UTILIZATION OF RESIDENTIAL MECHANICAL VENTILATION SYSTEMS

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SUMMARY

Mechanical ventilation systems must not only possess the appropriate physical capabilities with respect to flow capacity, air distribution, etc., they must also be utilized on a regular basis if the systems are to perform, or be allowed to perform, their intended function. To date, most investigations of residential ventilation systems have focused on developing or evaluating these system capabilities. Little consideration has been given to system usage.

A multi-year study was carried out to monitor the utilization of 12 conventional air-to-air Heat Recovery Ventilators (HRVs), two exhaust-only HRVs and three central exhaust systems. The systems were installed in occupied R-2000 and conventional houses, all of which were built with airtight building envelopes. Monitoring periods ranged from 9 to 40 months and produced a total of 45 house-years of field data.

Homeowner utilization of the three central exhaust systems was found to average only 0.62 hours (37 minutes) per day, producing an average seasonal mechanical ventilation rate of 0.01 ac/hr. This represented less than 3% of the ventilation rate which would have been achieved if the systems had been operated continuously at the minimum ventilation capacity specified by CSA F326 "Residential Mechanical Ventilation Systems". In one of these houses, a slight amount of additional mechanical ventilation was also provided through the make-up air duct connected to the furnace's return air plenum. But in all three cases, natural infiltration provided the majority of the total air change rate.

In contrast, the 12 conventional air-to-air HRVs were operated an average of 19.3 hrs/day, giving an average seasonal mechanical ventilation rate of 0.33 ac/hr, although large variations in usage were found among houses and during different seasons. This average seasonal rate represented 75% of the minimum ventilation capacity specified by CSA F326, if continuous ventilation at that rate was assumed. No difference was found between ventilation rates delivered by first and second generation HRVs, whereas houses with forced air heating systems experienced lower mechanical ventilation rates than those with electric baseboard heating. Natural infiltration rates, although of roughly the same magnitude as those experienced by the three houses with central exhaust systems, were small compared to the mechanical ventilation rates.

The study concluded that if the intent of standards such as CSA F326 are to be achieved, additional thought must be devoted to homeowner education and to the operation and control of ventilation systems, particularly the homeowner interface.

This study was conducted as part of the Flair Homes Energy Demo/Canadian Home Builders Association Flair Mark XIV project in Winnipeg.

RÉSUMÉ

Pour que les installations de ventilation mécanique puissent remplir ou être capables de remplir sur demande le rôle prévu, non seulement faut-il qu'elles possèdent les capacités physiques appropriées en ce qui a trait au débit d'air, à la distribution de l'air, etc., mais elles doivent également être exploitées régulièrement. À ce jour, la plupart des études qui portaient sur les installations de ventilation résidentielles ont mis l'accent principalement sur le développement ou l'évaluation des capacités de ces installations et n'ont que peu tenu compte du facteur exploitation.

Une étude pluriannuelle a été menée en vue de contrôler l'utilisation de 12 ventilateurs échangeurs de chaleur air-air, de deux (2) ventilateurs échangeurs de chaleur à extraction seulement et de trois (3) installations à extraction centrale. Les systèmes étaient installés dans des maisons R-2000 et des maisons de construction classique occupées. La construction de toutes ces maisons incorporait une enveloppe du bâtiment étanche à l'air. Les périodes de contrôle s'échelonnaient sur 9 à 40 mois, pour un total de 45 années-maisons accumulées en termes de données sur le terrain.

L'étude a révélé que l'exploitation par le propriétaire des trois installations à extraction centrale ne totalisait en moyenne que 0,62 heure (37 minutes) par jour, ce qui donne un taux moyen de renouvellement d'air mécanique saisonnier de 0,01 renouvellement d'air par heure (ra/h). Ceci représente moins que 3 % du taux de renouvellement d'air qui aurait été obtenu si les installations avaient été exploitées de façon continue, à la capacité de ventilation mécanique minimale (débit unitaire de base) prescrite dans la norme CSA F326 («Ventilation des habitations»). Dans une de ces maisons, le conduit d'air de compensation relié au plénum de reprise d'air de l'appareil de chauffage représentait un faible apport supplémentaire de ventilation mécanique. Cependant, dans les trois cas, la majeure partie du taux de renouvellement d'air était assurée par l'infiltration naturelle.

Par contraste, les 12 ventilateurs échangeurs de chaleur air-air de type classique ont fonctionné en moyenne 19,3 h/d, pour un taux moyen de renouvellement d'air mécanique saisonnier de 0,33 ra/h, bien qu'on ait noté des fluctuations importantes de l'utilisation parmi les différentes maisons et selon les saisons. Ce taux moyen saisonnier représentait 75 % du débit unitaire de base prescrit dans la norme CSA F326, en présumant que la ventilation est maintenue continûment à ce débit. On n'a noté aucune différence entre les taux de renouvellement d'air obtenus avec les ventilateurs échangeurs de chaleur de première génération, alors que les maisons dotées d'une installation de chauffage à air chaud pulsé offraient des taux de renouvellement d'air mécanique inférieurs à ceux des maisons dotées de plinthes chauffantes électriques. Les taux d'infiltration naturelle, bien qu'étant d'une ampleur à peu près identique à celle notée pour les trois maisons dotées d'une installation à extraction centrale, étaient peu élevés en comparaison des taux de renouvellement d'air mécanique.

Selon les conclusions de l'étude, pour en arriver à répondre aux critères de normes telles que la CSA F326, il sera nécessaire de se préoccuper davantage de l'éducation des propriétaires et de l'exploitation ainsi que du contrôle des installations de ventilation, plus particulièrement en ce qui concerne l'interface propriétaire.

Cette étude a été menée dans le cadre du Projet de démonstration de la maison à haut rendement énergétique/Mark XIV de l'ACCH, de Flair, à Winnipeg.

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

1.1 UTILIZATION OF RESIDENTIAL MECHANICAL VENTILATION SYSTEMS

A mechanical ventilation system must meet two requirements to be an effective tool for improving indoor air quality. First, it must possess the appropriate capabilities such as a sufficient installed air flow capacity, an adequate distribution network and the ability to minimize adverse interactions with other systems, appliances or the house envelope. The second criterion is, simply, that it must be used on a regular basis. The most expertly designed, carefully installed and conscientiously commissioned ventilation system will be worthless if it is not used by the homeowners or is unable to function.

From a regulatory perspective, most of the emphasis has been placed on the first requirement, that is, establishing standards for the ventilation system and its components. For example, the 1990 National Building Code specifies a system capacity of 0.30 air changes per hour (ac/hr) for all new houses (NBC 1990). CSA Standard F326 "Residential Mechanical Ventilation Systems" contains more detailed requirements with respect to capacity, air distribution and secondary interactions (CSA 1991). However, such documents recognize that the homeowner is free to operate the house and ventilation system as he wishes since building codes cannot legislate the occupants' behaviour.

1.2 OBJECTIVES

The objective of this study was to investigate the utilization of various types of residential mechanical ventilation systems under typical occupancy conditions.

1.3 SCOPE

The study was restricted to an analysis of ventilation system performance; the impact of system usage on indoor air quality is described in a separate report (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. Energy conservation levels ranged from those of conventional houses to those which met or exceeded the R-2000 Standard.

1.5 PROJECT HOUSES

This study was conducted in 17 of the Flair project houses, as shown in Table 1. Two types of mechanical ventilation systems were used: Heat Recovery Ventilators (HRVs) in 14 houses and central exhaust systems in the remaining three. All were detached bungalows with similar floor plans, full basements and floor areas ranging from 60 m^2 to 85 m^2 (646 ft^2 to 915 ft^2). Further details are provided in Proskiw (1992). The HRVs were classified as either "first" or "second generation" balanced, air-to-air units, or as unbalanced, exhaust-only appliances. The distinction between first and second generation units was introduced to reflect the evolution of HRV technology that has occurred since their introduction into the marketplace. Twelve of the 14 HRVs were conventional air-to-air units equipped with automatic controls and built-in defrost systems. The two exhaust-only HRVs were part of larger, integrated mechanical systems which provided domestic hot water heating, space heating and air-conditioning. The houses in which they were installed also contained booster fans to supplement the HRVs' exhaust capabilities. The ventilation systems in the R-2000 houses were designed to meet the requirements of that program while systems in the non R-2000 houses were designed to provide an equivalent flow capacity.

