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A Canadian Standard for Residential Ventilation Systems

A. Grant Wilson
Building Science Consultant
Ottawa, Ontario
Canada, K1R 5K6

Increasing air-tightness of houses in Canada in recent years, and related concern over indoor air quality and excessive humidity in winter, has led to provisions in the National Building code of Canada for mechanical ventilation systems in all new self-contained dwelling units. This paper describes the development of national consensus standards to provide detailed guidance on design, installation and performance verification of such systems. The need to account for their interaction with, and impact on other components and systems is stressed. This includes the effect of house pressurization on condensation in the building envelope, and the effect of depressurization on the venting of fuel-fired combustion equipment.

INTRODUCTION

The National Building Code of Canada (NBC) generally forms the basis of provincial building code regulations. Requirements for mechanical ventilation of houses in the NBC have been evolving in recent years. In 1980, ventilation of rooms could be provided either by national means, through windows or equivalent openings, or by a mechanical system having the capability of providing at least one air change per hour (ach). Since windows are required for most rooms, mechanical ventilation was generally limited to exhaust fans in windowless bathrooms and kitchens. An exhaust system with a capacity of at least 50L/S was required for all houses with non-fuel-fired heating systems to provide ventilation for humidity control in winter.

In the 1985 NBC[1] all dwelling units were required to have a mechanical ventilation system capable of providing at least one-half ach during the heating season, with provision for make-up air from outside, in addition to provisions for natural ventilation. This new requirement was in response to increasing concern over inadequate indoor air quality, and particularly excessive humidity in winter, with the trend toward increasing air tightness of house envelopes.

Rigorous requirements for envelope air tightness were specified for the super energy efficient home program (R-2000), initiated in 1984 and supported by EMR Canada. Mechanical ventilation systems, usually incorporating exhaust air heat recovery, were required. Ventilation guidelines evolved from experience and were published in 1986[2]. These called for outdoor air supply to individual rooms, and exhaust from kitchens and bathrooms generally in accordance with residential requirements in ASHRAE Standard 62-81[3]. There were also limits on the increase in pressure difference across the building envelope resulting from any imbalance in the supply and exhaust provided by the system.

Some provinces, in considering application of the 1985 NBC residential ventilation requirements, identified the need for more specific definition of design, installation and compliance criteria for mechanical systems in the form of a national consensus standard. Those responsible for the R-2000 program also supported the development of such standards as a successor to their ventilation guidelines. Consequently the Canadian Standards Association appointed a technical committee in 1986 with this objective, and "preliminary" standards[4,5,6] covering performance requirements, installation and performance verification, have now been published. While experience in their use is being accumulated, development of the documents into a national standard is continuing. This paper will describe the principal provisions in the current documents and some of the modifications being considered.

VENTILATION AIR REQUIREMENTS

An early decision was made to take no account of the ventilating effects of uncontrolled air leakage, or of natural ventilation through operable windows, in determining the required capacity of the mechanical ventilation system. The standard is intended for new construction. The air tightness of Canadian houses has been increasing and this trend is expected to continue. In some regions the equivalent leakage area (ELA) of the house envelope, per unit area of exposed envelope, averages less than 1.8×10^{-4} m^2/m^2. The maximum allowable value for R-2000 houses is 0.7×10^{-4} m^2/m^2. Uncontrolled air leakage under typical winter conditions is extremely small within this range of air tightness. Even in Regions where ELA values of 3 to 5×10^{-4} m^2/m^2 are typical, the uncontrolled leakage during some periods of winter weather can be shown to be quite low over periods of several hours.

It was also decided to specify both a minimum total house ventilation (outdoor air) rate and minimum ventilation rates for individual rooms, including an exhaust capability for kitchens and bathrooms. The rates for individual rooms are patterned after residential requirements in ASHRAE 62-81, and are shown in Table 1. Experience with the R-2000 houses indicated the desirability of ensuring a reasonable distribution of ventilation air throughout the house.

The minimum total outdoor air capacity of the system is the sum of the individual room requirements but not less than 0.3 ach, based on the conditioned volume of the dwelling unit. For example, a 3-bedroom bungalow with 637 m^2 of floor space on the main floors might require a total of 60L/s, based on individual room requirements, which would correspond to 0.33 ach. For a larger house, with the same number of rooms, the minimum rate would be 0.3 ach. The Committee reasoned that a minimum air change value would account for greater rates of contaminant generation from building sources in larger houses. In this example the average rate per person, with four occupants, would be 15L/s, which is twice the minimum called for in ASHRAE 62-89. The minimum rate refers to a 24 hour average with periods of no ventilation air supply (eg. for defrosting of exhaust air heat recovery devices) not to exceed 2 hours.

