor sealed.
3. HRV flow rates measured using FMS.
4. Forced air (F/A) duct leakage defined as difference between supply and return grille flow rates.
5. Exhaust system duct leakage defined as difference between FMS and grille flow rates.
6. E2 ductwork carefully sealed.

TABLE 4
GRILLE AIR FLOW RATE MEASUREMENT - HOUSE #24

TEST	HRV SPEED	EXHAUST FAN	INTERIOR DOORS	DUCTWORK	HRV EXHAUST (l/s)	HRV SUPPLY (l/s)	VENTILATION (l/s) V1	V2	V3	V4	V5	SUM (V)	EXHAUST (l/s) E1	E2	E(E)	DUCT LEAKAGE HRV EXHAUST (l/s)	HRV EXHAUST %	HRV SUPPLY (l/s)	HRV SUPPLY %
DESIGN	HIGH	ON		CONT-SLD	50	50	10.0	5.0	5.0	20.0	10.0	50.0	0.0	50.0	50.0				
1	LOW	OFF	OPEN	CONT-SLD	33	33	2.7	3.0	3.0	9.7	8.7	27.0	0.0	24.3	24.0	8.0	26	6.0	17
2	HIGH	OFF	OPEN	CONT-SLD	44	44	4.1	3.5	4.1	13.0	13.0	38.0	0.0	31.4	31.0	12.0	28	6.0	14
3	LOW	ON	OPEN	CONT-SLD	33	35	3.0	2.7	2.7	9.5	10.8	29.0	25.7	23.8	49.0	9.0	27	6.0	17
4	HIGH	ON	OPEN	CONT-SLD	45	44	3.5	3.8	3.5	12.2	11.4	34.0	23.0	28.9	52.0	16.0	35	10.0	22
5	LOW	OFF	CLOSED	CONT-SLD	36	33	2.7	3.0	2.7	11.1	8.1	28.0	0.0	26.4	25.0	9.0	26	5.0	16
6	HIGH	OFF	CLOSED	CONT-SLD	45	43	3.2	3.2	4.1	12.4	10.8	34.0	0.0	30.3	30.0	14.0	32	9.0	21
7	LOW	ON	CLOSED	CONT-SLD	34	34	3.5	3.8	3.5	10.8	10.3	32.0	25.1	23.0	48.0	11.0	32	2.0	5
8	HIGH	ON	CLOSED	CONT-SLD	44	44	3.0	3.0	3.8	11.4	12.4	34.0	24.3	29.5	54.0	15.0	33	10.0	23
9	LOW	OFF	OPEN	SEALED	37	36	3.0	3.0	3.3	13.2	14.3	36.8	0.0	29.4	29.0	8.0	21	0.0	0
10	HIGH	OFF	OPEN	SEALED	49	50	3.8	3.8	3.8	14.3	17.6	43.4	0.0	38.2	38.0	11.0	22	7.0	14
11	LOW	ON	OPEN	SEALED	36	40	3.6	3.0	3.3	12.1	13.7	35.7	24.7	25.8	51.0	10.0	27	4.0	11
12	HIGH	ON	OPEN	SEALED	48	50	4.1	3.6	3.8	15.4	17.0	44.0	24.5	37.1	62.0	11.0	23	6.0	13
13	LOW	OFF	CLOSED	SEALED	36	36	3.3	3.0	3.3	11.0	13.7	34.4	0.0	25.3	25.0	11.0	30	2.0	5
14	HIGH	OFF	CLOSED	SEALED	50	50	4.4	4.1	3.8	14.3	17.0	43.7	0.0	36.8	37.0	13.0	27	6.0	12
15	LOW	ON	CLOSED	SEALED	36	38	3.6	3.0	3.0	11.8	13.2	34.6	24.7	26.1	51.0	9.0	27	3.0	9
16	HIGH	ON	CLOSED	SEALED	49	50	4.4	3.8	4.4	15.9	17.3	45.9	24.5	36.8	61.0	12.0	25	4.0	9
17	LOW	OFF	SEALED	SEALED	37	37	3.3	2.7	3.0	12.1	13.2	34.4	0.0	28.6	29.0	9.0	23	3.0	7
18	HIGH	OFF	SEALED	SEALED	50	49	4.4	3.8	3.8	15.9	16.8	44.8	0.0	37.4	37.0	12.0	25	4.0	9
19	LOW	OFF	OPEN	SEALED	0	44	4.1	3.3	3.3	13.2	16.8	40.7	0.0	0.0	0.0	N/A	N/A	3.0	7
20	HIGH	OFF	OPEN	SEALED	0	50	4.4	3.8	3.6	16.4	17.6	44.8	0.0	0.0	0.0	N/A	N/A	5.0	11
21	LOW	OFF	CLOSED	SEALED	0	43	3.8	3.3	3.0	13.2	17.0	40.4	0.0	0.0	0.0	N/A	N/A	2.0	6
22	HIGH	OFF	CLOSED	SEALED	0	50	4.1	3.6	3.8	15.9	18.7	46.2	0.0	0.0	0.0	N/A	N/A	4.0	7

