THE EFFECTIVENESS OF LOW - COST CONTINUOUS VENTILATION SYSTEMS

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EXECUTIVE SUMMARY

1 INTRODUCTION

CSA standard F326(1) describes requirements for mechanical ventilation systems that will in general provide adequate indoor air quality control in single family residences. When builders undertake to meet these requirements they typically choose to install heat recovery ventilators (HRV's), a very good but high first-cost approach. As a result, there is a common perception that meeting the requirements of F326 is expensive. This study was initiated to investigate some lower cost alternatives to providing adequate indoor air quality control. The need includes houses with and without forced-air distribution systems and with and without natural draft combustion appliances. Applicability to the lower cost housing market was of particular importance.

2 OBJECTIVE

The primary objective of this work was to demonstrate whether or not simple inexpensive ventilation systems can meet the intent of CSA standard F326. Secondary objectives were to determine:

(1) What ventilation rates and distribution flows are required to permit adequate indoor air quality control.

(2) What restrictions will avoid interference with other devices in the dwelling.

(3) What maintenance and operational considerations are necessary.

3 APPROACH

An overview of the approach taken to achieve the above noted objectives is presented here and details are provided in sections 4, 5 and 6. The major components of the approach are:

(1) The analysis of monitored air quality data for two residences, both with HRV's installed with distributed exhaust pick-up points (kitchen & bathrooms). In one house fresh air was distributed through the heating system duct work with a continuously operating furnace fan while in the other a single point fresh air supply was used without a mechanical air recirculation system. By examining hourly average CO_2 levels in different zones of each house, in conjunction with hourly average ventilation rates, the ~~adequacy of the~~ ventilation system for that particular situation was ascertained.

(2) Commissioning of a number of lower cost ventilation systems in two houses provided the opportunity to determine how well the different systems were able to: distribute ventilation air; avoid pressurization or depressurization of the house envelope and provide adequate air quality control. This activity also provided the opportunity to assess some of the operational considerations associated with the different systems.

(3) Simulation of contaminant levels using ENERPASS-CONTAM in the two houses where low-cost ventilation systems were commission-tested allows the results of this testing to be generalized thereby permitting evaluation of the various ventilation systems capability in controling air quality.

4 ANALYSIS OF MONITORED CONTAMINANT LEVELS

Several months of CO_2 concentration data (hourly-average) measured in two R2000 houses, described in Table 1, were obtained for analysis. Each house employed an HRV which exhausted air from the bathrooms and kitchen. In house A fresh air was distributed through the heating system duct work with a continuously operating furnace fan. In house B a single-point fresh air supply in the utility/mechanical room was used without any mechanical air recirculation.

Examination of the data recorded in the family room, kitchen, dining room and master bedroom of house A revealed that the CO_2 concentration never exceeded 1000 ppm but on an occasional basis exceeded 800 ppm in each of the monitored rooms, for a few hours in the evening. The pattern was consistent with visitors being present in the house as well as the two regular occupants. The fresh air supply for the whole period averaged 39 l/s(20 l/s per occupant) or 0.2 air changes per hour while the average indoor CO_2 level was about 380 ppm with an outdoor concentration of approximately 330 ppm. This ventilation rate was more than adequate to provide good CO_2 level control in this lightly occupied house. Subsequent formaldehyde concentration measurements suggest that the ventilation was also more than adequate to keep this contaminant concentration well under comfort level limits (2).

In house B indoor CO_2 levels were measured in the family room and master bedroom and the fresh air supply flow rate was varied above and below the norm of about 40 l/s or 0.3 ACH. Figure 1 shows the ventilation rates and resulting average CO_2 concentrations measured for seven different time periods. It shows a clear relationship that suggests average CO_2 levels may be kept below 600 ppm in this house with ventilation rates of roughly 40 l/s or 0.3 ACH. Closer examination of the data show, however, that in November when this ventilation rate was used, family room CO_2 concentrations fairly regularly peaked at over 1000 ppm while bedroom levels were typically under 650 ppm. This house is occupied by two adults, two children, a dog and a cat.

Formaldehyde levels were measured in four rooms of this house for three different periods. The maximum concentration observed was 0.053 ppm (well below the 0.1 ppm comfort level) for a period when the HRV was not operating. This suggests that if the CO_2 concentration is controlled to be within a comfortable range, the Formaldehyde concentration will be well under the comfort limit.

It is expected that family room pollutant concentrations could have been effectively reduced through the use of either a supply or exhaust connection to that room. However, it appears

Table 1 House Descriptions

House	Type	Floor Area (m2)	Volume (m3)	Heating System	Ventilation System	Air Tightness	
						Cr (L/s.Pa^n)	n
A	Two levels plus Basement	206	748	Electric / Heat Pump Forced-Air	HRV-plenum supply 4 exhaust points	13.8	0.785
B	Two levels incl. Basement	175	483	Hot Water Radiant Floor	HRV-single supply 5 exhaust points	4.1	0.919
G	Two levels plus Basement	206	750	Gas (Std. Efficiency) Forced-Air	see Table 2	31.0	0.808
E	Two levels plus Basement	216	796	Electric Baseboard	see Table 2	49.6	0.761

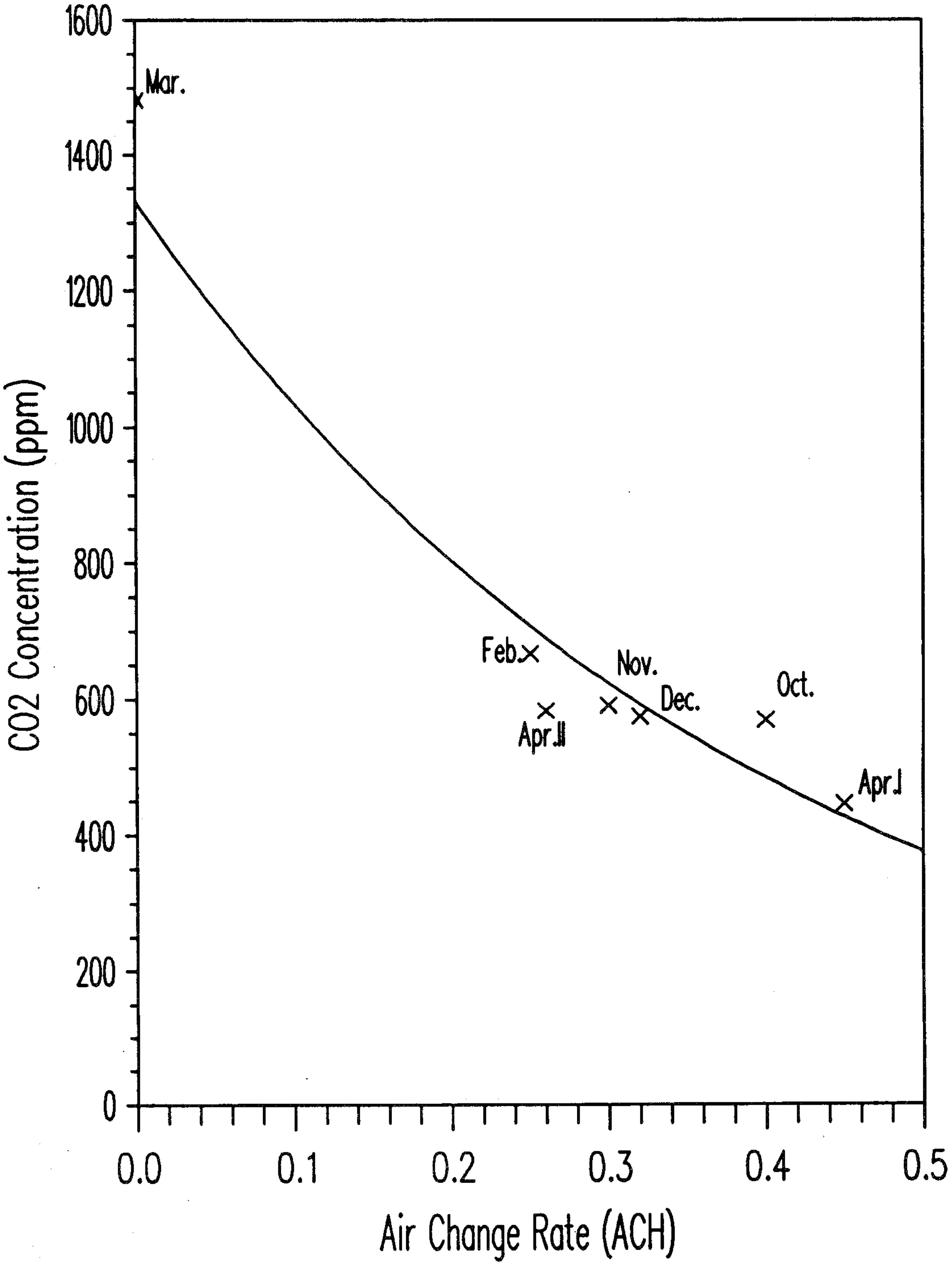


Figure 1 CO2 versus Air Change Rate

that a ventilation rate of about 10 l/s per occupant will provide reasonably good air quality control even with a one-point distribution/multi-point exhaust system with no mechanical recirculation.

