#3622

SUPER ENERGY EFFICIENT HOME PROGRAM

BACKGROUND ON THE DEVELOPMENT OF THE R-2000 HOME PROGRAM DESIGN AND INSTALLATION GUIDELINES FOR VENTILATION SYSTEMS

NOVEMBER 1, 1986

Canadian Home Builders' Association

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Energy, Mines and Resources Canada   Énergie, Mines et Ressources Canada

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ACKNOWLEDGEMENTS

This report was prepared under the direction of M. Riley, Chief, Residential Technology and Industry Development, R-2000 Home Program, Energy, Mines and Resources Canada. The author also acknowledges the contribution of Buchan, Lawton, Parent Ltd. and Gustav Handegord of Trow Ltd. in the development of the ventilation guidelines and the preparation of this report.

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BACKGROUND ON THE DEVELOPMENT OF THE R-2000 HOME PROGRAM DESIGN AND INSTALLATION GUIDELINES FOR VENTILATION SYSTEMS

1.0 INTRODUCTION

This report outlines the development of the Design and Installation Guidelines for Ventilation Systems for R-2000 Homes. This set of guidelines represents one of the first initiatives to develop comprehensive requirements for the design and installation of mechanical ventilation systems in residential buildings. The guidelines outline requirements for a continuous supply of ventilation air to dilute and therefore control contaminants produced from dispersed sources in a home (e.g. occupants and building materials), an additional capability for periods of high humidity or contaminant production and also specify that some contaminants and odours in kitchens and bathrooms must be removed at their source and exhausted directly to the outside.

Most of the information presented in this report is now reflected in the R-2000 training and education courses provided through the Canadian Home Builders' Association (CHBA) and the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI).

2.0 RATIONALE FOR CHANGES TO THE EXISTING GUIDELINES

The new ventilation guidelines were developed in response to a review of the technical requirements for R-2000 homes conducted by the Bureau of Management Consulting [1], and the results of a program of testing and monitoring of the initial R-2000 homes.

During the review of technical requirements, more than seventy individuals across Canada, including builders, mechanical contractors, equipment suppliers and manufacturers, representatives from government housing agencies and utilities, warranty and regulatory authorities and building scientists were surveyed. For the monitoring program, approximately three hundred R-2000 homes and a sample of control homes representing typical construction were monitored to measure levels of various airborne contaminants and to determine the performance of ventilation systems installed in R-2000 homes.

The technical review and the monitoring program both identified a number of important issues and concerns which needed to be addressed.

1. Regulatory authorities and building inspectors generally felt that the original ventilation guidelines were too vague and presented difficulties in enforcement and compliance.

2. While the monitoring results showed that, on average, the air quality in the initial R-2000 homes was as good as, or superior to, the air quality in the sample of conventional homes, there was some variation among individual homes [2]. The results indicated a need to ensure that minimum ventilation rates are met in all houses and that ventilation air is distributed to all areas of the house.

3. Most of the individuals surveyed indicated that there was a need for greater flexibility in the types of ventilation systems that could be installed in R-2000 homes. More specifically, it was felt that the existing requirements focused primarily on balanced air-to-air heat recovery ventilators (HRVs) and virtually excluded other types of ventilation systems, including those incorporating simple, inexpensive fans.

4. Concern was expressed that there was no mechanism for accommodating unbalanced ventilation systems, including new heat recovery systems which recover heat from stale exhaust air to heat domestic water.

5. The survey indicated that requiring makeup air for all exhaust equipment, regardless of size or time operated, was too rigid. It was felt that revision of the R-2000 technical requirements to restrict the use of those combustion appliances most susceptible to backdrafting or spillage of combustion products has substantially reduced concern over negative pressures in the house. Some organizations were particularly concerned that the use of recirculating kitchen range hoods was being encouraged, and that clothes dryers were being vented inside the house.

6. The review indicated that the issue of when and how makeup air would be provided to the building was inadequately addressed in the existing guidelines, since no guidance was provided on the sizing of makeup air ducts or on the issue of compliance.

7. Concern was expressed that some ventilation systems, though installed with sufficient capacity, were not being operated, or were operated infrequently, and therefore were not adequately controlling contaminants. This indicated a need to address the issues of ventilation system controls and operation.

8. There was concern that the existing requirement for a ventilation capacity of 0.5 ach (air changes per hour) was excessive for large homes and the required equipment would be prohibitively expensive to install and operate.