NOTES:

1. House #24 airtightness during grille air flow rate measurements: air change rate at 50 Pascals: 1.39 ac/hr.
2. "CONT-SLD" = Contractor sealed.
3. HRV flow rates measured using FMS.
4. HRV duct leakage defined as difference between FMS and grille flow rates.
5. Tests #17 and #18: Bedroom partition walls taped to sub-floor to simulate carpet, no obvious cracks in sub-floor. Bedroom door undercuts sealed.
6. Tests #19 to #22: HRV exhaust line sealed shut.

SECTION 4

COMPLIANCE WITH THE VENTILATION REQUIREMENTS OF CSA F326

4.1 OVERVIEW OF THE VENTILATION REQUIREMENTS OF CSA F326

CSA Standard F326 "Residential Mechanical Ventilation Systems" has three major requirements pertaining to system capacity and distribution:

1. Minimum Ventilation Capacity for Dwelling Units (clause 5.1)
   The ventilation system must have the capacity to provide a minimum amount of outdoor air depending on the number and type of rooms with a lower default limit of 0.3 ac/hr. In most houses, the system capacity would be in the order of 0.4 to 0.5 ac/hr. The standard does not imply continuous operation of the ventilation system, but only stipulates the required capacity.

2. Minimum Ventilation Capacity for Rooms (clause 5.2)
   The ventilation system must be able to distribute the fresh air to all major rooms in the house with the room ventilation rates conforming to the minimum values shown in Table 5. For recirculation systems, such as forced air heating systems, the fresh air can be distributed by the furnace blower provided specific minimum flow rates are attained as detailed in the standard. With a baseboard or radiant heating system, it would generally necessary to install a dedicated ventilation-only ductwork system to insure proper room ventilation.

3. Exhaust from Kitchens and Bathrooms (clause 5.4)
   The ventilation system must have the capability to exhaust air from kitchens and bathrooms at rates of 50 l/s and 25 l/s respectively on an intermittent basis or 30 l/s and 10 l/s respectively on a continuous basis.

The standard contains other requirements, such as those relating to pressurization/depressurization limits and compliance testing, but these were not investigated in this study.

The remainder of this section reviews the performance of the five types of ventilation system types described in Section 2 with respect to their compliance with the three requirements discussed above.

TABLE 5
CSA F326 MINIMUM VENTILATION AIR REQUIREMENTS

Space Classification	Column 1 Base Flow Rate (l/s)	Column 2 Intermittent Exhaust (l/s)	Column 3 Continuous Exhaust (l/s)
Category A			
Master Bedroom	10	---	---
Basement	10	---	---
Single Bedrooms	5	---	---
Living Room	5	---	---
Dining Room	5	---	---
Family Room	5	---	---
Recreation Room	5	---	---
Other	5	---	---
Category B			
Kitchen	5	50	30
Bathroom	5	25	10
Laundry	5	---	---
Utility Room	5	---	---