5 LOW COST VENTILATION SYSTEMS

The choice of ventilation system design is generally dependent on the type of heat distribution system installed. The duct system installed as part of forced-air heating systems provide a convenient means of distributing fresh air in houses so equipped while houses with non-duct heating systems (steam, radiant, baseboard) require the addition of some means of doing this. It is not immediately obvious, however, how extensive a fresh air distribution system is necessary. For most effective operation, ventilation systems for both types require the exhaust air to be drawn from the odour and contaminant generating spaces such as kitchens and bathrooms. In this project low cost ventilation systems suitable for heating systems, using both duct and non-ducted distribution systems were investigated. All systems are intended to meet the continuous ventilation requirements of houses.

5.1 VENTILATION SYSTEM DESIGN

Four different ventilation system configurations were selected for houses without forced-air distribution and four others for houses with forced-air. These systems are summarized in Table 2. All had to be workable in relatively modest housing where consideration of first cost is extremely important. The ventilation systems appropriate for houses having forced air distribution systems were intended to be appropriate for both fossil-fired and electric heating systems. While one of these incorporates a draft-inducing fan that is aimed specifically at fossil-fired heating appliances the same or slightly less costly equipment may be used as a central exhaust fan in the absence of combustion products and a flue.

5.1.1 Systems for Houses Without Forced-Air Distribution Systems

System E1, Figure 2, uses continuously operating kitchen and bathroom fans, as in systems G1, G2 and G3, and a small diameter duct system to supply 5 l/s of fresh air to each category A room (1) except the master bedroom and basement to which 10 l/s are supplied. The supply of 80 l/s through a 150 mm diameter plenum with 52 mm diameter branches can easily be provided by a 37 W (1/20 H.P.) operating against a static pressure loss of 90 Pa (0.36" H_2O).

System E2, Figure 3 is much the same as E1 except supply ducts are only provided to the bedrooms and basement. Evaluation of this system should determine if the supply to each category A room is essential.

System E3, Figure 4 uses the same exhaust provisions as E1 and E2 but fresh air is provided by small continuously operating fans installed in the exterior wall of each category A room.

Table 2 Ventilation System Summary

House	System Identifier	Supply	Exhaust
Electric	E1	Central Supply Fan (75 l/s) Ducts to each Category A Room	Kitchen Window Fan (45 l/s) Bathroom Exhaust Fan (30 l/s)
	E2	Central Supply Fan (75 l/s) Ducts to Bedrooms and Basement	Kitchen Window Fan (45 l/s) Bathroom Exhaust Fan (30 l/s)
	E3	8 Window Mounted Supply Fans @ 10 l/s	Kitchen Window Fan (45 l/s) Bathroom Exhaust Fan (30 l/s)
	E4	8 Window Mounted Passive Inlets	Kitchen Window Fan (45 l/s) Bathroom Exhaust Fan (30 l/s)
Gas	G1	Duct to Cold Air Return Continuous Furnace Recirculation	Kitchen Rangehood (53 l/s) Bathroom Exhaust Fan (22 l/s)
	G2	Central Supply Fan (75 l/s) Continuous Furnace Recirculation	Kitchen Rangehood (53 l/s) Bathroom Exhaust Fan (22 l/s)
	G3	Central Supply Fan (75 l/s) No Recirculation	Kitchen Rangehood (53 l/s) Bathroom Exhaust Fan (22 l/s)
	G4	Central Supply Fan (75 l/s) Continuous Furnace Recirculation	Continuously Operating Draft Inducer (75 l/s)