In summary, the review of technical requirements and the monitoring results indicated that the existing ventilation guidelines required major revisions to broaden the types of ventilation equipment that can be used in R-2000 homes and to ensure that builders and mechanical contractors receive precise information and guidance on the design of ventilation air supply and distribution systems, the installation of makeup air inlets and methods of measuring airflows to ensure compliance.

3.0 DEVELOPMENT OF THE NEW GUIDELINES

Gustav Handegord, formerly of the National Research Council of Canada (NRC) and a member of the American Society of Heating, Refrigeration and Air Conditioning Engineers' (ASHRAE) committee on indoor air quality, was retained as technical consultant to assist Energy, Mines and Resources Canada (EMR) and the Canadian Home Builders' Association (CHBA) in the development of the new ventilation guidelines. Subsequently Buchan, Lawton, Parent Ltd., in consultation with building researchers working in the field, assisted in the development of those requirements relating to the provision of makeup air for unbalanced ventilation equipment and procedures to determine compliance with the guidelines.

Existing standards formed the basis for developing the new ventilation guidelines. In particular, ASHRAE Standard 62-81, Ventilation for Acceptable Indoor Air Quality [3] was used as the basis for establishing a continuous minimum ventilation rate for each room of the house to control contaminants generated by the occupants and other interior sources such as building materials and furnishings. However, refinements were necessary in order to address a number of issues not covered in this standard, including the supply of ventilation air to basement and utility areas and the need to control excessive humidity and very high levels of contaminants generated on an intermittent basis.

Installation requirements for equipment were based primarily on the Canadian Standards Association (CSA) draft standard for the installation of heat recovery ventilators [4], the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI) Residential System Design Manual [5] and experience gained during the initial phase of the R-2000 Home Program.

The guidelines assume that outside air is suitable for ventilation use and therefore no provision is made for filtering or conditioning it.

The first draft of the new guidelines was sent to the seventy individuals included in the initial survey and to ventilation equipment manufacturers and suppliers, members of the CSA Committee on Installation Guidelines for Heat Recovery Ventilators (CSA Standard C444), some members of the committee responsible for ASHRAE Standard 62-81, and other consultants and researchers. Revisions were made as a result of the comments received, and the revised draft was submitted to the R-2000 Technical Advisory Committee for approval in principle. Editing and refinements followed comments from other industry representatives involved with the implementation of the R-2000 Home Program. The guidelines were then recommended for implementation by the R-2000 Technical Requirements Committee.

4.0 RELATIONSHIP WITH ASHRAE STANDARD 62-81

ASHRAE 62-81 focuses primarily on the control of carbon dioxide and body odour generated by occupants and recommends a minimum ventilation rate of 5 L/s (10 cfm) for each habitable room. This rate was adopted as the continuous ventilation rate for general contaminant control in habitable rooms, kitchens and bathrooms.

ASHRAE 62-81 also contains recommendations concerning the removal of contaminants from sources like kitchens and bathrooms. It is recommended that in these rooms, exhaust capacities of 50 L/s (100 cfm) and 25 L/s (50 cfm) respectively should be installed. This exhaust capacity requirement has also been incorporated into the R-2000 ventilation guidelines.

ASHRAE 62-81 does not address the issue of ventilation for basement, workshop or utility rooms. These are areas with particular ventilation requirements because of activities carried out and materials stored in them. A continuous ventilation rate of 10 L/s (20 cfm) for these areas was proposed and met with acceptance. This requirement has the added advantage of allowing subsequent finishing of the basement as two habitable rooms without requiring modification of the ventilation system capacity. Utility rooms are defined as areas that are entered and where activities are carried out, such as laundry rooms and workshops, but exclude areas such as closets, storage rooms, mechanical rooms and furnace rooms with a combustion air supply.

ASHRAE 62-81 also does not address the issue of controlling excess humidity or higher-than-normal levels of contaminants generated on a short-term basis. This was felt to be an important issue since excessive humidity can increase the risk of damage to the building envelope or result in condensation, mould and mildew within the building. The R-2000 ventilation guidelines therefore include a requirement for additional intermittent capacity of 25 L/s (50 cfm), to be activated manually or by a humidity controller.

The program also had to address the issue of large open areas which comprise more than one functional room, such as a combined living/dining-room area. The guidelines specify that these areas should be treated as two individual rooms. Some judgement and interpretation will be needed in order to determine whether a particular area should be considered as one or more rooms. For example, a small eating area in a kitchen would not be regarded as a separate room.