4.2 FORCED AIR HEATING SYSTEM WITH EXHAUST-ONLY VENTILATION

Minimum Ventilation Capacity for Dwelling Units

F326 requirement: 50 l/s (0.40 ac/hr)
Measured capacity: 71 l/s (0.57 ac/hr), (see Test 2 in Table 2)
F326 compliance: Satisfied

Minimum Ventilation Capacity for Rooms

Measured capacity: Measured supply air flow rates exceeded F326 requirements for all rooms (see Test 2 in Table 2)
F326 compliance: Satisfied

Exhaust from Kitchens and Bathrooms

Measured capacity: 23 l/s, kitchen
32 l/s, bathroom (see Test 2 in Table 2)
F326 compliance: Not satisfied for the kitchen

The requirement for Exhaust from Kitchens and Bathrooms was not met because of the slightly low exhaust rate from the kitchen. This could have been corrected by better balancing of the exhaust air from the kitchen and bathroom.

4.3 FORCED AIR HEATING SYSTEM WITH PARTIALLY BALANCED VENTILATION

Minimum Ventilation Capacity for Dwelling Units

F326 requirement: 50 l/s (0.41 ac/hr)
Measured capacity: 93 l/s (0.76 ac/hr), with kitchen fan running, (see Test 2 in Table 3)
F326 compliance: Satisfied

Minimum Ventilation Capacity for Rooms

Measured capacity: Measured flow rates exceeded F326 requirements for all rooms (see Test 2 in Table 3)
F326 compliance: Satisfied

Exhaust from Kitchens and Bathrooms

Measured capacity: 69 l/s, kitchen
24 l/s, bathroom (see Test 2 in Table 3)
F326 compliance: Satisfied

4.4 BASEBOARD HEATING SYSTEM WITH EXHAUST-ONLY VENTILATION

Minimum Ventilation Capacity for Dwelling Units

F326 requirement: 50 l/s (0.40 ac/hr)
Measured capacity: 70 l/s (0.56 ac/hr), (see Test 3 in Table 2)
F326 compliance: Satisfied

Minimum Ventilation Capacity for Rooms

Measured capacity: Well below minimums for all main floor rooms, basement OK (see Test 5 in House #22 in Table 1)
F326 compliance: Not satisfied

Exhaust from Kitchens and Bathrooms

Measured capacity: 22 l/s, kitchen
29 l/s, bathroom (see Test 3 in Table 2)
F326 compliance: Not satisfied

The room flow rates were calculated from the tracer gas data using the true ZVR data for two of the bedrooms and the basement. Air flow rates to the two bedrooms were 46% and 38% of that required by CSA F326 whereas the basement was heavily over-ventilated. In fact, the mechanically delivered air flows to the main floor rooms were slightly lower than those shown in Table 1 since the tracer gas data includes natural infiltration (although this would have been minimal given the weather conditions), whereas F326 pertains only to mechanical ventilation. The requirement for Exhaust from Kitchens and Bathrooms was not met because of the low exhaust rate from the kitchen.

4.5 BASEBOARD HEATING SYSTEM WITH PARTIALLY BALANCED VENTILATION

Minimum Ventilation Capacity for Dwelling Units

F326 requirement: 50 l/s (0.40 ac/hr)
Measured capacity: 68 l/s (0.54 ac/hr), (see Test 4 in Table 4)
F326 compliance: Satisfied

Minimum Ventilation Capacity for Rooms

F326 compliance: Could not be conclusively determined from the grille air flow data however several main floor rooms, including the master bedroom appear to have been underventilated (see Test 4 in Table 4).

Exhaust from Kitchens and Bathrooms

Measured capacity: 29 l/s, kitchen
23 l/s, bathroom (see Test 4 in Table 4)
F326 compliance: Not satisfied

The grille air flow rate data does not include ventilation due to envelope leakage so a positive evaluation of compliance with the Minimum Ventilation Capacity for Rooms requirement could not be made. However, since the measured master bedroom supply air flow rate was only 35% of the design value, it appears unlikely that this requirement was satisfied. The requirement for Exhaust from Kitchens and Bathrooms was not met because of the low exhaust rate from the kitchen.