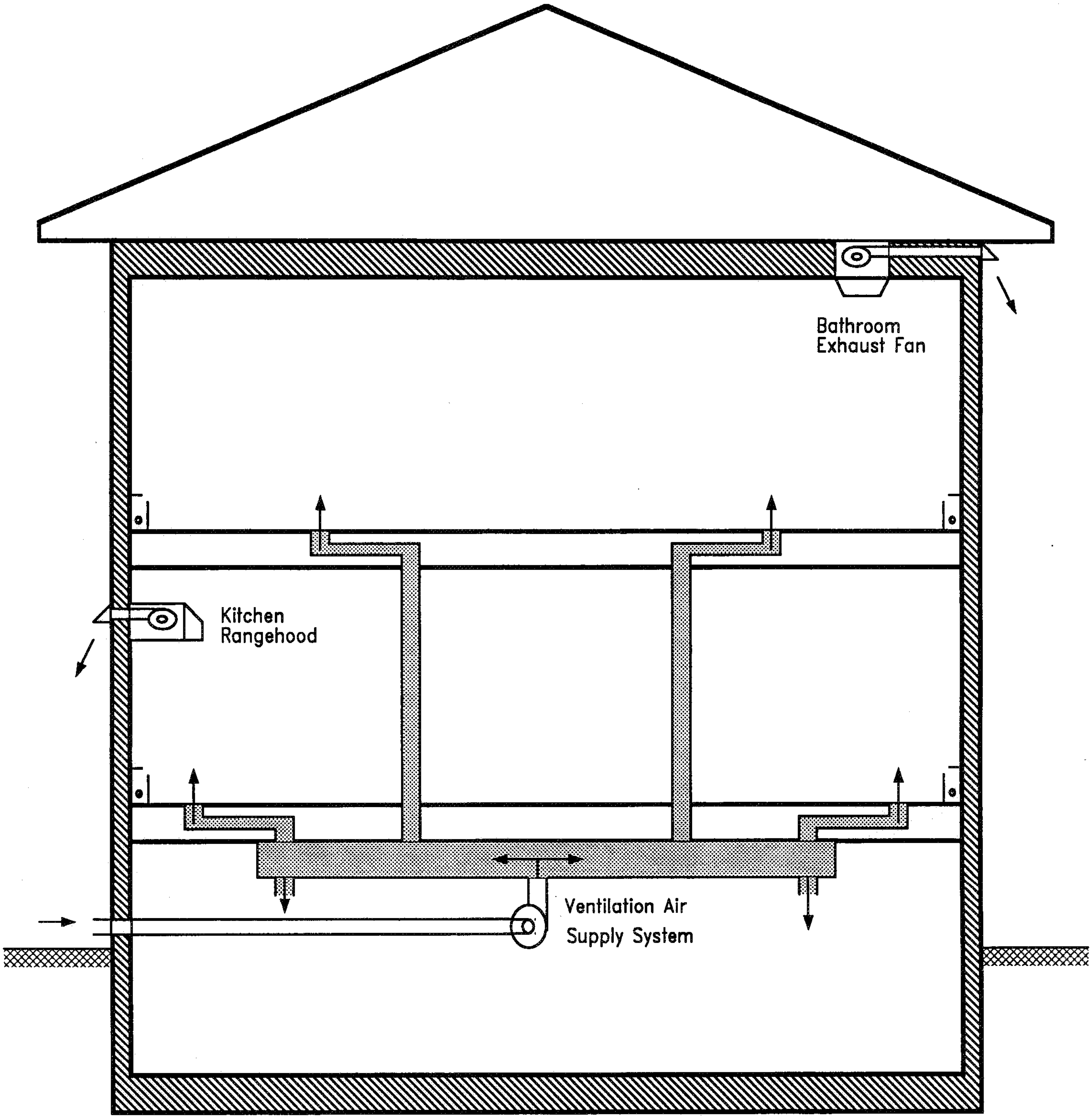


Figure 2 Electrically Heated House : Ventilation System E1

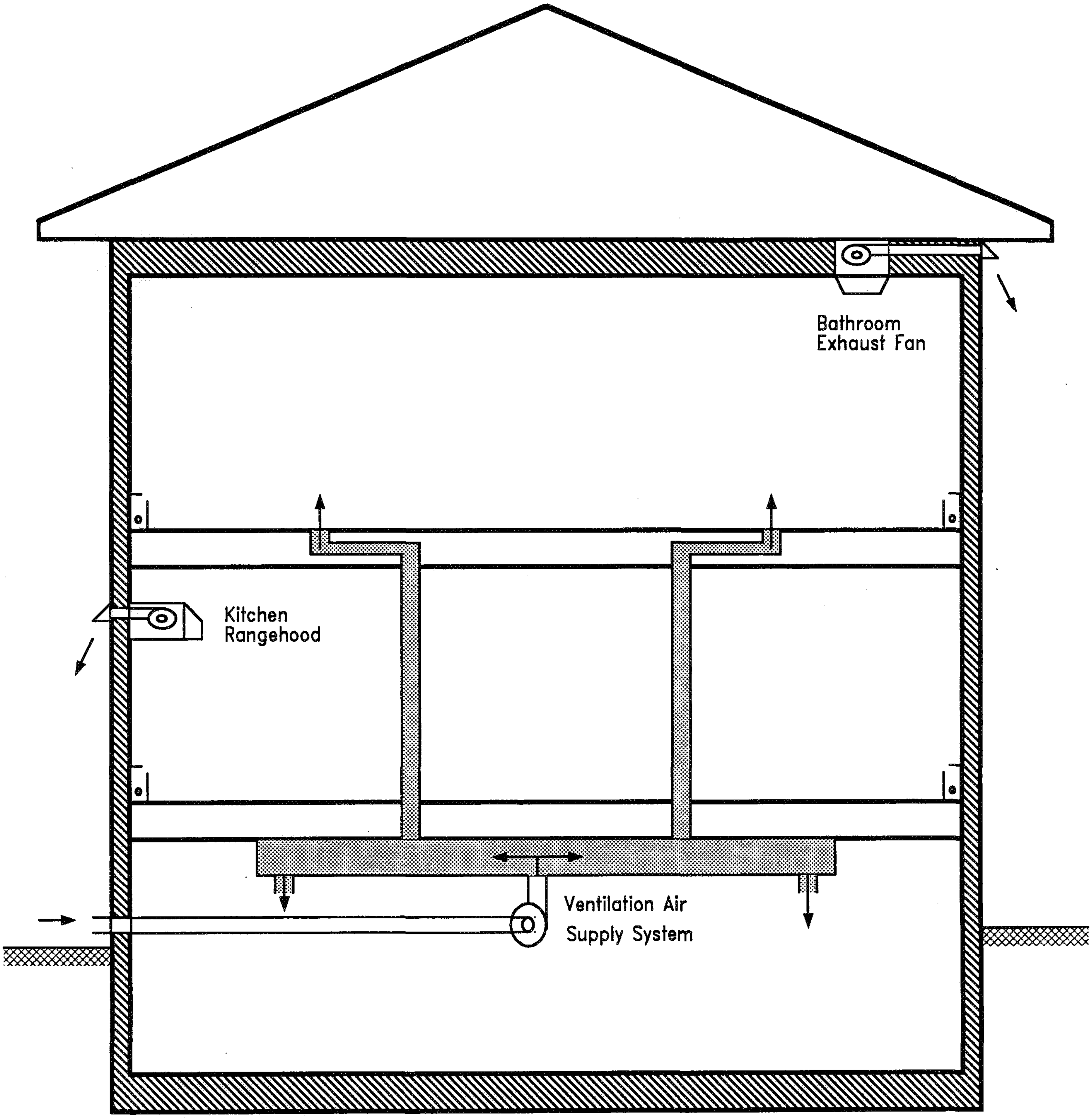
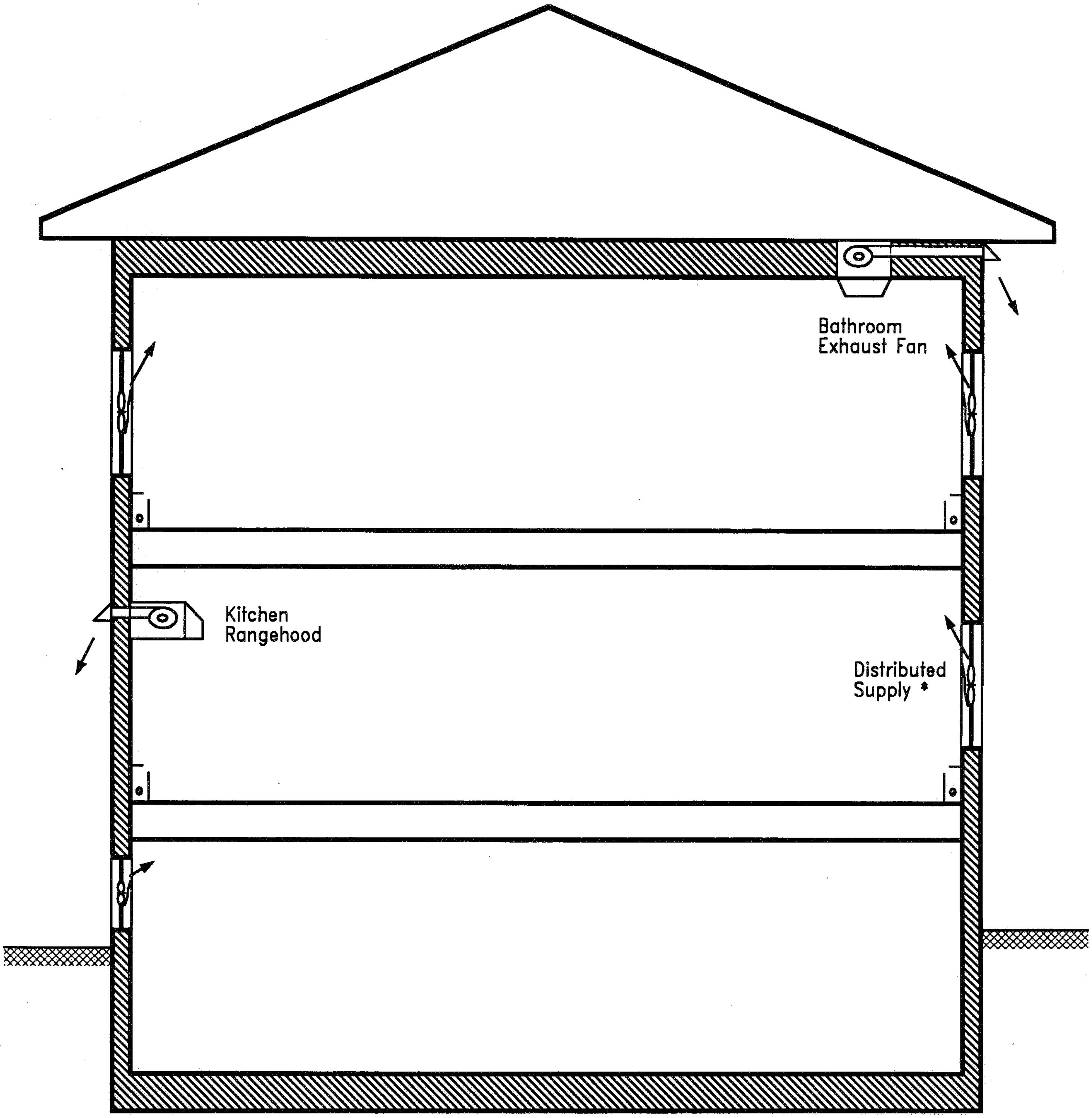


Figure 3 Electrically Heated House : Ventilation System E2



* Distributed supply utilizes : – Fans in test E3
– Passive ports in test E4

Figure 4 Electrically Heated House : Ventilation Systems E3 & E4

System E4, also Figure 4, is very much like system E3 except that the small fresh air supply fans are replaced with openings through which fresh air is allowed to enter. Evaluation of this system should allow the effectiveness of a passively distributed fresh air supply to be determined.

5.1.2 Systems for Houses Having Forced-Air Distribution

System G1, Figure 5, consists of a passive fresh air duct connected directly to the cold air return plenum of the furnace with bathroom and kitchen exhaust fans together providing the total house exhaust requirement. Continuous operation of the furnace distribution fan and the two exhaust fans is required. in order to achieve the required flow rates and low noise levels necessary for continuous operation, products that are upgraded relative to standard builder installed equipment generally must be used.

System G2, Figure 6, is essentially the same as G1 but with a fan added to the fresh air supply duct, to ensure the ability to provide balanced ventilation.

System G3, also Figure 6, is the same as system G2 except that the furnace fan is not run continuously. Instead the fresh air supply fan is used to distribute air through the supply and return ducts. Evaluation of this system should determine if continuous furnace fan operation is actually necessary.

System G4, Figure 7, utilizes a fresh air fan and continuously operating furnace distribution fan as in system G2. A draft inducer is used to vent exhaust products from the furnace and the domestic hot water tank and also exhaust air from the living space. Exhaust fans are also provided in the kitchen and bathrooms to be operated intermittently as required. This system should ensure that design ventilation rates are reliably provided while ensuring that combustion products from the furnace and hot water tanks are safely exhausted and the operation of these appliances should not add significantly to the amount of house ventilation as would be the case with independently operating ventilation and heating systems.