TABLE 1

PROJECT HOUSES

HOUSE	SPACE HEATING SYSTEM	VENTILATION SYSTEM				ENERGY STANDARD
		TYPE	OPERATING MODES	DISTRIBUTION	CONTROLS	
1 to 6	Forced Air Electric Furnace	Heat Recovery Ventilator (First Generation)	Continuous Operation, Two Speed with Automatic Defrost	Combined with Furnace Distribution System	Automatic; Dehumidistat with Manual Override Switches	R-2000
7 and 8	Forced Air Electric Furnace	Central Exhaust with Make-up Air Duct to Return Air Plenum	Intermittent	Envelope Leakage	Automatic; Dehumidistat with Manual Override Switches	Conventional
11 and 12	Electric Baseboards and Integrated Heat Pump	Exhaust-Only Heat Pump and Booster Fan	Continuous Operation, Four Speed	Primarily Envelope Leakage	Continuous	R-2000
13 and 14	Forced Air Electric Furnace	Heat Recovery Ventilator (Second Generation)	Continuous Operation, Two Speed with Automatic Defrost	Combined with Forced Air Distribution System	Automatic; Dehumidistat with Manual Override Switches	R-2000
19 and 20	Electric Baseboards	Heat Recovery Ventilator (Second Generation)	Continuous Operation, Two Speed with Automatic Defrost	Dedicated Ductwork System	Automatic; Dehumidistat with Manual Override Switches	R-2000
22	Forced Air Electric Furnace	Central Exhaust	Intermittent	Envelope Leakage	Manual	Conventional
23	Forced Air Electric Furnace	Heat Recovery Ventilator (Second Generation)	Continuous Operation, Single Speed with Automatic Defrost	Combined with Forced Air Distribution System	Automatic; Dehumidistat with Manual Override Switches	R-2000
24	Electric Baseboards & Radiant Ceiling Panels	Heat Recovery Ventilator (Second Generation)	Continuous Operation, Two Speed with Automatic Defrost	Dedicated Ductwork System	Automatic; Dehumidistat with Manual Override Switches	R-2000

The houses were constructed by Flair Homes (Manitoba) Ltd., a large tract building firm which had produced energy efficient homes in the Winnipeg market since 1980. The ventilation systems were installed by an experienced mechanical contractor who was also responsible for repairs during the monitoring period. The systems were commissioned by personnel from UNIES Ltd.

Airtightness tests were conducted on a regular basis during the study and all of the houses were found to meet the airtightness requirements of the R-2000 Program. This information was used, along with weather data, to estimate natural air infiltration rates.

1.6 HOMEOWNER EDUCATION

Purchasers of the project houses were informed that their homes were to be monitored in the multi-year study. They received verbal and written descriptions on the ventilation systems, their purpose, operation and maintenance requirements. Further assistance was provided by a technician during monthly site visits and whenever repairs were carried out.

SECTION 2

MONITORING PROGRAM

2.1 OVERVIEW

The utilization of the ventilation systems was determined using data collected from elapsed time monitors which were installed on the system controls and from supply and exhaust flow rates measured during the monthly site visits.

2.2 ELAPSED TIME MONITORS

Custom-built elapsed time monitors were designed and manufactured for the study and then hard-wired into the control unit of each ventilation system. The units recorded the number of hours of operation in each of the following modes:

HRVs (conventional)
- o Total hours of operation
- o Hours in high speed
- o Hours in low speed
- o Hours in defrost

Central exhaust systems
- o Total hours of operation

All monitors were read during the monthly site visits. Monitors were not installed on the exhaust-only HRVs because they ran continuously to provide other appliance functions.

2.3 AIR FLOW RATES

Ventilation system air flow rates were measured during the monthly site visits using permanently-installed Flow Measuring Stations and an Air Flow Resources Inc. MP6KD micromanometer.

2.4 MONITORING

Monitoring commenced in 1986 (between March and December, depending on the house) and continued to March 1989 for Houses #1 to #8, #13, #14, #19 and #20. Monitoring of Houses #22 to #24 began in March/June of 1989 and continued to March/April 1990. Only data from those periods during which the houses were occupied was used in the analysis. Comments from the homeowners and general observations on system performance were also collected during the monthly visits. The monitoring periods, summarized in Table 2, ranged from 9 to 40 months and the total data collected represented 45 house-years of operation.

The data was tabulated, edited and the resulting mechanical ventilation rates calculated as the product of the measured flow rates multiplied by the

TABLE 2

MONITORING PERIODS

HOUSE	MONITORING PERIOD	NO. OF MONTHS
1	November/85 to March/89	40
2	November/85 to March/89	40
3	November/85 to March/89	40
4	November/85 to March/89	40
5	November/85 to March/89	40
6	November/85 to March/89	40
7	November/85 to March/89	40
8	November/85 to March/89	40
11	July/86 to March/89	32
12	July/86 to March/89	33
13	July/86 to March/89	32
14	July/86 to March/89	32
19	December/86 to March/89	27
20	August/86 to March/89	31
22	June/89 to April/90	9
23	June/89 to April/90	10
24	April/89 to March/90	11
TOTAL MONITORING HISTORY: 537 months or 45 years		

number of hours of operation in each mode. Data was analyzed on an annual and seasonal basis. The winter period was defined as November to March, the shoulder seasons as April and October, and summer as May through September.

Some adjustments to the ventilation rates were made during the monitoring as part of other investigations, typically by unbalancing the HRVs to achieve a (positively or negatively) pressurized condition while still maintaining the same air change rate. These adjustments did not have a significant impact upon the results of this study.

SECTION 3

CENTRAL EXHAUST SYSTEMS

3.1 SYSTEM DESCRIPTION

The three central exhaust systems were designed for intermittent operation and used single-speed blowers which were located in the basement and controlled by dehumidistats and/or manual switches on the main floor. In Houses #7 and #8, a dehumidistat, located in the central hall, was used in conjunction with override switches in other rooms; in House #22 only manual switches in the bathroom and kitchen were used. Based on checks of the dehumidistat readings and settings conducted during the monthly site visits, it is believed that the homeowners generally activated the systems using the manual switches or used the dehumidistat as a switch. Relative humidity settings on the dehumidistats were routinely adjusted by the homeowners and the settings found during the site visits ranged from 35% to 100%. Sixty-six site visits were made to Houses #7 and #8 and only one occurrence was noted in which the ventilation system was found to be operating under the control of the dehumidistat.

The three houses also contained 100 mm (4") make-up air ducts installed from the outdoors to the furnace return air plenum (which induced a flow whenever the blower was operating). Supplemental measurements of make-up air duct flow rates were made in two of the three houses using a hot wire anemometer and duct traverses. In House #7, the flow rate was found to be comparatively large - 36 l/s (76 cfm), while in House #22 it was only 3 l/s (6 cfm). The difference was created by the respective ducting arrangements; in House #7 the make-up air duct entered the plenum quite close to the furnace while in House #22 it entered almost at the end of the plenum at a considerable distance from the furnace where the static pressure was minimal. Flow rates for House #8 could not be measured but were believed to have been similar to those in House #22 because the geometric configurations of the two duct systems were similar.

No mechanical problems were recorded with any of the central exhaust systems and no repairs were carried out during the monitoring period.

3.2 UTILIZATION

Utilization by the homeowners of the three central exhaust systems was found to be minimal, averaging only 37 minutes per day as shown in Table 3 and Figs. 1 and 2.