5.0 VENTILATION BASED ON NUMBER OF ROOMS INSTEAD OF HOUSE VOLUME

It is felt that using the number of rooms in the house as the basis for calculating the ventilation requirements has clear advantages over using the house volume. A calculation based on the number of rooms provides a relatively simple method for builders and installers to determine ventilation requirements and for inspectors to verify compliance of a ventilation system.

A calculation based on the interior volume of a house is particularly dependent on the foundation type and size of the rooms. The amount of ventilation air provided to the house could vary greatly depending on whether the house is constructed with a slab-on-grade, crawl-space or full basement foundation or whether rooms have cathedral ceilings.

The relationship between the ventilation rate calculated by the per-room method and house volume is demonstrated in Figure 1. For example, a small bungalow with a slab-on-grade foundation would have a volume of about 300 M^3. The ventilation rate, depending on the number of rooms, could be equivalent to an air change rate in excess of 0.5 ach. The same house with a full basement would have twice the volume and therefore have a ventilation rate equivalent to 0.30 ach.

The per-room requirement ensures that a minimum amount of ventilation air is supplied to the occupied zone of each room regardless of the overall construction of the house or size of room. Ventilation rates in R-2000 homes would typically range from 0.30 to 0.45 ach. The average ventilation rate for R-2000 homes built to date is equivalent to 0.35 ach [2].

Concern was expressed that the air change rate achieved in some houses, particularly those with small rooms and a slab-on-grade foundation or a fully finished basement, could be excessive for some types of occupancy. Therefore the R-2000 Technical Requirements Committee agreed that the continuous ventilation rate could be adjusted downwards to be equal to an air change rate of 0.45 ach. However, the installed system must be still capable of providing the total unadjusted capacity required to meet the minimum rate specified by the per-room calculation.

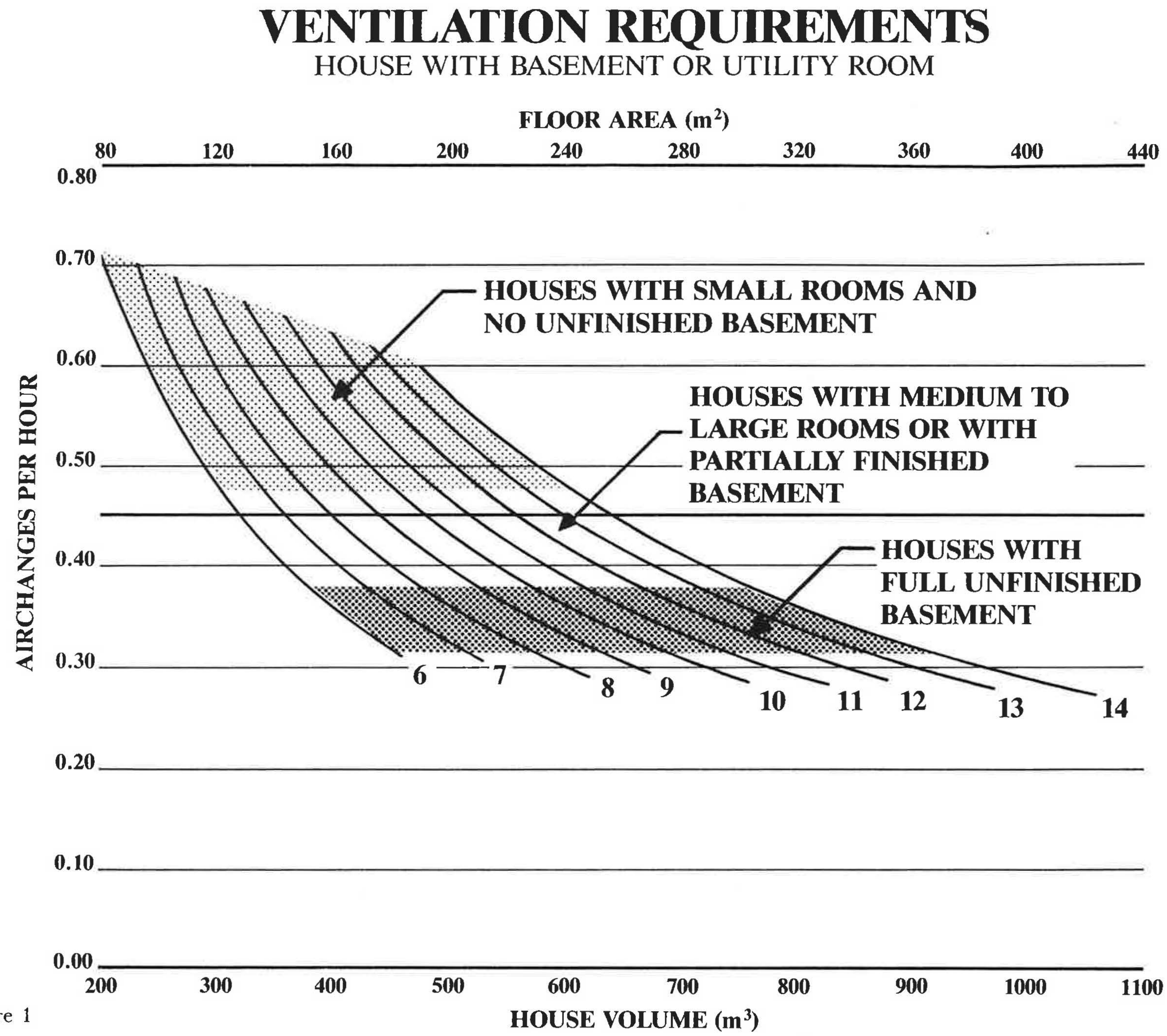
VENTILATION REQUIREMENTS
HOUSE WITH BASEMENT OR UTILITY ROOM
FLOOR AREA (m²)
80
120
160
200
240
280
320
360
400
440
AIRCHANGES PER HOUR
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
HOUSES WITH SMALL ROOMS AND NO UNFINISHED BASEMENT
HOUSES WITH MEDIUM TO LARGE ROOMS OR WITH PARTIALLY FINISHED BASEMENT
HOUSES WITH FULL UNFINISHED BASEMENT
6
7
8
9
10
11
12
13
14
200
300
400
500
600
700
800
900
1000
1100
HOUSE VOLUME (m³)