5.2 INSTALLATION AND COMMISSIONING

An electric baseboard heated house and a forced gas heated house, described in Table 1, were selected for ventilation system installation and commission-testing. Both are two-storey plus basement structures, typical of new urban single-family home construction in Southern Ontario. The were both well suited to allow installation of the required ventilation system configurations, close to average air tightness for two-storey houses, as given by Shaw (3) and owned by co-operative and interested parties. The electric-baseboard heated house was also equipped with a full forced-air distribution system which

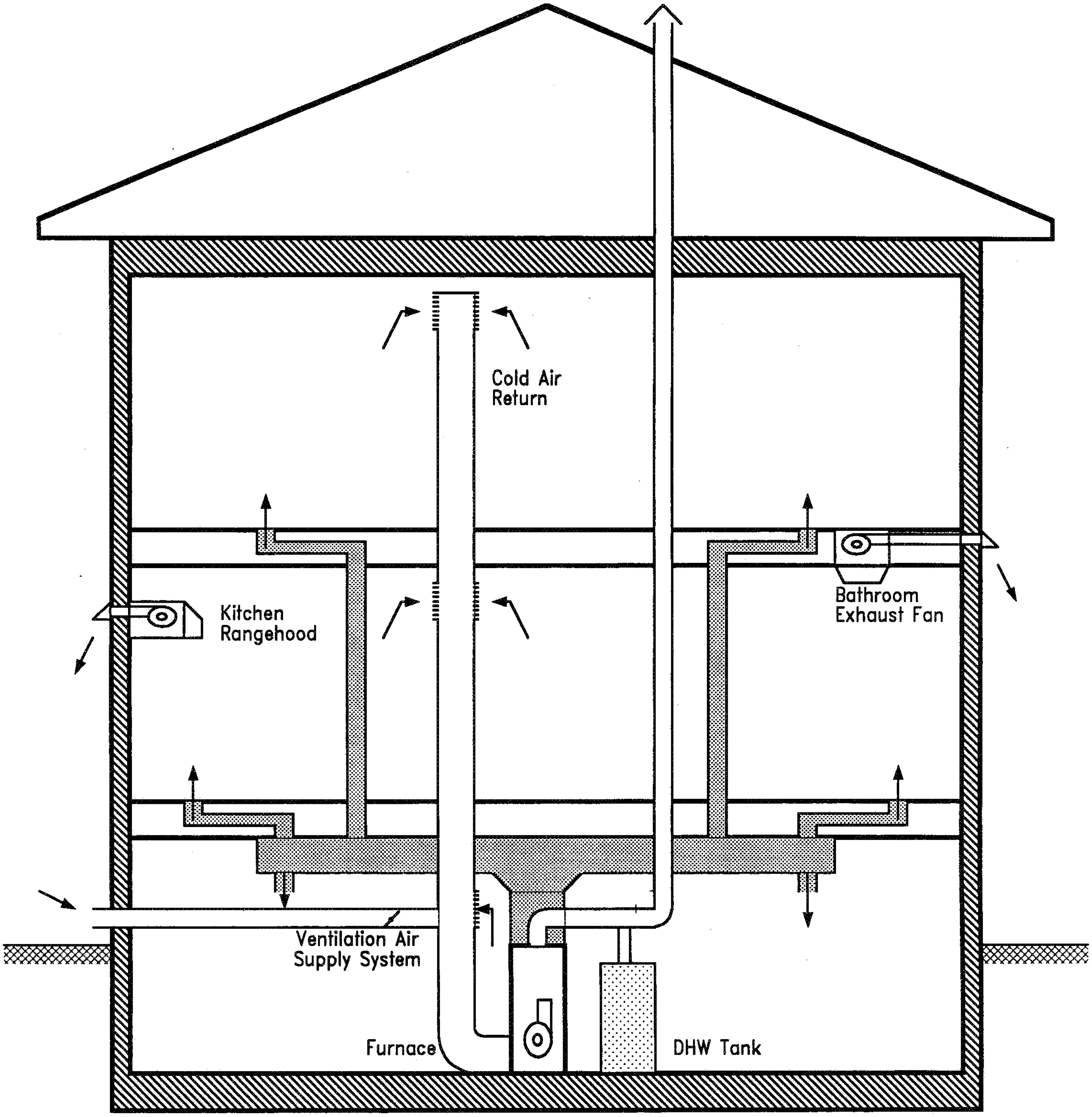
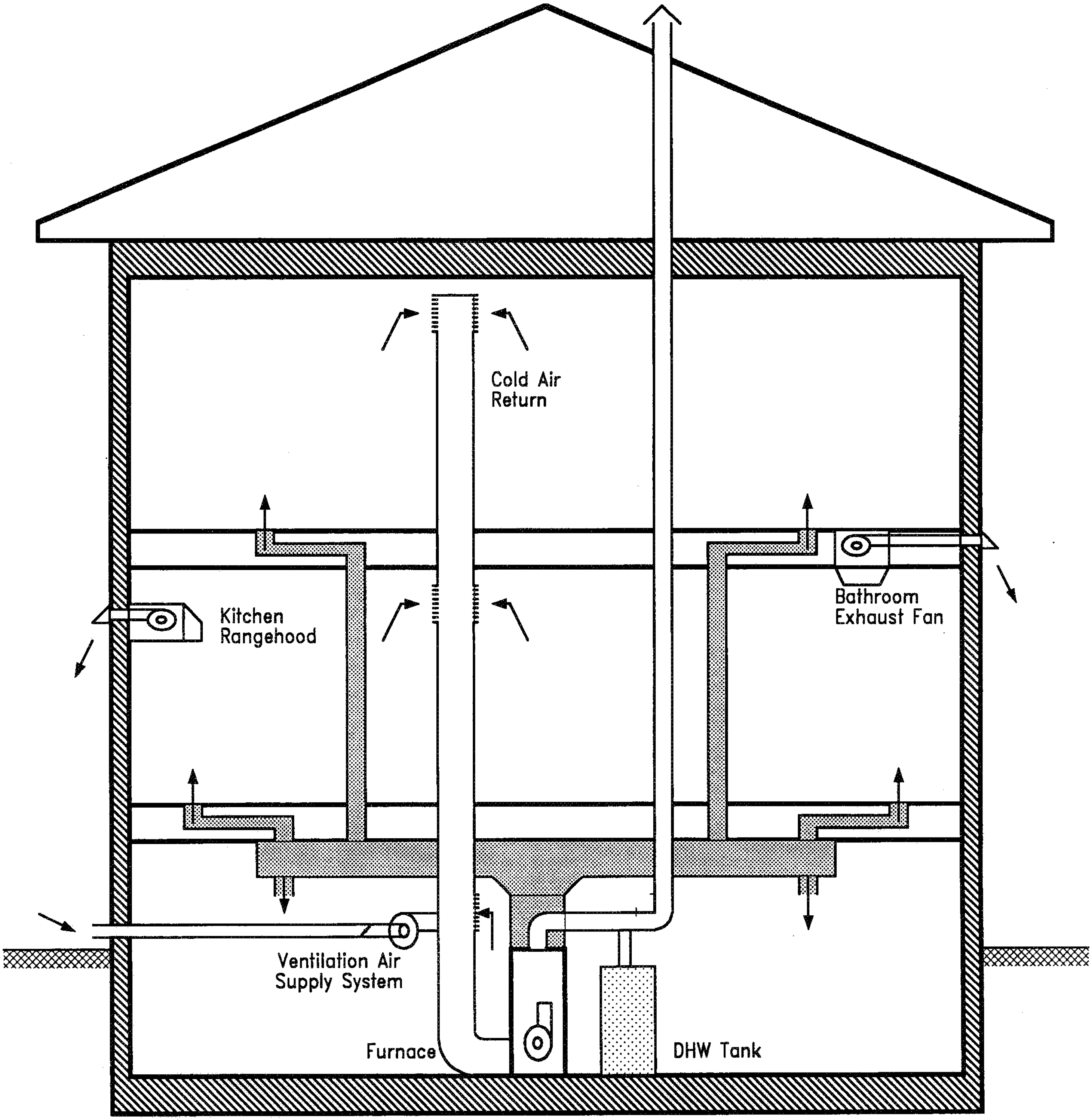