3.3 MECHANICAL VENTILATION RATES

Due to the low system utilization, the mean annual mechanical ventilation rate produced by the three central exhaust systems, exclusive of the make-up air

TABLE 3

CENTRAL EXHAUST SYSTEMS

UTILIZATION (HRS/DAY)

HOUSE	7	8	22	MEAN
MEAN	0.3	0.9	0.7	0.62
MINIMUM	0.0	0.1	0.4	
MAXIMUM	2.2	3.8	1.2	

MECHANICAL VENTILATION RATES (AC/HR)

HOUSE	7	8	22	MEAN
CENTRAL EXHAUST SYSTEMS:				
ANNUAL	0.01	0.02	0.02	0.01
WINTER	0.01	0.02	0.02	0.01
SHOULDERS	0.01	0.01	0.01	0.01
SUMMER	0.01	0.02	0.02	0.02
FIRST YEAR	0.01	0.02	N/A	
LAST YEAR	0.01	0.01		
CHANGE	0.00	-0.01		
CSA F326 MINIMUM VENTILATION CAPACITY:	0.57	0.41	0.39	0.46
% OF CSA F326 MINIMUM VENTILATION CAPACITY PROVIDED BY CENTRAL EXHAUST SYSTEMS:	1%	4%	4%	3%
MAKE-UP AIR DUCT	0.05	0.00	0.00	0.02
NATURAL INFILTRATION	0.09	0.08	0.05	0.07

FIGURE 1

CENTRAL EXHAUST SYSTEM UTILIZATION

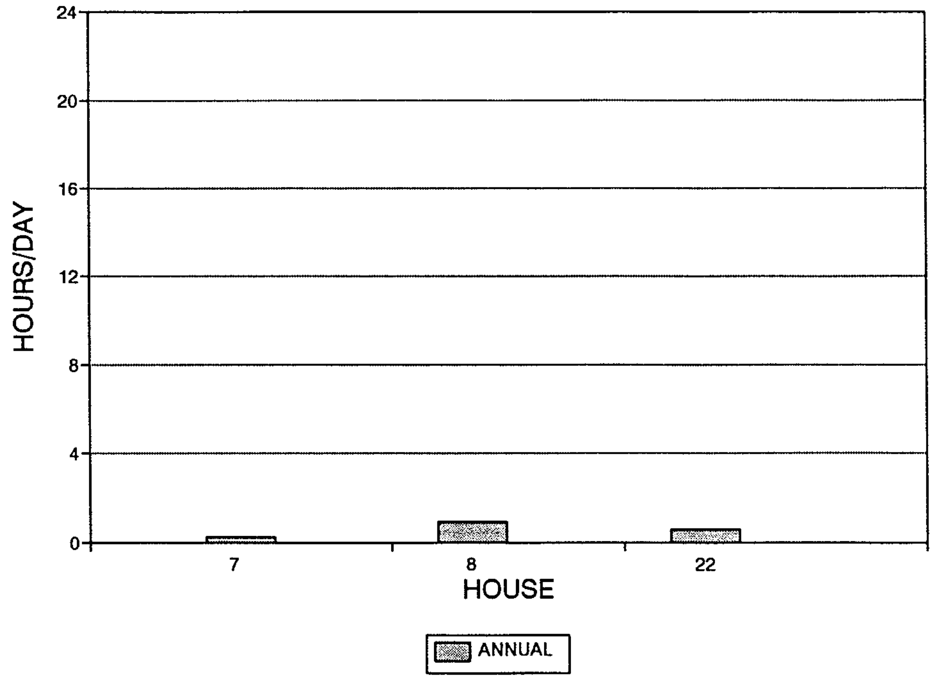
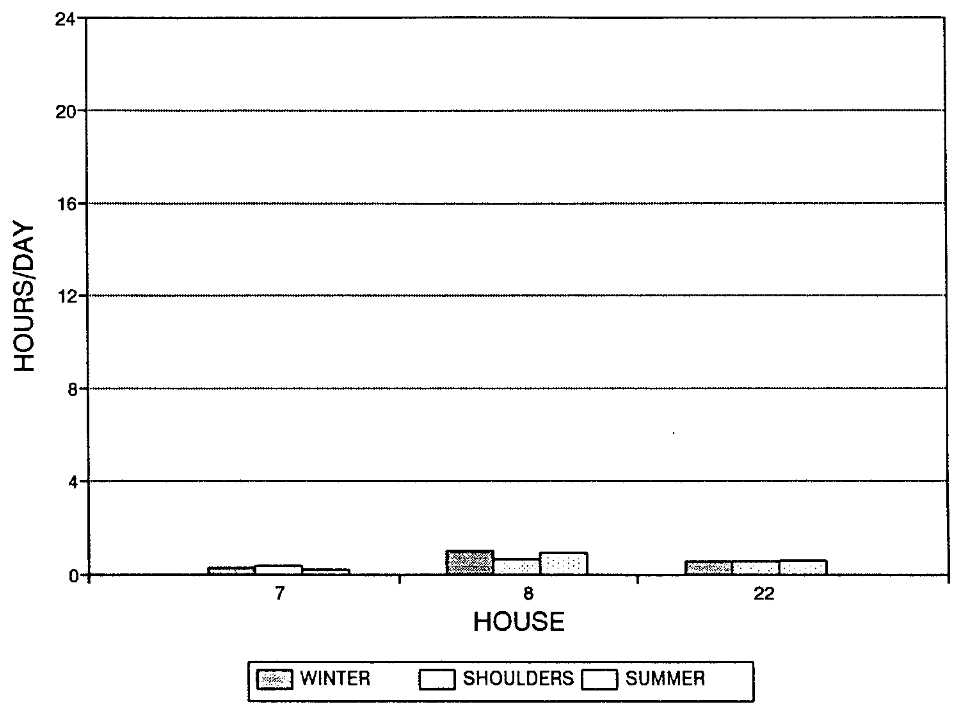


FIGURE 2

CENTRAL EXHAUST SYSTEM UTILIZATION



duct contribution, was 0.01 ac/hr even though the installed flow capacities ranged from 0.45 ac/hr to 0.72 ac/hr. Table 3 and Figs. 3 and 4 summarize the annual and seasonal mechanical ventilation rates provided by the central exhaust systems. Also shown in Table 3 are the air change rates attributable to natural infiltration.

For comparison purposes, the air change rate which would have been produced by the central exhaust systems if they were operating on a continuous basis at the "minimum ventilation capacity" specified by CSA F326 is also shown. Although the standard does not make any comment on utilization, it is useful as a benchmark for evaluating the degree to which the intent of the standard was realized. As evident, the central exhaust systems achieved average mechanical ventilation rates far below the minimum ventilation capacity rates. In fact, the average mechanical ventilation rate produced by the central exhaust systems (exclusive of the make-up air duct contribution) was only 3% of this value. Since the minimum ventilation capacity is not an operating requirement, compliance was neither necessary nor expected. Nonetheless, the wide difference between the observed ventilation rates and the capacity values specified by CSA F326 is a point of concern. The majority of the total air change rate experienced by the three houses was produced by natural infiltration. In House #7, the make-up air duct contributed an average of 0.05 ac/hr which was significantly larger than that provided by the central exhaust system, but still less than that from natural infiltration. In the other two houses, the make-up air duct contribution was negligible.

Changes in the mechanical ventilation rates, between the first and last year of operation, were also explored. As shown in Table 3, the rates were found to be consistent for both years.

3.4 BOOSTER FAN UTILIZATION

Utilization of the booster fans in Houses #11 and #12 was also monitored to provide complementary data on devices which, it was felt, would be perceived by the homeowner in a similar light as central exhaust systems in that their operation was controlled directly through a manual switch in the bathroom. These fans were located in the exhaust line from the bathroom and fed into the HRV exhaust. Usage was recorded by an elapsed time monitor; flow rates were not monitored.

Utilization patterns, summarized in Table 4 and Figs. 5 and 6, paralleled those of the central exhaust systems with an average usage of only 1.2 hours (69 minutes) per day.