Table 1
Minimum Ventilation Air Requirements

Space classification	Column 1 Base flow rate, L/s*	Column 2** Intermittent exhaust, L/s*	Column 3** Continuous exhaust, L/s*
Category A			
Double/Master bedroom	10	-	-
Basement	10	-	-
Single bedrooms	5	-	-
Living room	5	-	-
Dining room	5	-	-
Family room	5	-	-
Recreation room	5	-	-
Other	5	-	-
Category B			
Kitchen	5	50	30
Bathroom	5	25	15
Laundry	5	-	-
Utility room	5	-	-

*Based on air at a density of 1.204 kg/m^3.
Each area in a basement that is separated by a wall and doorway shall have a minimum ventilation requirement of 5 L/s. This does not include furnace rooms, storage rooms, and closets.
Ventilation requirements for any combined living room, dining room, and kitchen shall be determined as if they were individual rooms.
Other habitable rooms not listed shall have a minimum ventilation requirement of 5 L/s. This does not include spaces intended solely for access, egress, or storage, such as vestibules, halls, landings, and storage rooms. Habitable rooms are designated as category A or B, the latter being those that are usually the major sources of moisture and odours but are generally occupied for short periods. Ventilation air for these can be provided indirectly from other rooms by removing air at the rates in Table 1. **Either intermittent or continuous exhaust is required.

An exception to supplying outdoor air to Category A rooms at the rates in Table 1 is allowed if there is recirculation of air within the house at one ach or greater, so that a substantial degree of mixing of outdoor air with house air is achieved. Under these conditions the requirements are deemed to be met if there is a continuous supply or removal of air from these rooms at 20 L/S or more. This exception would apply, for example, to recirculating warm air heating systems where the rate of air delivery to individual rooms is usually based on heating requirements at design conditions. The outdoor air might be introduced in the return air plenum of the of the recirculating system. Another application would be to systems incorporating exhaust fans to induce the required minimum total supply of outdoor air to the house by leakage through the envelope, or through intentional openings when there is no assurance of providing outdoor air to individual rooms at the required rates.

The objective of the requirements for recirculating systems is to achieve a ventilation effectiveness for individual rooms approximating that called for in Table 1. These exceptions are now being reassessed with a view to recognizing differences between the direct introduction of outdoor air into the recirculating system and thence its supply to individual rooms, and the indirect ventilation of rooms with air that comes from other parts of the house. In the first situation, the required minimum rate of total air supply to individual rooms would decrease as the proportion of outdoor air in the supply increased, and the total rate of recirculation would be irrelevant. The minimum values, when the air supply was 100% outdoor air, would be those in Table 1. The current minimum value of 20L/s appears to be appropriate when outdoor air represents about 1/3 of the total. Where the ventilation air is being provided indirectly by air from other rooms (counting upon uniform mixing of the outdoor air throughout the house), the minimum rate of supply or withdrawal may have to be increased above 20L/s, with a minimum total rate of recirculation specified.

DWELLING UNIT PRESSURES

The preliminary standard specifics maximum allowable increases or decreases in indoor pressure (relative to outdoors) resulting from imbalances in air supply to and air exhaust from the house. For this purpose two operating condition are considered: with the system operating in its normal continuous mode to supply the minimum base flow rate of ventilation air (the base flow rate condition); and under a reference exhaust flow rate conditions in which any intermittent exhaust components of the system are also in operation, along with a clothes dryer and the highest capacity additional exhaust device (whether or not a part of the ventilation systems).

House pressure increases are of concern primarily because of the resulting increase in air exfiltration into wall and roof spaces and the potential for condensation in winter.

The preliminary standard place a limit on the excess of supply over exhaust, under the base flow rate condition, of 0.12 L/s per m^2 of the interior surface of the building envelope. There is apparently no published information on the tolerance of houses to increased exfiltration resulting from increases in pressurization. Ventilation systems consisting of an outdoor air supply duct connected to the return air plenum of recirculating warm air heating systems are relatively common in parts of Canada. The limiting value in the preliminary standard for the maximum allowable excess of supply over exhaust was derived from estimates of the outdoor air supply induced by these systems. There is an over-riding maximum allowable pressure increase of 10 Pa, which would occur only with very tight houses.