Figure 1

It should be noted that this reduction is generally small in terms of actual airflow. For example, if a small slab-on-grade bungalow has seven rooms and a utility room, the per-room calculation specifies a ventilation rate of 45 L/s. This is equivalent to 0.54 ach if the house volume is 300 M^3. Adjusting the continuous ventilation rate to the equivalent of 0.45 ach reduces the required flow rate to 37.5 L/s. An air change rate of 0.45 ach plus 0.05 ach of natural infiltration is equivalent to the minimum ventilation rate required for similar homes in Sweden.

The issue of distributing ventilation air is also addressed by the use of a per-room requirement. The guidelines state that the amount of ventilation air provided to each room must not be less than the per-room requirement specified in the guidelines for that room type.

Provisions in the guidelines allow kitchens, bathrooms, utility areas and basements to be ventilated indirectly with air supplied from another room. This can be used to advantage in designing a ventilation system or to increase ventilation to certain rooms without increasing the overall ventilation rate. For example, ventilation air for kitchens and/or bathrooms can be provided via living rooms and bedrooms, providing stale air is being exhausted from the kitchens and bathrooms at the ventilation rate specified for those rooms. Practically, this means that there must be either a continuous supply or continuous exhaust of air from a room. This permits the use of balanced ventilation equipment such as an HRV to supply air directly to some rooms while exhausting air from others to meet all ventilation requirements.

ASHRAE is now considering revising Standard 62-81 and basing the ventilation rate on house volume. The proposed rate of 0.35 ach reflects average air change rates monitored in the initial R-2000 demonstration homes [2] and is equivalent to the average ventilation rate for these homes calculated by the per-room procedure specified in the new R-2000 guidelines. The proposed revision to the ASHRAE standard is at the draft stage.

It should be noted that the CSA draft national standard for residential ventilation [6] is based on a per-room requirement similar to that included in the R-2000 guidelines, rather than on a single average ventilation rate based on house volume.

6.0 MAXIMUM PRESSURE DIFFERENCE ACROSS THE BUILDING ENVELOPE

The R-2000 ventilation guidelines no longer include a specific requirement for balanced airflows for ventilation systems. This issue is addressed by specifying maximum allowable pressure differences between the interior and the exterior of the building envelope rather than balanced airflows. This will permit the installation of a wide range of ventilation equipment including exhaust-air heat pump heat recovery systems that are not designed to operate with balanced airflows. These can now be installed in R-2000 homes provided excessive pressure differences are not created across the building envelope.