FIGURE 3

CENTRAL EXHAUST SYSTEMS

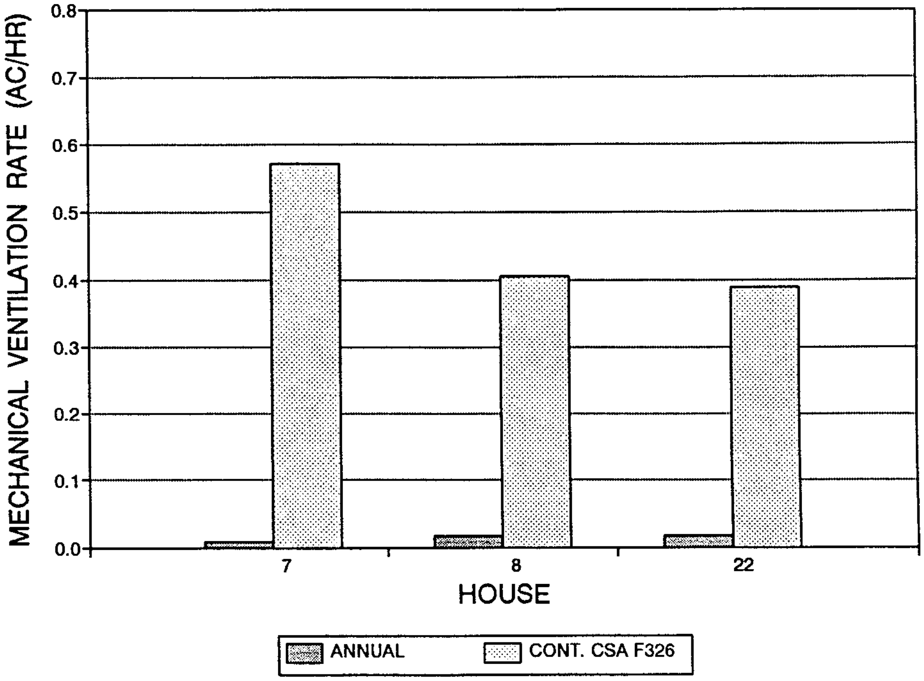


FIGURE 4

CENTRAL EXHAUST SYSTEMS

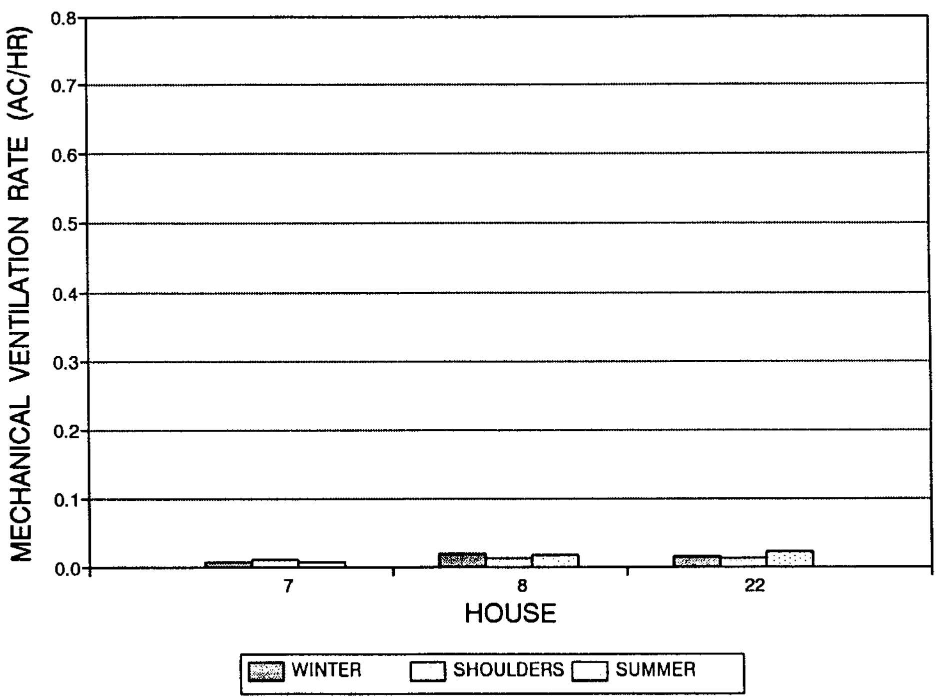


TABLE 4

BOOSTER FANS

UTILIZATION (HRS/DAY)

HOUSE	11	12	MEAN
ANNUAL	2.3	0.0	1.2
WINTER	1.9	0.0	1.0
SHOULDERS	2.1	0.1	1.1
SUMMER	2.7	0.0	1.4

FIGURE 5

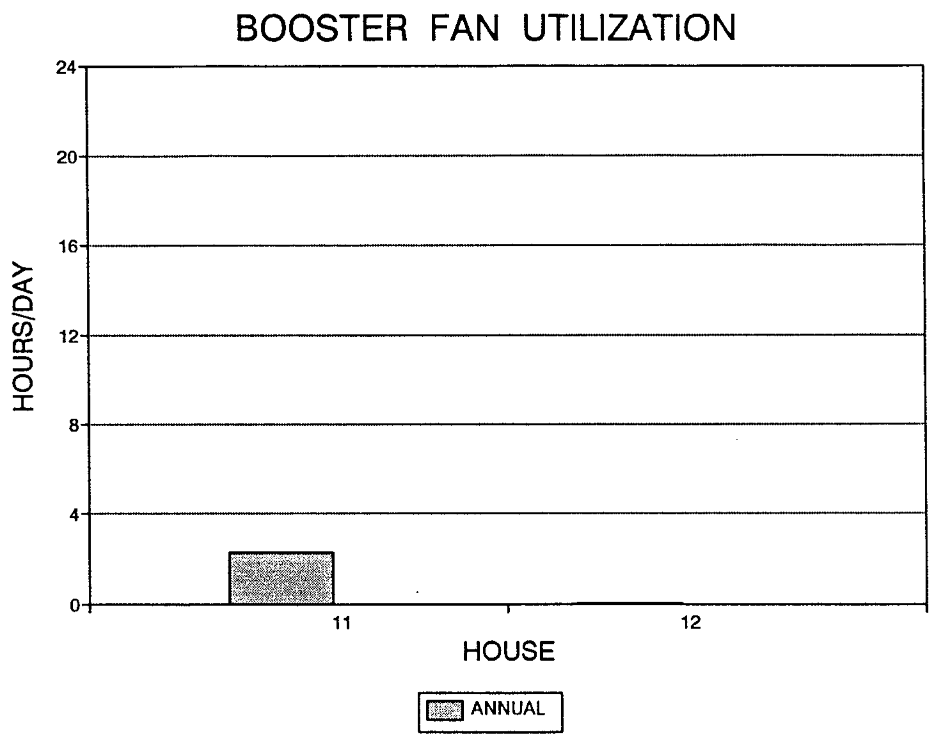
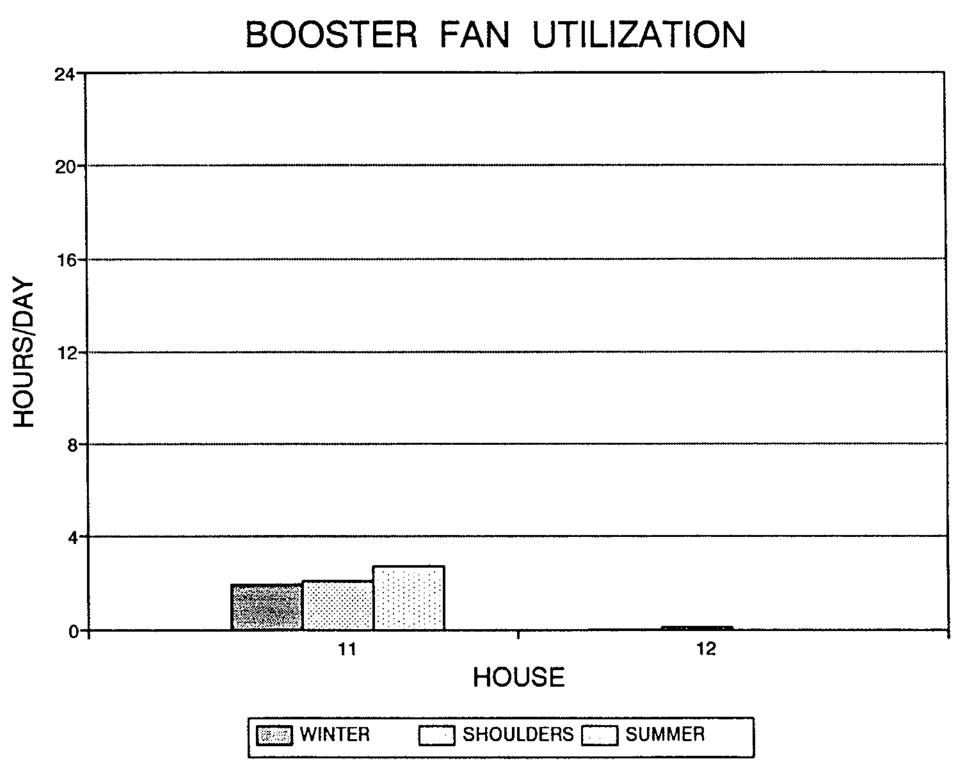


FIGURE 6



SECTION 4

HEAT RECOVERY VENTILATORS

4.1 SYSTEM DESCRIPTION

The conventional HRV systems were designed for continuous low speed operation, with high speed operation prompted by dehumidistat activation or by manual override switches in the bathrooms and kitchens. The units could only be turned off by unplugging them, an intentionally inconvenient method since they were located in the basements.