House pressure decreases are of concern primarily because of their adverse effect on the venting of combustion products from fuel-fired appliances. Such appliances and their venting systems vary in the amount of depressurization that they can tolerate without allowing excessive flue gas spillage into the dwelling. Combustion appliances in Canada are currently not tested and certified for tolerance to depressurization. In the absence of such certification the Committee identified three categories of fuel burning appliances based on recent field studies. Category 1 appliances, with a depressurization limit of 5 Pa, are those that take combustion air, and dilution air for venting control, from the dwelling and depend on natural draft to vent products of combustion. Category 11 appliances, with a depressurization limit of 10 Pa, are those that take combustion air from the dwelling but have their flue sealed from the dwelling. Category 111 appliances, with a depressurization limit of 20 Pa, are those that have a sealed outdoor combustion air supply and a sealed flue. The preliminary standard requires that these limits not be exceeded under the reference exhaust flow rate condition. It also requires that the house depressurization not exceed 10 Pa under base flow rate conditions, primarily because of concern over the possibility of increasing soil gas entry under continuous depressurization.

Designing ventilation systems to meet these limits requires an estimate of the leakage characteristics of the house envelope and any intentional vents that may be provided to control pressure differences and flow balances across the house envelope. For example, if the excess of supply over exhaust exceeds the limiting value, a passive exhaust vent can be used to reduce the exfiltration through the envelope. A similar vent can be used to allow inflow of outdoor air to limit depressurization when system exhaust exceeds supply.

The Committee has debated the logic of including exhaust devices that are not part of the ventilation system when establishing the reference conditions under which the depressurization limits must be met. One argument is that the manufacturers of exhaust devices (eg. clothes dryers, central vacuums, ranges with integral exhausts) should be responsible for providing make-up air. There are currently no such requirements, except for fuel-burning appliances, and it is not clear that providing for tempered make-up air at each such appliance would be an economical solution. Installation codes for fuel-burning appliances drawing air from the house call for passive vents. While the basis for the sizes specified varies, they are generally large enough to provide the necessary outdoor air at a house depressurization of about 5 Pa with Category 1 appliances.

Those that favour accounting for other exhaust devices argue that it is necessary for someone to take a "systems" approach to this aspect of house performance; and that the HVAC contractor, who generally installs both the heating and ventilating equipment, is the logical candidate. This also allows the contractor to take credit for air infiltration and exfiltration through the house envelope in developing design solutions to meet pressurization and depressurization limits.

The Committee has debated the prudence of defining depressurization limits for fuel-burning appliances as part of the ventilation standard. The problem is that, without such limits, the worst case (eg. 5 Pa) would have to be assumed, and this greatly restricts the types of ventilation systems that can be used. Appliance manufacturers are being encouraged to include depressurization limits in certification and labelling. The ventilation standard would then refer to the certified limit as the design requirement.

APPLICATION

As noted, preliminary standards on installation and performance verification have been published by CSA. In addition, the HVAC industry association has produced a design manual based on the CSA documents and is offering courses to its membership. A second edition of the Manual will soon be published. The document on performance verification calls for measurement of supply and exhaust flow rates, but other performance requirements can be verified by computation if the design is carried out in accordance with the Manual and is so certified by the installing contractor. Otherwise verification by test is required.

Consolidation of the three preliminary standards into a single document is proceeding, with the objective of publishing a national standard in 1991. Development of a supplementary guideline on design, installation and performance verification has also been initiated. There is evidence that the National Building Code of Canada will utilize the standard as the basis of residential mechanical ventilation requirements in the 1995 edition. In the meantime similar requirements have been incorporated in at least one provincial code.

A number of studies and research projects related to the application of the standard have been sponsored, notably by Canada Mortgage and Housing Corporation. These have included the development of generic design approaches and assessment of the impact of the standard on the industry. It is anticipated that manufacturers will offer components tailored to the requirements of the standard.

CONCLUSION

Increasing air tightness of houses in Canada, and related concern over indoor air quality and excessive humidity in winter, has led to provisions in the National Building Code for mechanical ventilation systems in all new self-contained dwelling units. Orderly and rational implementation of such provisions in residential construction requires that clear and appropriate guidance be provided on design, installation and performance verification.

A Technical Committee of the Canadian Standards Association has developed a set of preliminary standards covering these aspects, and is working towards the publication of a national standard in the near future. The HVAC industry association has published a complementary design manual and is offering courses to its members.

The documents are intended to provide flexibility in the design of ventilation systems while taking account of their impact on the performance of other dwelling components and sub-systems. Although logical, this systems approach requires participation and action by all affected parts of the industry. It also requires a new level of knowledge and understanding for those responsible for design, installation, verification of compliance, and use.