Figure 5 Gas Heated House : Ventilation System G1



Note : For test G3 the furnace fan is turned off

Figure 6 Gas Heated House : Ventilation Systems G2 & G3

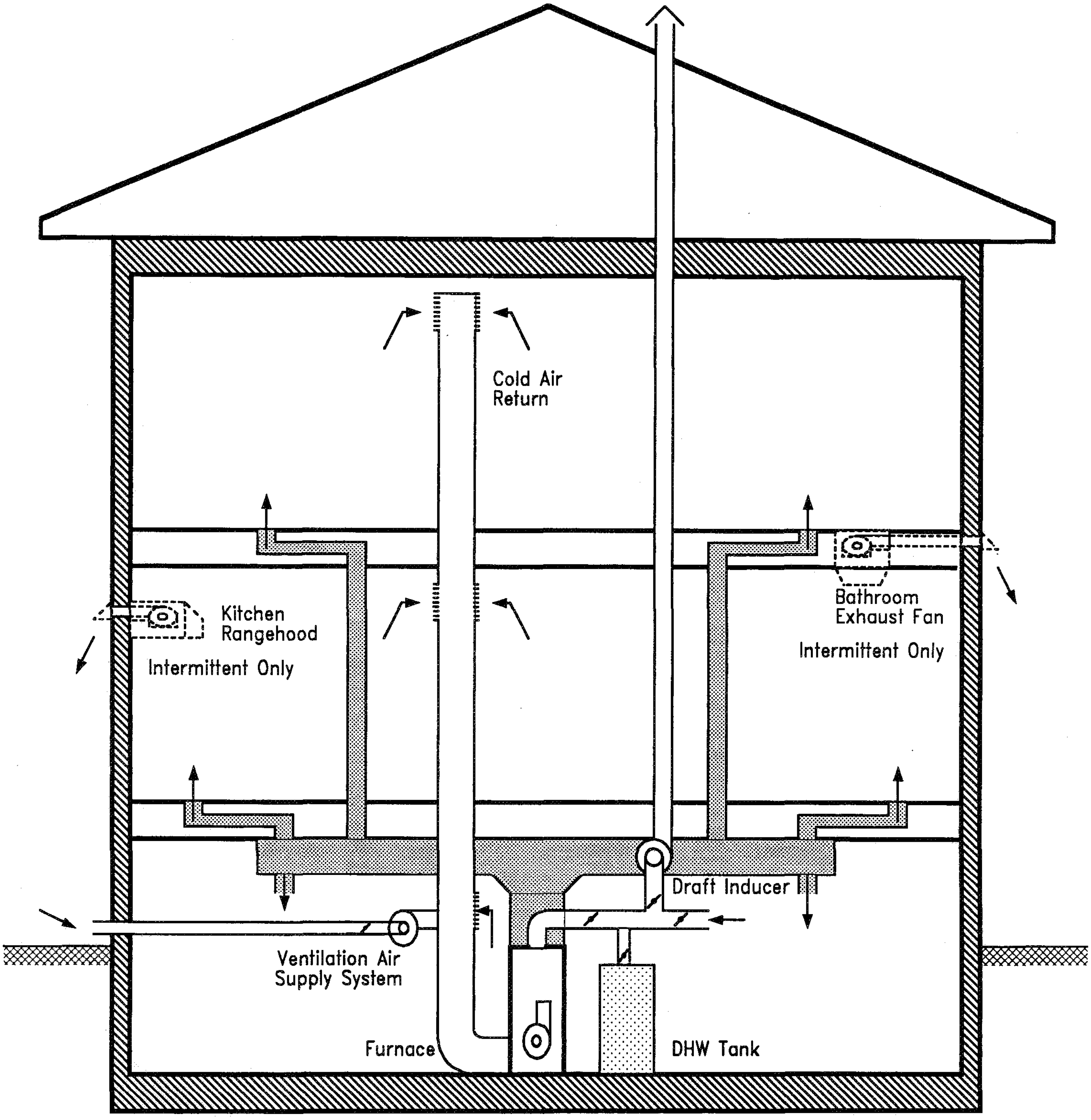


Figure 7 Gas Heated House : Ventilation System G4

simplified installation of the duct fresh air supply ventilation systems E1 and E2. Floor plans of the two houses appear in Figures 8 and 9.

System E1

An axial propeller type exhaust fan with variable-speed control was installed and sealed in the kitchen window opening of the electric-heated house, as the existing kitchen range hood was of the non-vented recirculation type. An upgraded exhaust fan was also installed in the second floor bathroom. A 150 mm diameter duct was connected to a baffle board carefully sealed into a basement window opening. This fresh air supply duct was connected through a centrifugal fan, with variable-speed control to the forced air distribution system supply plenum. The cold air return plenum was carefully sealed off where it connected to the electric furnace/heat pump indoor section. Branches of the distribution system that supplied the bathrooms and the kitchen were sealed closed so that fresh air would only be supplied to category A room.

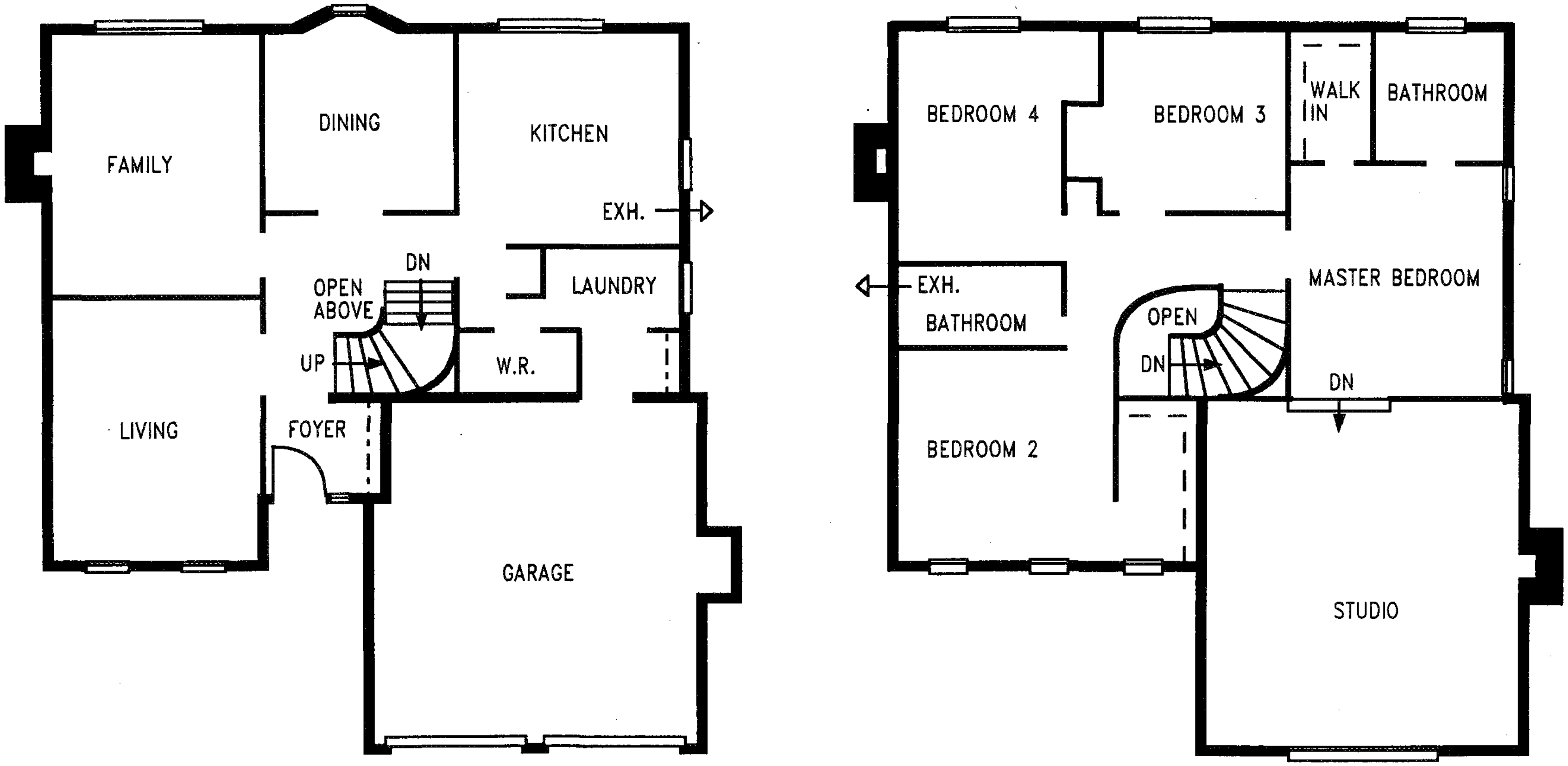
The fresh air and exhaust fans were turned on and adjusted (except for the single-speed bathroom fan) to achieve flow rates of 74 l/s fresh air, 30 l/s bathroom exhaust and 45 l/s kitchen exhaust. Air flows measured at each supply grille, using an ACIN Type 153 Flow Finder pressure drop compensating flow hood. Outdoor to indoor pressure difference was measured at the sill plate level using an AIR Ltd MP6KD micromonometer. The procedure used to perform a CO_2 decay test in the living room follows. The furnace fan was forced to run while compressed CO_2 gas was injected into the cold air return of the furnace. The carbon dioxide concentration was measured in the living room using and HORIBA analyzer and a strip chard recorder. Once the concentration steadied at a sufficiently high level (3-4000 ppm) the release of CO_2 was stopped, the furnace fan shut off, the cold air return plenum re-sealed and the house evacuated for approximately one hour.

System E2

As ventilation system E2 is essentially the same as E1 but with a reduced number of fresh air supply points, the commission-testing followed the same procedure described for E1.