4.2 UTILIZATION OF THE CONVENTIONAL HRVs

Homeowner utilization of the 12 conventional HRV systems is summarized in Table 5 and Figs. 7 and 8. Annual system operation averaged 19.3 hours per day, although significant variations were noted among houses. Several systems were operated on a continuous or near-continuous basis, in fact all but the system in House #13 ran for at least 16 hours per day. In the latter case, the HRV was operated for only a few hours per day, despite several requests and recommendations to the homeowner that the ventilation rate be increased. Large variations in seasonal usage were found in approximately one-third of the houses. Ventilation rates were generally lower in the summer and shoulder seasons, possibly because of increased window usage. Also included in Table 5 are the natural air change rates.

The utilization data includes the effects of mechanical breakdowns, which occurred mainly with the first generation units due to motor failures or control problems.

4.3 MECHANICAL VENTILATION RATES, CONVENTIONAL HRVs

Table 5 and Figs. 9 to 12 summarize the average annual mechanical ventilation rates for the twelve units along with the CSA F326 minimum ventilation capacity rates (assuming continuous operation). The average annual mechanical ventilation rate for the conventional HRVs was 0.33 ac/hr, representing 75% of the CSA F326 minimum ventilation capacity rate, dramatically different from the values observed for the central exhaust systems. As a result, the majority of the total air change rate was provided by mechanical ventilation not natural infiltration. Surprisingly, average ventilation rates were identical for the first and second generation units, despite improved performance and quieter operation of the latter machines, a factor which might have been expected to increase homeowner usage.

These results are consistent with those reported in a survey of several hundred R-2000 homes in which 90% of the homeowners stated they ran their HRVs continuously during the winter (Buchan, Lawton, Parent Ltd., 1988). In addition, 50% reported they ran them continuously during the summer.

TABLE 5

HEAT RECOVERY VENTILATORS

UTILIZATION (HRS/DAY)

HOUSE	1	2	3	4	5	6	13	14	19	20	23	24	MEAN
LOW	15.7	16.8	20.3	16.9	10.2	5.8	1.1	14.5	17.9	12.1	0.0	19.6	12.6
HIGH	1.3	2.3	0.6	5.0	1.8	12.3	2.0	1.3	5.2	10.9	23.7	3.7	5.9
DEFROST	1.0	1.2	1.6	2.1	0.3	1.9	0.1	0.3	0.7	0.6	0.4	0.7	0.9
TOTAL	17.9	20.3	22.5	24.0	12.4	20.0	3.2	16.1	23.8	23.6	24.0	24.0	19.3

MECHANICAL VENTILATION RATES (AC/HR)

HOUSE	1	2	3	4	5	6	13	14	19	20	23	24
ANNUAL WINTER SHOULDERS SUMMER	0.26 0.38 0.26 0.10	0.26 0.25 0.31 0.27	0.31 0.33 0.36 0.25	0.42 0.45 0.40 0.38	0.43 0.65 0.48 0.12	0.28 0.33 0.28 0.22	0.06 0.07 0.05 0.05	0.33 0.42 0.40 0.20	0.57 0.58 0.58 0.56	0.48 0.49 0.47 0.47	0.21 0.24 0.11 0.22	0.31 0.32 0.33 0.28
FIRST YEAR LAST YEAR CHANGE	0.18 0.26 0.08	0.12 0.33 0.21	0.05 0.27 0.21	0.45 0.42 -0.03	0.49 0.24 -0.26	0.34 0.20 -0.14	0.05 0.08 0.03	0.52 0.20 -0.31	0.51 0.61 0.10	0.52 0.44 -0.07	N/A	N/A
CSA F326 MINIMUM VENTILATION CAPACITY:	0.57	0.40	0.57	0.40	0.58	0.41	0.41	0.41	0.41	0.41	0.40	0.39
% OF CSA F326 MINIMUM VENTILATION CAPACITY:	45%	66%	54%	105%	74%	70%	15%	82%	141%	118%	52%	78%
NATURAL INFILTRATION	0.08	0.06	0.08	0.07	0.06	0.07	0.04	0.06	0.05	0.04	0.08	0.08