Concern about the consequences of negative pressure in the building has been reduced, since the new R-2000 Technical Requirements do not alow the intallation of naturally aspirating combustion appliances for space and water heating. They also specify that only well-designed fireplaces and wood stoves with sealed doors and a separate supply of outside air directly to the firebox can be installed.

However, there remains some concern about the impact of very high negative pressures across the building envelope on the operation of combustion appliances and, in some areas, about the entry of soil gases into the house. Therefore, the ventilation guidelines have set limits for the maximum pressure difference allowed across the building envelope.

The guidelines specify an allowable pressure difference of 10 pascals (Pa) during continuous operation of the ventilation system and 20 Pa during the intermittent operation of any individual equipment or single appliance while operating simultaneously with continuous operation of the ventilation system. For example, an HRV with supply fan shut down for defrost or a kitchen exhaust fan might represent the largest intermittent unbalanced airflow in a house. In either case, only the single device with the largest unbalanced airflow is considered, since the standard assumes that exhaust devices would rarely operate simultaneously.

The allowable pressure differences are significantly higher than those which would be considered for conventional homes, where naturally aspirating combustion appliances and open fireplaces are permitted. The CSA draft residential ventilation requirements standard [6] suggests an allowable pressure difference of only 5 Pa to minimize backdrafting problems in these homes.

Further monitoring is required to determine whether further restrictions are necessary for those areas with high radon concentrations. To date, radon levels have been low in most R-2000 homes across Canada.

7.0 PROVISION OF MAKEUP AIR

Unbalanced ventilation airflow will cause a change in the pressure difference across the building envelope. The magnitude of this change will be determined by the magnitude of the unbalanced airflow and the air leakage characteristics of the building envelope. Where unbalanced airflows are large and/or when air leakage through the building envelope is small, excessive pressure differences could develop unless makeup air from the exterior is provided. It was therefore necessary to provide procedures for identifying cases where makeup air would be required and for determining the number and size of makeup air inlets [7].

Appendix A of the guidelines describes three methods by which program authorities and builders can determine compliance with the pressure difference limits specified in the guidelines. These methods were formulated with the intention of avoiding the need for expensive additional tests on the building and providing the flexibility to determine compliance at both the design and/or post-construction stages.

Manufacturers' specifications for airflow rates for ventilation fans and other air-exhaust equipment, when tested to recognized standards such as ASHRAE 51-75 or CSA C260.2-1976, were accepted as a means to determine maximum airflows without the need to measure airflows for all ventilation and air-exhaust equipment installed in homes. In most cases, only the minimum continuous ventilation rate must be confirmed by measurement.

The envelope air leakage characteristics, as determined by the fan depressurization test [8] performed for all R-2000 homes, was recognized as a suitable source of information for determining compliance with the requirement for ensuring that any unbalanced airflows to not result in pressure differences across the building envelope exceeding permissible limits.

This method uses the equivalent leakage area (ELA) of the building envelope, obtained by means of the fan depressurization test, to determine compliance. The ELA is the sum of all the unintentional openings in a building envelope. A chart has been developed which gives the relationship between the building ELA and the maximum allowable unbalanced airflow to cause a 10 or 20 Pa pressure difference across the building envelope, based on the typical characteristics of R-2000 homes. For buildings where the ELA is insufficient to limit pressure differences to 10 or 20 Pa, a table has been developed which gives the additional ELA that can be provided by installing makeup air inlet ducts of different sizes. Duct sizes are based on an effective duct length of 25 m (75 ft).

A second option involves determining, at the design stage, the size of makeup air inlet which will provide enough makeup air to limit pressure differences caused by unbalanced airflows for those cases where fan depressurization test data are not known or where the builder wishes to design for the worst case. A table has been developed which indicates the size of makeup air inlet ducts required for limiting pressure differences to 10 and 20 Pa for various unbalanced airflows. The table assumes a minimal amount of leakage through the building envelope. Duct sizes are also based on an effective duct length of 25 m (75 ft).

The third method determines compliance by means of a test to measure pressure differences across the building envelope. This test is normally used only for borderline cases, since the ELA of a building, as determined by the fan depressurization test, can be directly related to the maximum allowable unbalanced airflow at 10 or 20 Pa. The instruments required for this test are the same as those used for measuring continuous ventilation rates in homes.