4.6 BASEBOARD HEATING SYSTEM WITH SUPPLY-ONLY VENTILATION

Minimum Ventilation Capacity for Dwelling Units

F326 requirement: 50 l/s (0.40 ac/hr)
Measured capacity: 50 l/s (0.40 ac/hr), (see Test 20 in Table 4)
F326 compliance: Satisfied

Minimum Ventilation Capacity for Rooms

Measured capacity: Below minimums for all main floor rooms, basement OK, (see Test 20 in Table 4)
F326 compliance: Not satisfied

Exhaust from Kitchens and Bathrooms

Measured capacity: Not evaluated

4.7 GENERAL OBSERVATIONS

The field trials provided several interesting observations, however it should be remembered that these were singular experiences and do not provide definitive statements on the ability of each system type to meet CSA F326.

- The Minimum Ventilation Capacity for Dwelling Units requirement was met by all five systems indicating the design method coupled with proper commissioning procedures provided a satisfactory means of attaining this goal.

- The two ventilation systems intended for houses with forced air heating were able to meet the Minimum Ventilation Capacity for Rooms requirement because of the high recirculation rate produced by the furnace blowers.

- The two baseboard heating systems with exhaust-only or supply-only ventilation did not meet the Minimum Ventilation Capacity for Rooms requirement. The tests also suggested that the baseboard heating system with partially balanced ventilation was unable to meet this goal. These are regarded as significant findings which support the argument that dedicated ventilation ductwork systems, or equivalent, will be required in houses using baseboard or radiant heating systems to meet CSA F326. Although this does not guarantee complete compliance, as evidenced by the baseboard heating system with supply-only ventilation (Section 4.6), it does improve room flows relative to those achieved without a distribution system.

- Three of the four systems (which could be evaluated) were unable to meet the Exhaust from Kitchens and Bathrooms requirement because of duct leakage and incorrect flow distribution between the two rooms.

- Significant leakage was found from the forced air heating system ductwork. Comparisons of the total supply and return grille flow rates showed that typically over 40% of the furnace air flow ended up as leakage.

SECTION 5

MEASURED VS. DESIGN VENTILATION SYSTEM FLOW RATES

5.1 DESIGN AND INSTALLATION OF THE VENTILATION SYSTEMS

The three houses contained five types of air handling devices intended to provide ventilation: a central exhaust blower in #22, a kitchen range hood in #23, a bathroom exhaust fan in #24 and the HRV's in #23 and #24. These systems were designed in accordance with good engineering practice, installed by an experienced mechanical contractor and properly commissioned - an ideal situation from a quality control perspective. To evaluate the success of the system design and installation procedures, the measured air flow rates were compared to the design values and their corresponding distribution patterns. Results of this analysis are summarized in Table 6.

5.2 ABILITY TO MEET THE DESIGN AIR FLOW RATES

Two of the three exhaust systems achieved their design flow rates although in House #22 this required duct leakage to be included. The third system ran at slightly below the design value although this probably resulted from measurement discrepancies between commissioning and monitoring; the system was thus judged to have had adequate capacity. With respect to the HRV systems, the ratio of measured-to-design flow rates was 0.7 in House #23 and 0.9 in House #24.

5.3 VENTILATION DUCTWORK LEAKAGE

Duct leakage between the exhaust grilles and the Flow Measuring Stations, located close to the point where the ductwork exited the building, was measured and found to range up to 35% of the FMS flow rate with the ductwork sealed to "contractor standards", i.e. only major, obvious joints taped (see Tables 2, 3 and 4). To study the effect of "high quality" sealing, the HRV ductwork in House #24 was sealed with duct tape and a paint-on product normally used in commercial applications. Sixty-three circumferential joints in the ductwork were carefully sealed, requiring approximately one man-hour to complete. This effort was found to be moderately successful and reduced leakage on the supply side from 22% to 13% and on the exhaust side from 35% to 23%.