FIGURE 7

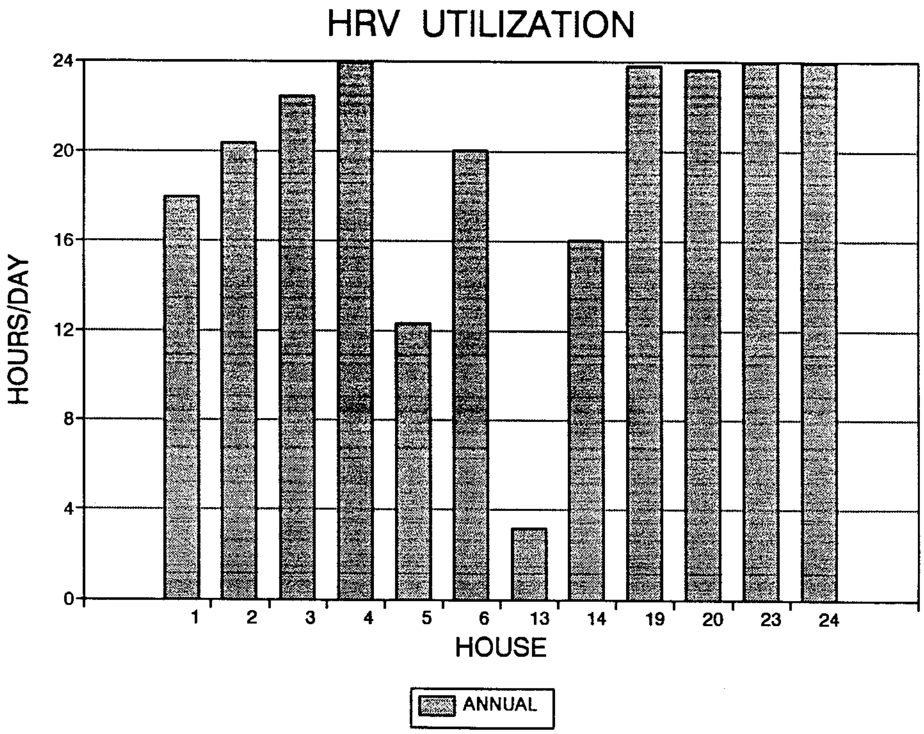


FIGURE 8

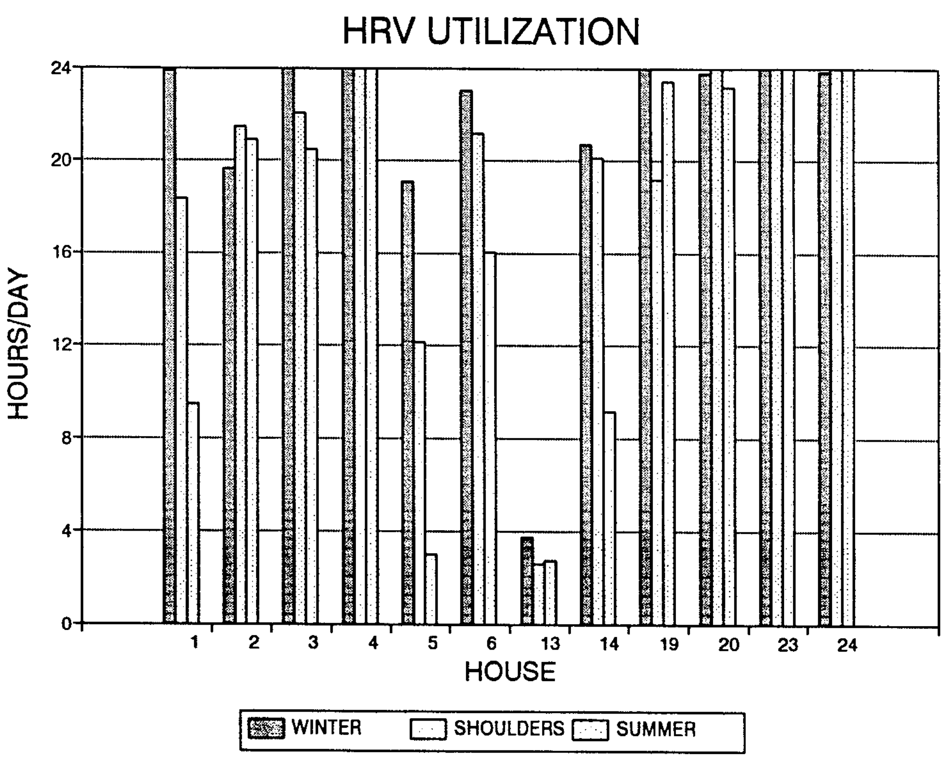


FIGURE 9

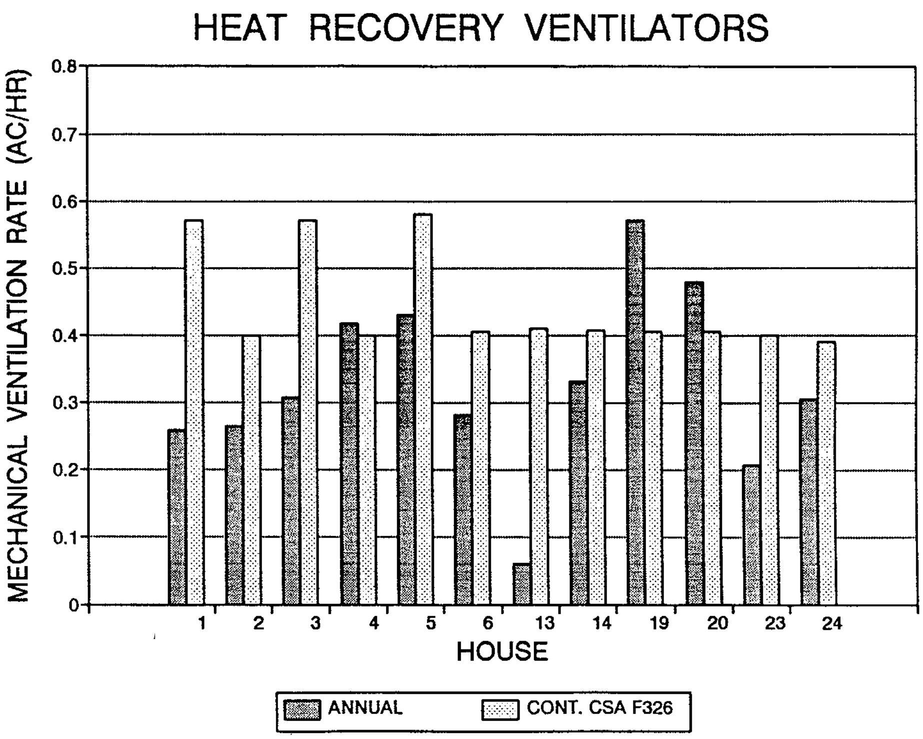


FIGURE 10

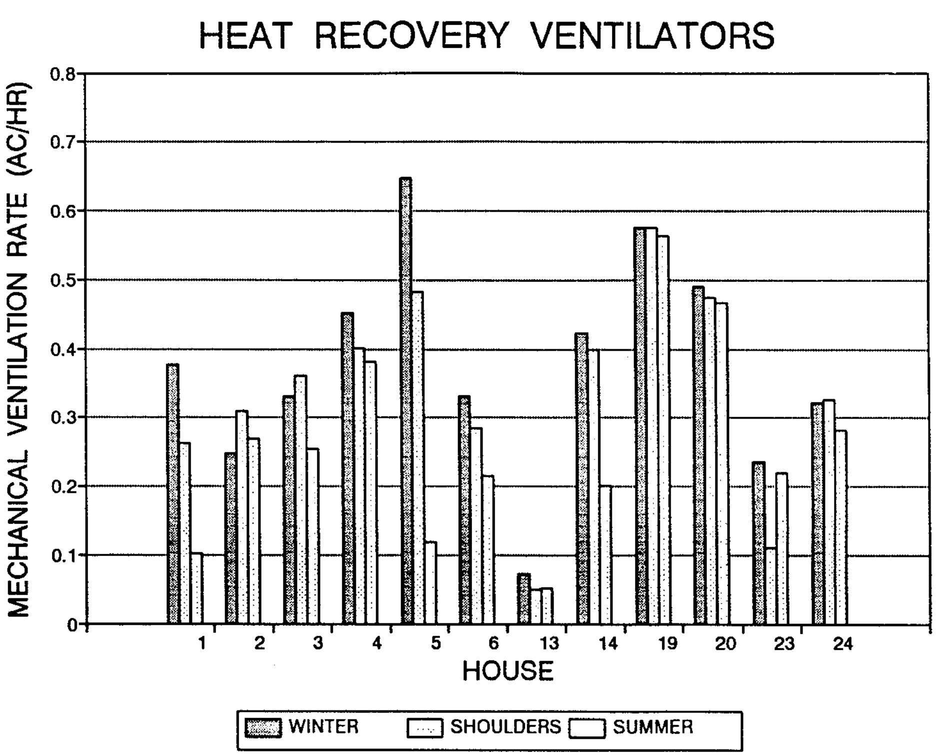


FIGURE 11

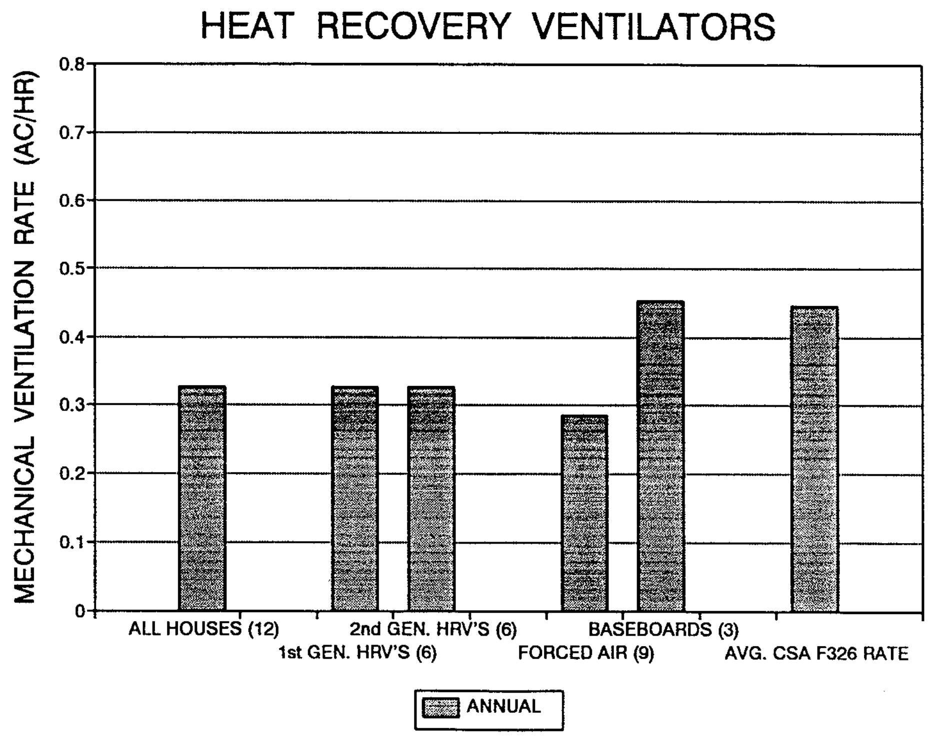
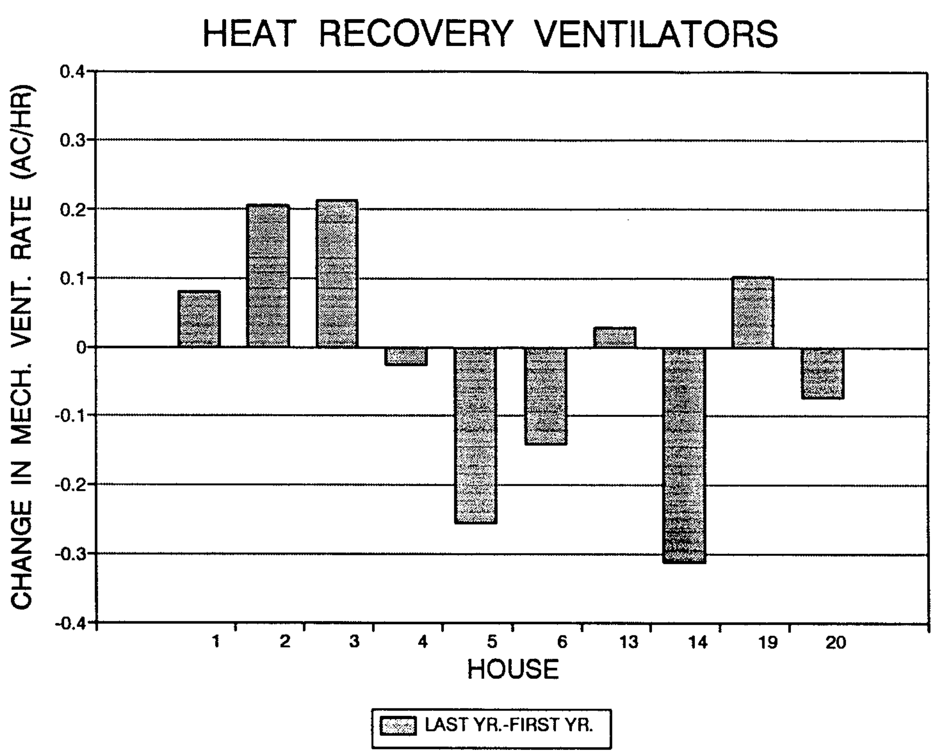