To assist builders at the design stage, a routine in the R-2000 energy analysis program (HOT-2000) estimates the ELA of the house and the allowable unbalanced airflow at 10 or 20 Pa pressure difference before makeup air would be required. This is based on fan depressurization test results from 250 R-2000 homes.

Experience with existing R-2000 homes has shown that the average R-2000 Home would require a makeup air inlet when unbalanced airflow exceeds 50 L/s (100 cfm) for continuous operation and 70 L/s (140 cfm) for intermittent operation.

It should be noted that there are separate codes and requirements for the supply of outside air for combustion to all fuel-fired space and water heating equipment, including wood-burning appliances such as fireplaces. Therefore the ventilation guidelines do not provide information on combustion air inlet requirements for combustion equipment, nor can combustion air be used as makeup air for unbalanced ventilation equipment. The supply of combustion air for fuel-fired appliances is a separate requirement from supplying makeup air for ventilation equipment to control pressure differences across the building envelope.

8.0 COMPLIANCE WITH VENTILATION REQUIREMENTS

For compliance and inspection purposes, the guidelines require that flow-measuring devices or sensors be permanently installed in the supply and/or exhaust ducts of the mechanical ventilation system in locations that allow the continuous ventilation rate to be accurately measured. The sensors will also permit inspectors to quickly verify that required airflows are being provided and will allow airflows to be checked simply and inexpensively during service visits.

Appendix B of the guidelines gives information on locating and installing sensors in ductwork and procedures to measure airflows accurately.

Where kitchen and bathroom fans are used for intermittent ventilation, the rated capacity would normally be accepted, though it is recognized that the actual installed airflows could be lower than those specified. The issue of installed airflows which are lower than rated airflows will be addressed in planned revisions to existing standards governing the rating of fans and ventilators. Where the installation appears to be deficient, an inspector may wish to have confirmation that the installation meets the intent of the standard.

The guidelines also specify that a report must be completed by the installing contractor stating that the ventilation requirements have been met.

9.0 ACCEPTABLE VENTILATION SYSTEM CONFIGURATIONS

The guidelines specify the ventilation performance to be achieved rather than prescribe certain configurations. In many houses a single central system, such as an HRV, is able to meet all the ventilation requirements. In others it may be desirable to use more than one component. For example, separate fans can be used to meet specific intermittent exhaust requirements when it is difficult to exhaust through a central system or when there is insufficient capacity to meet program requirements.

The guidelines require that each room in the house be supplied with ventilating air. This can be achieved by a separate ducted ventilation system or by an existing forced-air heating system providing it is designed to circulate air continuously throughout the house.

The guidelines also permit an installer to use dampers in the ductwork or other airflow control devices to switch the same airflow used for intermittent exhaust between different bathrooms when there is insufficient capacity to meet all intermittent exhaust requirements simultaneously.

Since the guidelines allow kitchens, bathrooms, utility areas and basements to be ventilated indirectly with air supplied via another room, the builder can increase the supply of ventilation air to such areas as living rooms and bedrooms to more than the minimum of 5 L/s, while exhausting stale air from kitchens and/or bathrooms. This permits the effective use of balanced ventilation equipment, such as HRVs, to supply ventilation air directly to some rooms while exhausting stale air from other rooms.

While a balanced heat recovery ventilator is still viewed as an effective means of meeting the R-2000 energy consumption target, alternative approaches, such as recovering heat from stale exhaust air for domestic water heating, can now be used. For homes with high levels of insulation which use particularly energy-efficient heating systems such as heat pumps, the ventilation requirements could be met by one or more conventional exhaust fans, providing the R-2000 energy consumption target is achieved.

In summary, while the types of ventilation systems which have become commonplace in R-2000 homes remain attractive and allowable under the new ventilation guidelines, a far greater range of design possibilities has been opened up for builders.

Appendix C of the guidelines shows illustrated examples of suitable ventilation system configurations.

10.0 CONCLUSIONS

The new R-2000 Ventilation Guidelines are the most comprehensive requirements developed to date for the ventilation of residential buildings. They attempt to address a wide range of issues relating to air quality and the design, installation and compliance of ventilation systems. They represent a significant advance in the evolution of design and construction standards, not only for R-2000 homes but for residential buildings in general.

Although the guidelines represent a major milestone, further work is underway to develop and refine national consensus standards for ventilation requirements and equipment. In conjunction with experience gained from the use of the new guidelines and data gathered from an ongoing monitoring program, this activity will demonstrate whether any refinements will be necessary in the future.

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