System E3

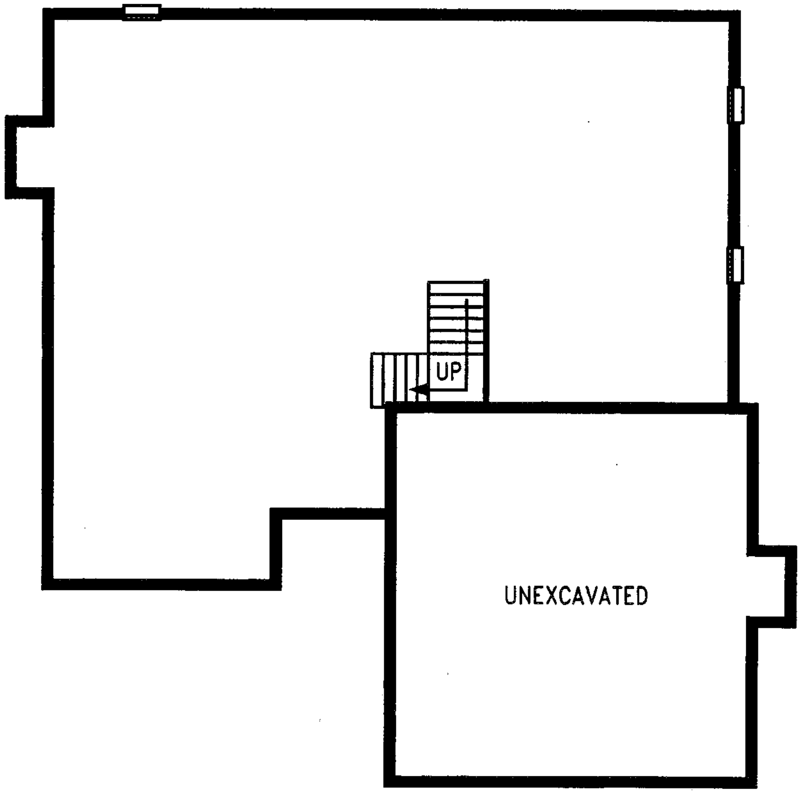
Ventilation systems E3 utilized the same exhaust system as E1 but a completely different fresh air supply system; In each of 8 category A rooms a panel containing a small fresh air supply fan was sealed into a window opening. Each of the fans was adjusted to provide a design flow rate of approximately 10 l/s, directed toward the ceiling. The supply and exhaust flows and the outdoor to indoor pressure difference were measured using the instruments noted above.



MAIN FLOOR PLAN

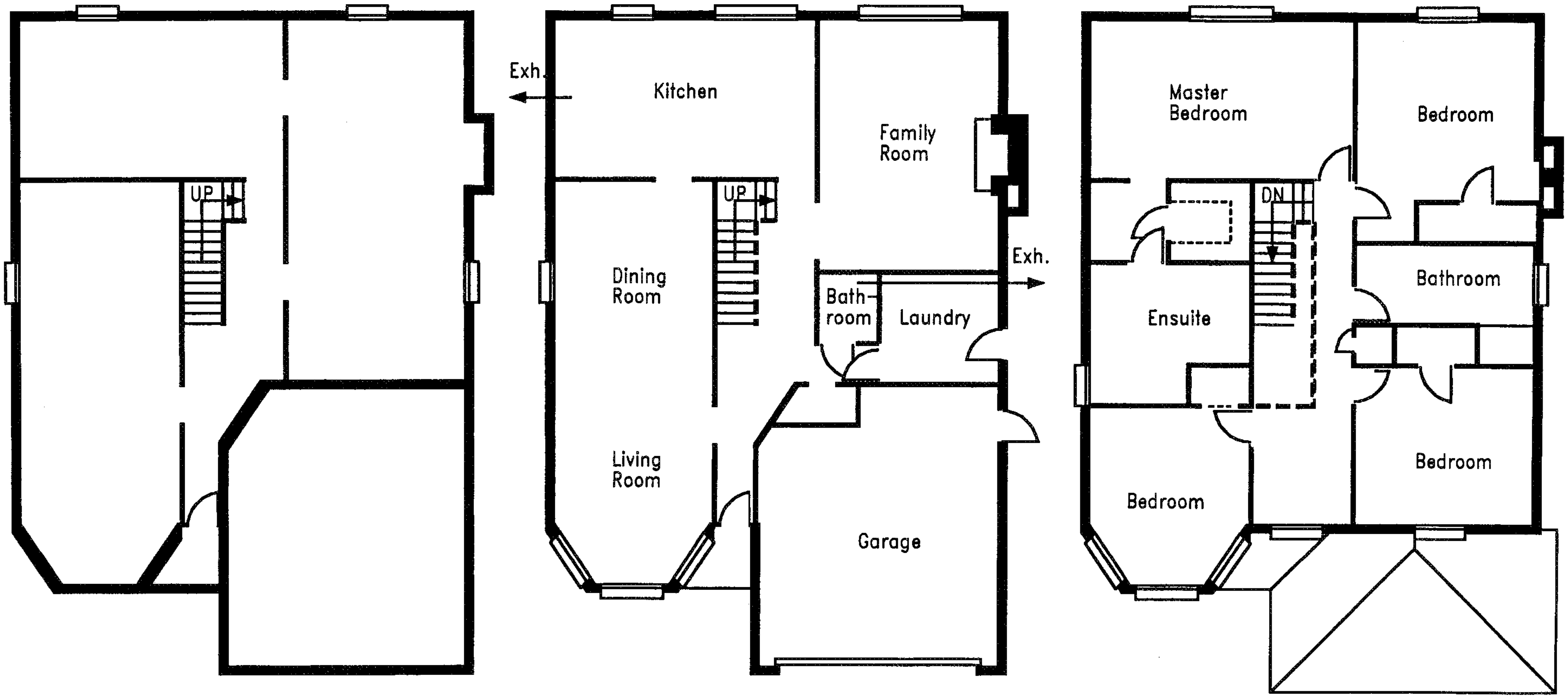
SECOND FLOOR PLAN

Figure 8 Electrically Heated House Floor Plans



BASEMENT FLOOR PLAN

Figure 8 Electrically Heated House Floor Plans (Continued)



BASEMENT FLOOR PLAN

MAIN FLOOR PLAN

SECOND FLOOR PLAN

Figure 9 Gas Heated House Floor Plans

System E4

As ventilation system E4 is very similar to E3 but without the 8 fresh supply fans, the commission-test procedure was essentially identical to that for system E3. The most significant difference between the procedures was in the measurement of fresh air flow rates which were roughly and order of magnitude smaller than for system E3, making the flow hood measurements inherently less accurate.

System G1

An upgraded kitchen range hood and an upgraded bathroom exhaust fan were installed in the gas-heated house to allow these two units to provide for the total continuous exhaust requirement. A 150 mm diameter duct was connected to a panel carefully sealed into a basement window opening and to the cold air return plenum of the furnace. The exhaust fans were turned on and adjusted to operate at design flow rates while the furnace fan was forced to run continuously. Fresh air supply (with fresh air return air mixer installed and removed) and exhaust fan flow rates were measured as were air flow rates at each distribution system supply and return grille. The heating system distribution air flow rate (recirculation) was also measured. An attempt was made to measure outdoor to indoor pressure difference at the sill plate level but gusty winds prevented good readings from be obtained.

System G2

As system G2 was essentially the same as system G1 except that a fan was added to the fresh air supply duct the commission test procedures were essentially the same except that the fresh air/return air mixer was left in place and a CO_2 decay test, as described in 5.2.1 was performed.

System G3

Again the system and commission-test procedure are essentially the same as described for system G2 except that the furnace fan was turned off and therefore the recirculation flow rate was not measured.

System G4

System G4 used the same fresh air supply system as G2 but the continuous exhaust requirement was met with a draft inducing fan as described in Section 5.1.1. The commission-test procedure was essentially the same as for system G2 except that exhaust gas temperatures were measured as were flow rates in each of the exhaust branches.

6 SIMULATION OF CONTAMINANT LEVELS

Simulations generally permit numerical "experiments" to be quickly performed at a fraction of the cost of actually carrying out physical tests. In this case simulation are intended to allow year-long evaluation of several different ventilation system configurations that have actually been commissioned and tested for only a short time in the field.

6.1 COMPARISON OF MEASURED AND SIMULATED LEVELS

The program used was ENERPASS-CONTAM87 which is a combination of the National Bureau of Standards (now N.I.S.T.) contaminant concentration simulation program and the Enermodal Engineering building energy analysis program. To ensure that software was correctly predicting contaminant levels, ENERPASS-CONTAM87 was used to simulate the R2000 house B, referred to in Section 4. Important characteristics of this tight, two level house are listed in Table 1 and the floor plan, showing ventilation system supply and exhaust points, appears in Figure 10. The house was simulated as a four zone building: the mechanical/laundry room, the bedrooms, the family room and the remainder of the upper floor.

Simulated CO_2 concentrations were compared to levels measured in the house for two different periods of approximately one month duration. The indoor CO_2 production rate schedule, used Figure 11, was developed using generation rate data from ASHRAE 62-1989 (4) and occupancy estimates provided by one of the adult occupants. Outdoor air temperature and solar radiation inputs were taken from data measured on site while the wind speed was recorded at the closest Environment Canada weather station. The initial simulation predicted family room CO_2 levels that were lower than measured while bedroom levels were very close through the day and predicted to be a little high at night. This suggested that some of the CO_2 source should be placed in the family room and that perhaps the CO_2 production rate in the bedroom was slightly lower than anticipated. Adjustments were made and the results of these predictions show significant improvement.