5.4 VENTILATION AIR DISTRIBUTION

Since house #24 used a dedicated ventilation-only system, it was possible to compare the measured and design ventilation rates for each room. As shown in Table 4 (Test 4), the measured and design rates agreed rather poorly. Main floor rooms were all under-ventilated with the master bedroom receiving about one-third of its design flow rate. In contrast, the basement was over-ventilated. Also, these figures do not include the effects of duct

TABLE 6
MEASURED VS. DESIGN FLOW RATES

SYSTEM	DESIGN FLOW RATE (l/s)	MEASURED FLOW RATE (l/s)		RATIO OF MEASURED/DESIGN	NOTES
		GRILLE	FMS		
Central Exhaust (House #22)	75	55	71	1.0	Excess System Capacity, Flow Dampered Down
Kitchen Range Hood (House #23)	50	69		1.4	Excess Capacity, No Damper
Bathroom Exhaust Fan (House #24)	25	23		0.9	Adequate Capacity, Flow Dampered Down
Heat Recovery Ventilator (House #23)	38	24	28	0.7	Inadequate System Capacity
Heat Recovery Ventilator (House #24)	50	29	45	0.9	Inadequate System Capacity

leakage which would have provided additional air flow to the basement. Careful sealing of the ductwork did not correct the poor distribution although the total flow capacity did increase with much of the extra air going to the basement.

This could have been corrected by keeping the basement supply grilles closed and then allowing the basement to be supplied via duct leakage.

SECTION 6

EFFECT OF INTERIOR DOOR POSITION

6.1 SIGNIFICANCE OF INTERIOR DOOR POSITION

A ventilation system must be capable of functioning under various house conditions, including a situation in which the interior doors are closed for extended periods. In particular, the Zone Ventilation Rates should not be adversely affected by door position. This issue was investigated by measuring the ventilation systems' performance in various modes of operation, with interior doors opened and closed. Results are included in Tables 1, 2 and 4. For the tests, a door undercut of approximately 25 mm (1") was used. Since carpets and underlay were not installed at the time of testing, 13 mm (1/2") particleboard sheets were placed on the thresholds of interior doorways to simulate their effects.

6.2 FORCED AIR HEATING SYSTEMS

The grille air flow rates were measured in House #22 using four mechanical system configurations and were generally found to be unaffected by interior door position. Total Ventilation Rates, calculated from the tracer gas data, for Houses #22 and #23, gave slightly different results than the grille measurements. Three mechanical system configurations were tested in #22 and two showed no significant change in the TVR with door position. With one configuration (furnace and exhaust blowers both on), the TVR dropped by 28% when the doors were closed. In House #23, five system configurations were tested using the tracer gas method and in all cases the TVR decreased with the doors closed, by amounts ranging from 6% to 30%.

Although the evidence is not totally consistent, it suggests that the impact of interior door position upon ventilation system performance was minimal in the forced air heating systems equipped with individual room return grilles.

6.3 BASEBOARD HEATING SYSTEMS

Grille measurements were made in House #24 using ten different ventilation system configurations. House #24 used a dedicated ventilation-only ductwork system with supply grilles in each major room; exhaust air grilles were located in the kitchen and bathroom only. A further two tests were performed in which door undercuts and other visible cracks between the three bedrooms and the rest of the house were sealed to create a worst-case situation for air distribution since these rooms normally relied on inter-zone leakage for air circulation. The grille flow rate and FMS measurements showed that door position did not have a significant effect on either the Total Ventilation Rate or the Zone Ventilation Rates, particularly in the three bedrooms. Even in the extreme case with door undercuts and other cracks sealed, flow rates were not significantly affected.

These results indicate that the position of the interior doors had a minimal impact on ventilation system performance in the houses equipped with baseboard heating systems.