FIGURE 12



Average ventilation rates in the houses using forced air heating systems were slightly lower than in houses with baseboard heating. Homeowners in the former group may have been more inclined to turn off the HRV because another air moving device, i.e. the furnace blower, was present. In the baseboard heated houses, the HRVs were the only air circulation devices so their non-use would have been more noticeable.

Figure 12 shows the change in average mechanical ventilation rates between the first and last year of operation for ten houses from which there was sufficient data. Approximately one-third of the houses experienced significant decreases in ventilation rates, one-third enjoyed significant increases and rates in the remaining houses were roughly the same. The mean change for the group was negligible (-0.02 ac/hr).

4.4 MODE OF OPERATION

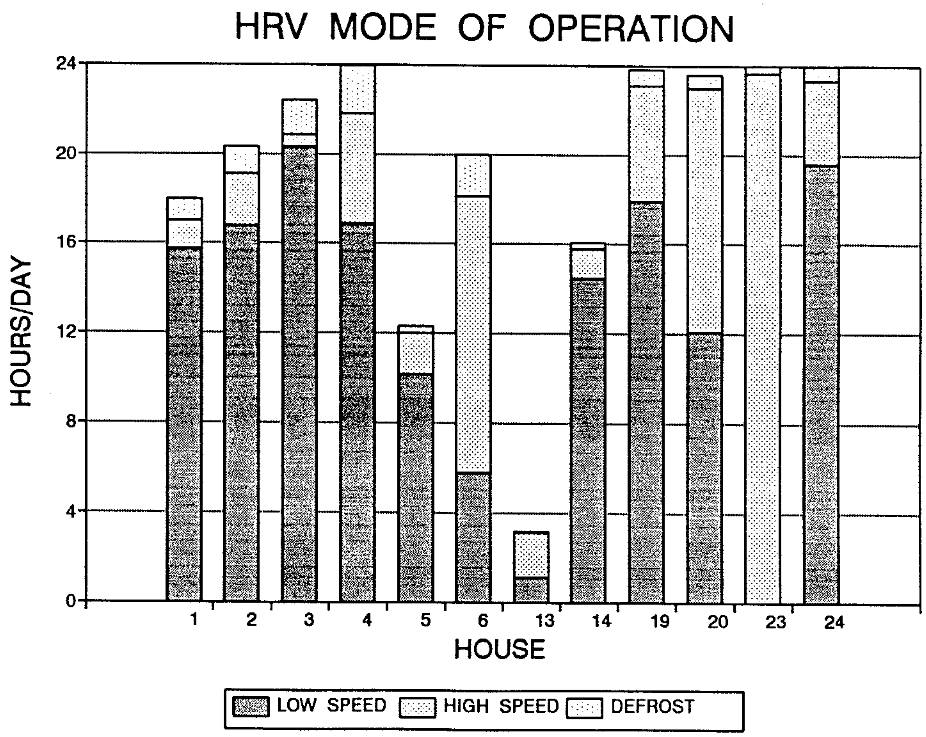
The average mode of operation (low speed, high speed or defrost) is shown in Fig. 13. As expected, the units operated mainly at low speed although a few systems ran predominately at high speed, such as that in House #23 which was designed for continuous high speed operation. Defrost mode operation was slightly more frequent in the first generation units (#1 to #6) than the second generation machines.

4.5 ANNUAL MECHANICAL VENTILATION RATES, EXHAUST-ONLY HRVs

The estimated average annual mechanical ventilation rates for the two exhaust-only HRVs are summarized in Table 6 and Figs. 14 and 15. Two sets of results are shown because the original units, installed at the time of construction and suffixed by (A), were replaced approximately one-third of the way through the monitoring period with upgraded models, identified as (B).

Note that these results are estimates based on the measured air flow rates recorded during the monthly site visits with the assumption of continuous system operation. This was considered a reasonable assumption because the ventilation blower could only be turned off with the loss of the hot water pre-heating, space heating and air-conditioning capabilities. Further, the multi-position speed controls were taped to a single speed setting and no means of shutting off the HRV was provided short of throwing the circuit breaker supplying power to the entire appliance.

FIGURE 13



Note: The HRV in House #23 was set-up to operate in high speed and defrost modes only.

TABLE 6

EXHAUST-ONLY HEAT RECOVERY VENTILATORS

ESTIMATED MECHANICAL VENTILATION RATES* (AC/HR)

HOUSE	11(A)	11(B)	12(A)	12(B)	MEAN
ANNUAL WINTER SHOULDERS SUMMER	0.48 0.62 0.25 0.09	0.42 0.35 0.27 0.45	0.45 0.41 0.18 0.34	0.45 0.40 0.26 0.49	0.44 0.42 0.24 0.36
CSA F326 MINIMUM VENTILATION CAPACITY	0.40	0.40	0.40	0.40	
% CSA F326 MINIMUM VENTILATION CAPACITY	122%	105%	114%	114%	

* Assuming continuous HRV operation (see text).