Following the brief validation/tuning exercise described above the same program was used to simulate contaminant levels in the gas and electrically heated houses, described in Section 4, that were used for the field installation and commissioning of a variety of low-cost ventilation systems. Five different house/ventilation systems, corresponding to G1, G3, G4, E1 and E2, were simulated, first the case of an initially high CO_2 level decaying, for comparison to field measured data as a calibration check. Subsequently each house/system was simulated for three longer periods representative of operation during cold, moderate and warm seasons, in each case with two different occupancy schedules. These simulations

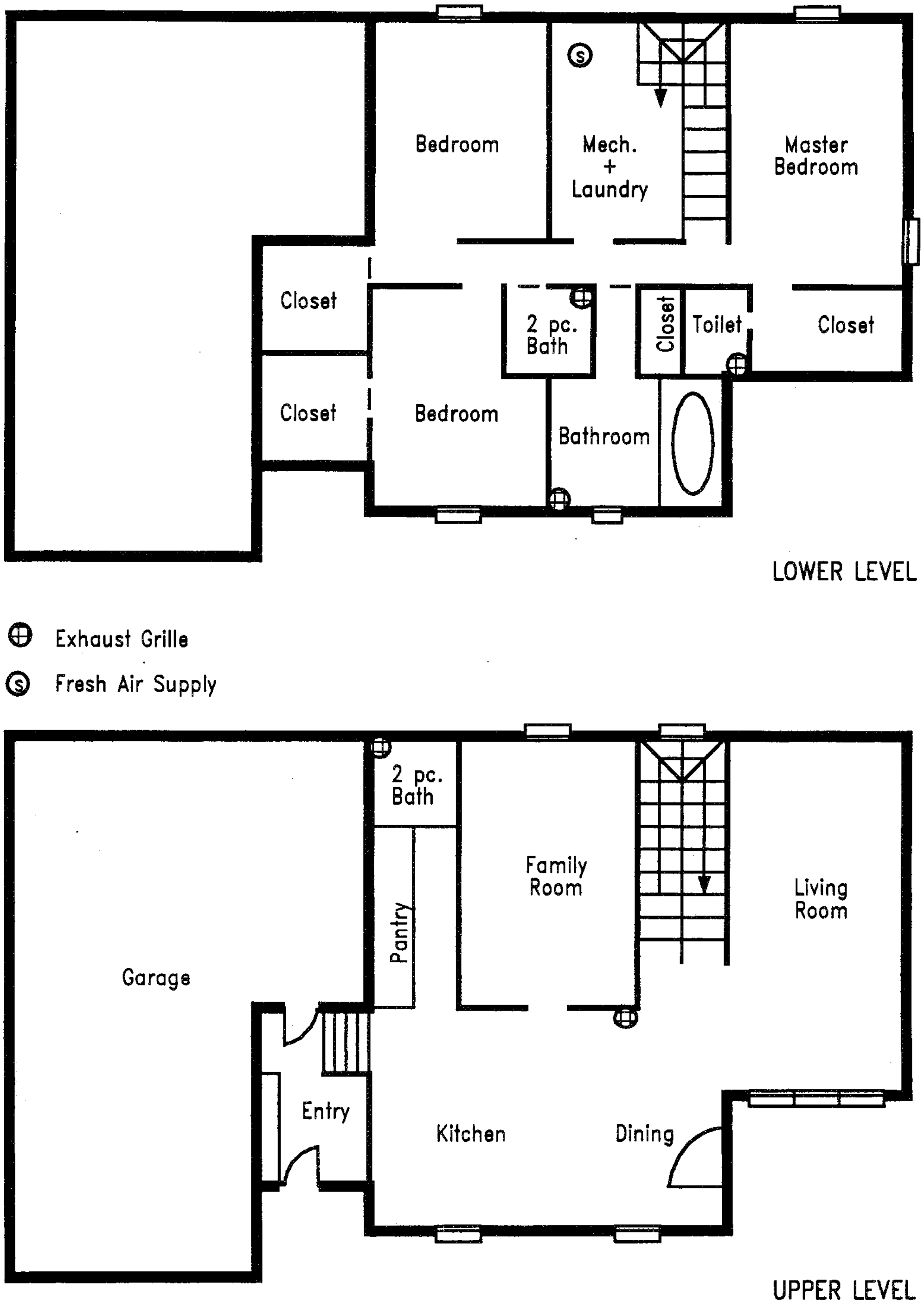


Figure 10 House B Floor Plans

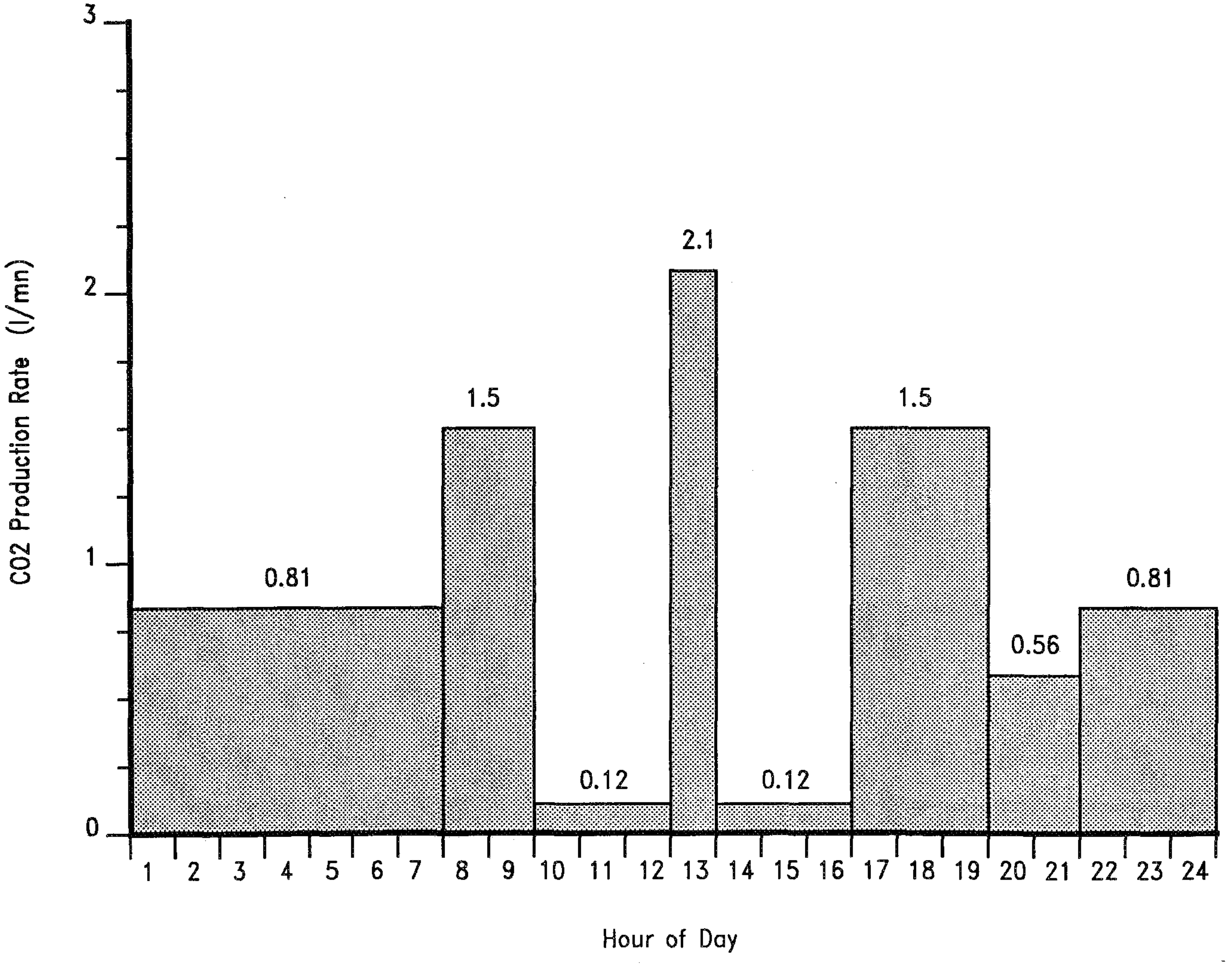


Figure 11 CO2 Production Rate Schedule

allow the contaminant and energy performance of these systems to be evaluated over the full range of expected operating conditions. The results of these simulations are summarized in Table 3.

Table 3 Measured and Simulated Living Room Air Change Rates

House	System Identifier	Measured (AC/h)	Simulated (AC/h)
Electric	E1	0.6	0.6
	E2	0.6	0.4
Gas	G2	0.6	0.5
	G4	0.6	0.5

7 RESULTS AND DISCUSSION

7.1 RESULTS OF COMMISSION TESTING

The measurements made on the ventilation systems commissioned in the electrically heated house have been summarized in Table 4 while data gathered on the systems in the gas heated house are presented in Tables 5 and 6.