SECTION 7

MAKE-UP AIR DUCT PERFORMANCE

7.1 EVALUATION

Make-up air ducts supply ventilation air to the house by utilizing the static pressure created by the furnace blower. They are typically connected from the outdoors to a convenient point on the return air plenum; flow measuring capability is seldom included so the installed performance is usually unknown. The performance of the make-up air duct in House #22 was evaluated by measuring the amount of ventilation air entering through the duct and comparing it to that drawn in through the envelope. The distribution between these two normally depends on several factors including the house airtightness, equivalent length of the make-up air duct and the static pressure produced by the furnace blower. House #22 used a 127 mm (5") duct with an exterior hood and screen, damper and Flow Measuring Station connected to a boxed-in floor joist space which was in turn connected to the return air plenum. The top half of the metal duct was cut away for a 0.3 m (1') section to create an indirect connection. The equivalent length from the outdoors to the boxed-in joist space was calculated to be 23 m (76'). The connection point on the return plenum was near the end of the duct, i.e relatively far from the furnace, which while not uncommon, is not the ideal situation since the available static pressure is small. (Connections in close proximity to the furnace are also to be avoided because of the thermal shock which outdoor air can induce upon the unit).

7.2 SOURCES OF VENTILATION AIR

For the design condition shown in Table 2 (Test 2), the sources of ventilation air were found to be roughly equally divided between the make-up air duct and envelope leakage. Also, as shown by the other test results in Table 2, this distribution was reasonably consistent regardless of the mechanical system configuration, interior door position or the extent of ductwork sealing.

SECTION 8

CONCLUSIONS

8.1 COMPLIANCE WITH THE VENTILATION REQUIREMENTS OF CSA F326

- o The five types of mechanical ventilation systems studied were all able to satisfy the CSA F326 Minimum Ventilation Capacity for Dwelling Units requirement.

- o The ventilation systems intended for forced air heating systems were able to meet the Minimum Ventilation for Rooms requirement because of the large air recirculation rates produced by the furnace blowers.

- o The baseboard heating system with exhaust-only ventilation (i.e. central exhaust) was unable to meet the Minimum Ventilation Capacity for Rooms requirement, even though it possessed sufficient capacity to meet the Minimum Ventilation Capacity for Dwelling Units requirement.

- o The baseboard heating system with supply-only ventilation was also unable to meet the Minimum Ventilation Capacity for Rooms requirement although the supply-only ductwork did improve room flows relative to those achieved with the (non-ducted) central exhaust system.

- o The data suggests that the baseboard heating system with partially balanced ventilation was also unable to meet the Minimum Ventilation Capacity for Rooms requirement.

- o The inability of the ventilation systems designed for houses with baseboard heating systems to meet the Minimum Ventilation Capacity for Rooms requirement supports the argument that houses which use baseboard or radiant heating systems will require dedicated ventilation ductwork, or equivalent, to meet the distribution requirements of CSA F326.

- o Three of the four systems evaluated were unable to meet the Exhaust Requirements from Kitchens and Bathrooms because of duct leakage and incorrect distribution of exhaust air between the two rooms.

8.2 MEASURED VS. DESIGN VENTILATION SYSTEM FLOW RATES

- o The measured ventilation flow rates to individual rooms in the ventilation-only ductwork system compared poorly to the design values. Main floor rooms received only a fraction of the design flow while the basement was over-ventilated. The problem was not corrected by careful sealing of the ductwork.

- o Air leakage in the ventilation systems' ductwork ranged up to 35% of the total flow when sealed to "contractor standards", i.e. only major, obvious joints sealed. Very careful sealing of the HRV ductwork in one house reduced leakage on the supply side from 22% to 13% and on the exhaust side from 35% to 23%.

8.3 POSITION OF THE INTERIOR DOORS

- o The position of the interior doors was not found to have a significant impact on ventilation system performance for either the forced air heating systems (which were also equipped with return grilles in each room) or the systems intended for baseboard heated houses.

8.4 MAKE-UP AIR DUCT PERFORMANCE

- o Tests on the exhaust-only ventilation system, with the make-up air duct connected at the low static end of the return air plenum, showed that the roughly half the ventilation air was provided by the make-up air duct and half through envelope leakage. Air flow rates through the duct, for this configuration, were unaffected by operation of the furnace blower, interior door position or the extent of ductwork sealing.

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