FIGURE 14

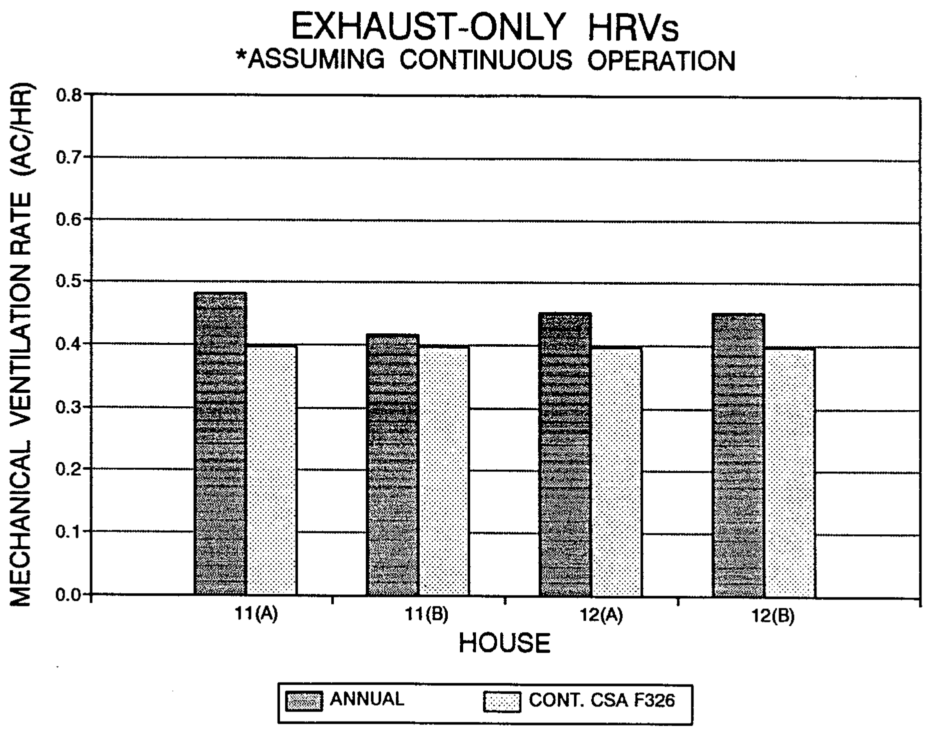
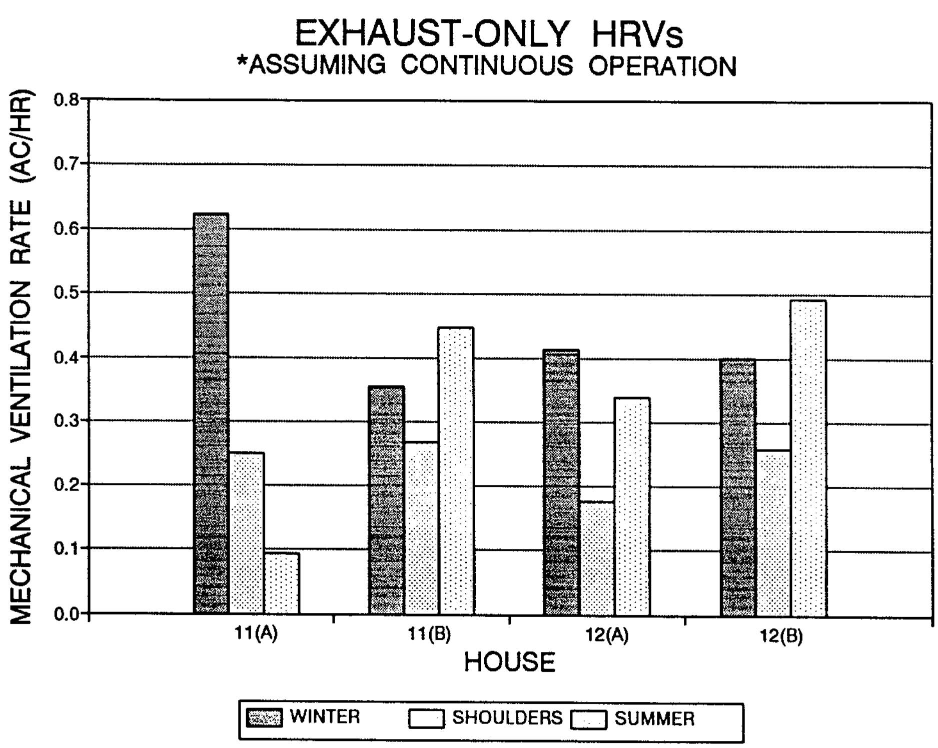


FIGURE 15



SECTION 5

DISCUSSION

5.1 MECHANICAL VENTILATION RATES

The most striking observation of this study is the disparity between the delivered average annual mechanical ventilation rates for the HRV systems (conventional and exhaust-only) compared to those of the central exhaust systems. The 14 HRVs typically achieved mechanical ventilation rates roughly equal to the minimum ventilation capacity specified by CSA F326 assuming it were maintained on a continuous basis. In contrast, the three central exhaust systems were seldom used, resulting in extremely low annual mechanical ventilation rates, even though the installed capacities were similar to those of the HRVs. In one house, the make-up air duct provided a slight amount of additional ventilation to augment the central exhaust system but the combined rate was still quite low. Utilization of the booster fans in two of the houses paralleled those of the central exhaust systems.

It is worth considering possible reasons for the different utilization patterns observed for the central exhaust and HRV systems. The most obvious explanation, mechanical reliability, can be ruled out since the HRVs, particularly the first generation models, experienced a number of breakdowns while not a single maintenance problem was recorded with the central exhaust systems.

One explanation for the difference may be that the homeowners with HRVs responded to the instructions and numerous reminders that their ventilation systems should be operated on a continuous or near-continuous basis. Homeowners with central exhaust systems were informed of the purpose of their systems and how they were to be operated but did not receive the same level of persuasion. The type of control systems may have also affected utilization. Two of the three central exhaust systems used automatic controls with single speed blower operation. Observations from the site visits suggest that the homeowners treated the dehumidistats as on/off switches. Psychologically, they may have regarded the central exhaust systems as an optional feature to be activated when there was a perceived need for ventilation, as opposed to a system designed to operate automatically. The large flow capacity of the central exhaust systems, relative to conventional ventilation systems, may have also increased perceptions of energy waste. In contrast, the HRVs may have been viewed as more complicated devices, whose operation, although not totally understood, required near-continuous use. Numerous comments were received from the homeowners that they did not understand the use or operation of their HRVs, even after two or three years of occupancy and in spite of the written instructions and verbal explanations. The heat recovery capability of the HRVs may have also reduced perceptions of energy waste.

5.2 IMPLICATIONS FOR VENTILATION STANDARDS

The results of this study have some significant implications for residential ventilation standards such as CSA F326. Based on the observed utilization, it is apparent that additional thought must be devoted to homeowner education as well as to the operation and control of ventilation systems, particularly the homeowner interface, if the intent of CSA F326 is to be realized. For example, if the results of this study are representative, mechanical ventilation rates for central exhaust (or equivalent) systems which meet CSA F326, may fall well short of those anticipated by the standard's creators.

One method of improving homeowner education may be to include, with the ventilation system, a short video which describes the proper use, operation and maintenance requirements of the system. Considering the success this medium has enjoyed as an educational vehicle, and the widespread use of cassette recorders, videos might be more frequently consulted than an instruction manual.

A final point to note is that the study homeowners were probably more typical of the general public than those in other research projects. Individuals who purchased the houses in the Flair project received incentives to do so in the form of free energy conservation options. As a result, many of them could not be classified as conservation enthusiasts with a special interest in the house and its unique energy related features. Investigations conducted on other R-2000 houses, have typically dealt with people who had made a conscious financial decision to purchase the conservation options for their perceived benefits (including improved air quality) and could thus be better expected to operate and maintain the ventilation system in its intended fashion. This observation takes on special significance considering that such documents as the National Building Code and CSA F326, are written to house the general public, not just energy enthusiasts. Thus, the results of this study may be indicative of actual usage patterns for merchant-built houses constructed to these codes and standards.

SECTION 6

CONCLUSIONS

6.1 UTILIZATION OF CENTRAL EXHAUST SYSTEMS

- o Homeowner utilization of the three central exhaust systems averaged only 0.62 hours (37 minutes) per day, producing an average annual mechanical ventilation rate of 0.01 ac/hr. This represented less than 3% of the CSA F326 minimum ventilation capacity assuming the F326 rate was maintained on a continuous basis. Most of the total air change rate was provided by natural infiltration.

6.2 UTILIZATION OF HEAT RECOVERY VENTILATORS

- o Homeowner utilization of the 12 conventional air-to-air Heat Recovery Ventilators averaged 19.3 hrs/day, producing an average annual mechanical ventilation rate of 0.33 ac/hr, although large variations were found between houses and seasons. This represented 75% of the CSA F326 minimum continuous ventilation capacity assuming the F326 rate was maintained on a continuous basis.

- o Ventilation rates delivered by the first and second generation HRV's were found to be similar. Lower ventilation rates were observed in houses with forced air heating systems compared to those houses with electric baseboard systems.

6.3 IMPLICATIONS OF THE STUDY

- o The results of the study indicate that additional thought must be devoted to homeowner education and ventilation system operation and control if the intent of ventilation standards such as CSA F326 is to be achieved.

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