7.1.1 Systems for Houses Without Forced-Air Distribution

System E1 made use of an air distribution system (which is sometimes used with an air source heat pump) that was already present in the electric-baseboard heated house instead of a small diameter system intended specifically for the distribution of small volumes of fresh air. As a result of leaks in the installed distribution system it was not possible to supply 5 l/s to three of the bedrooms and 10 l/s to the basement (Table 4). The living room CO_2 decay test indicated that the effective hourly air change rate in that room was 0.6 suggesting that contaminant control should be adequate.

As system E2 was essentially the same as E1 but with fewer fresh air supply outlets, the same limitation related to leaking duct work was evident. While fewer supply points suggest a simpler, lower cost distribution system installation they also imply inferior air distribution. However, the living room CO_2 decay test suggests that, in that room, the effective air change rate is essentially the same as for System E1.

System E3 provided excellent fresh air distribution but the cost of installing and providing power to a fan in all category A rooms may be prohibitive. Some potential for savings exists if the fan could be integrated into the baseboard heater.

Each of the fan driven fresh air supply systems (E1, E2 & E3) were able to provide balanced ventilation flows. System E4 was unable to provide balanced ventilation flows. The passive inlets on the main floor each supplied approximately 1.5 l/s of fresh air while those on the second floor delivered about 0.5 l/s. Since the outdoor to indoor pressure difference varies with temperature difference, wind speed and direction and volume flow rate of air being exhausted, this type of system would not reliably provide ventilation air especially to second storey rooms. Shaw (3) shows an example of such a system with the neutral pressure plane at the ceiling of the second storey. While this suggests that a small pressure difference will exist to drive air in through a passive vent, a decrease in the exhaust flow or the indoor to the outdoor temperature difference could readily stagnate or

Table 4 Measured Operating Conditions : Electrically Heated House

	Ventilation Systems			
	E1	E2	E3	E4
Exhaust Flow Rates (l/s)				
Kitchen	49	45	45	42
Bathroom	30	30	30	30
Supply Flow Rates (l/s)				
Master bedroom	10	10	10	0.5
Bedroom 2	3.5	3	10	0.5
Bedroom 3	2	2	10	0.5
Bedroom 4	0.5	1	10	0.5
Living Room	5	-	10	1.5
Dining Room	5	-	10	1.5
Family Room	5	-	10	1.5
Laundry Room	5	-	-	-
Bathroom	6	-	-	-
Basement	3.5	3.5	10	1.5
Sum	*45.5*	*19.5*	*80*	*8*
System Flowrate	*74*	*73*	-	-
Outdoor - Indoor ΔP (Pa)	2.0	2.0	3.0	5.5
Living Room Air Change (AC/h)	0.6	0.6	-	-

reverse this flow. There will also be a tendency for the ventilation rate to vary so that it will be at a minimum under relatively mild conditions when it is likely needed most, due to the reduction in natural leakage.

7.1.2 Systems for Houses With Forced-Air Distribution

Each of the fan driven fresh air supply systems (G2, G3 & G4) were able to provide balanced ventilation flows. However, the use of a 150 mm diameter passive inlet duct connected to the cold air return plenum of the furnace, to supply fresh air (system G1), did not provide balanced flows. With the fresh air mixer and wide-open damper in place the system delivered 40 l/s fresh air compared to a sum of 76 l/s being exhausted in the kitchen and bathroom. When the damper and mixer were removed approximately 50 l/s were supplied through the 3 m long duct.

The use of the furnace fan to distribute fresh air throughout the house appears, as might be expected, to provide reasonably good distribution. With 15% of the recirculation air being fresh air each category A room would need to have 33 l/s of recirculation air to provide 5 l/s of ventilation air. While this is not strictly the case, according to Table 5, flow through rooms from other areas appears likely to make up for any short fall.

System G2 which utilized this approach provided an effective hourly air change rate of 0.6 in the living room, equivalent to an effective ventilation rate of roughly 4.5 l/s for that space. As this space should be typical, the commission-testing suggests that this ventilation system is likely to provide adequate air quality control.

System G3 uses the distribution duct system but not the furnace recirculation fan. This results in much lower air flows (75 l/s versus 500 l/s) and generally poorer air distribution than with system G2, as may be seen in Table 5. Results of the living room CO_2 decay test indicate that, for that room, at least the effective air change rate was only about 10% lower than for system G2. This may be due to the high proportion of ventilation air being supplied to the adjacent dining room.

Only a single exhaust air pick up point is used in system G4 as it was installed. (This could of course be altered to allow exhaust pick up in the bathroom and kitchen for example). This system is otherwise similar to G2 in terms of air distribution. The living room CO_2 decay test showed an effective hourly air change rate of 0.56, essentially the same as that for G3 but in this case the room to room variation in ventilation air supply should be smaller, with less likelihood of problem areas.

Table 5 Air Distribution System Flowrates (l/s) : Gas Heated House

Grille Location	Recirculation Fan On		Recirculation Fan Off	
	Supply	Return	Supply	Return *
Master bedroom	11.5	28	1	1
Master Bedroom Closet	39	-	1	-
Ensuite	28	-	1	-
Bedroom 2	30	-	2	-
Bedroom 3	24	12	1	1
Bedroom 4	32	-	1	-
Bathroom	21	-	3	-
Upstairs Hall	32	27	2	4
Living Room	25	-	2	-
Dining Room	8	86	1	14
Kitchen	31	-	5	-
Family Room	26	14.5	3	4
Laundry Room	22	-	2	-
Front Hall	13.5	-	1.5	-
Study	12	-	1	-
Sum	*355*	*168*	*27.5*	*24*
System Flowrate	*500*	-	*78*	-

* return acted as a supply when the recirculation fan was off

Table 6 Measured Operating Conditions : Gas Heated House

Ventilation Systems G1 to G4		
Central Supply System	78 l/s	
Kitchen Rangehood	54 l/s	*(except G4)*
Bathroom Exhaust Fan	22 l/s	*(except G4)*
B-Vent without Draft Inducer	20 l/s	*(except G4)*
Heating System Recirculation	500 l/s	*(except G3)*
Outdoor - Indoor ΔP (sill)	3.5 Pa	*(fan supply : G2 - G4)*
	+/- 2.5 Pa	*(passive supply : G1)*
Fresh Air Supply Systems G1 to G4		
Temperatures		
Outdoor Air	-8.3 C	
Cold Air Return minimum	10.6 C	*(no recirculation : G3)*
Cold Air Return minimum	13.3 C	*(recirc. operating : G1,G2,G4)*
Cold Air return maximum	15.6 C	
Draft Inducer System G4		
Flow Rates		
Total Exhaust Flow	74 l/s	
Furnace Branch	29 l/s	
DHW Branch	8 l/s	
Exhaust Air	35 l/s	
Temperatures (both furnace and DHW burner operating)		
Furnace Exhaust	135 C	
Draft Inducer Exhaust	56 C	
Basement Air	16 C	
Living Room Air Change Rate		
System G2	0.60 AC/h	
System G3	0.55 AC/h	
System G4	0.56 AC/h	

8 CONCLUSIONS

Several low cost ventilation systems have been found to be practical through commissioning in the field and through computer simulation found to be effective in providing good air quality control.

Generally, upgraded bathroom exhaust fans and kitchen range hoods are an effective way of providing the required exhaust capacity.

For electrically-heated houses or other houses without a furnace flue and without a fresh air distribution system, the addition of a limited distribution system employing small diameter ducts appears to be a viable option.

In houses with forced-air distribution systems the addition of a central fan powered fresh air supply system is a relatively simple undertaking.

The use of a combined function exhaust air fan/draft inducer appears to be a promising option for houses with one or more natural draft heating appliances. Appropriate regulatory approvals must still be obtained before this approach may be used out of the lab.

9 RECOMMENDATIONS

The most promising systems, as identified in the conclusions should undergo more comprehensive field testing to confirm or evaluate.

(1) Room to room variations in air quality control
(2) Weather driven performance variations
(3) Longer term experience regarding durability, noise and vibration
(4) Representative installed costs

While upgraded bathroom exhaust fans and kitchen range hoods have demonstrated capability to provide the required exhaust flow, these products should be investigated to identify those with both good flow/static and low noise characteristics.

Further investigation of the exhaust air fan/draft inducer concept, in conjunction with the Canadian Gas Association, should be initiated to establish the acceptability of such a device from the standards approval perspective.

10 REFERENCES

(1) CSA Preliminary Standard F326.1-M1989, Residential Mechanical Ventilation Requirements, Canadian Standards Association, Rexdale, January 1989.

(2) Healthy Building Manual, Coordinating Council of Energy Management Task Forces, EMR, Ottawa, May 1988.

(3) C. Y. Shaw, Mechanical Ventilation and Air Pressure in Houses, I.R.C., N.R.C., Canadian Building Digest 245, Ottawa, May 1987.

(4) ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, Atlanta, June 1989.