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Current Approaches for Mechanical Ventilation of Houses

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This Update, the second of two on mechanical ventilation systems for houses, describes current approaches to design and installation. It also examines the distribution problem and looks at some of the shortcomings of current approaches and how they might be overcome.

Current Approaches

Current approaches to the mechanical ventilation of houses are found in the CSA Standard F326, "Residential Mechanical Ventilation Systems," and in the National Building Code of Canada 1995.

CAN/CSA-F326

The CSA Standard F326 was first published in 1989 and revised in 1991. It is the most comprehensive standard available on this subject, and attempts to address the critical issues in the design and installation of an ideal mechanical ventilation system (see Construction Technology Update No. 14 for a discussion of these issues). The extent to which Standard F326 has been able to do this is limited by available technology.

CAN/CSA-F326 is generally written in performance terms (that is, it states what must be accomplished rather than how to accomplish it) and therefore provides a great deal of flexibility with regard to the system configuration needed for compliance.

This standard addresses the pertinent issues as follows:

Control

The greatest shortfall of a system that complies with Standard F326 (hereafter referred to as F326), relative to an ideal system, is in the area of control. Because available technology for demand-controlled ventilation systems does not approximate the ideal very closely, F326 requires only that the system have an on/off switch. Other forms of control, such as dehumidistats, are permitted, but the on/off switch must be able to over-ride them.

Capacity

F326 requires the ventilation system to have a total capacity equal to the sum of the individual room ventilation requirements shown in Table 1. For most houses, this will add up to about 0.3 air changes

Table 1. *Ventilation Capacity*

Room	Capacity, L/s
Master bedroom	10
Other bedrooms	5
Living room	5
Dining room	5
Family room	5
Recreation room	5
Basement	10
Other habitable rooms	5
Kitchen	5
Bathroom or water closet room	5
Laundry	5
Utility room	5

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per hour (ach). The standard also requires that the system be capable of running at a rate of 50% of this amount. In other words, it must have at least two delivery modes — full capacity and half capacity.

Distribution

F326 requires that the system be capable not only of providing the total indoor/outdoor air exchange rate (determined from Table 1) but also of achieving this rate in each room. Although the standard does not specify how this is to be accomplished, a duct system is generally required.

Sound level

Currently, F326 does not set a maximum sound output for fans since methods of testing and acceptable sound levels had not been fully agreed upon when the standard was last revised. It is expected that this issue will be addressed in a future edition.

Interference with other systems

For dwellings with vented combustion appliances, F326 requires that the ventilation system, when operating at full capacity and at the same time as a clothes dryer and any other exhaust devices with a capacity of 75 L/s or greater, not depressurize the dwelling more than 5 Pa. This limit (of 5 Pa) can be exceeded if the combustion appliance has been rated for a higher level of depressurization. The potential for such depressurization can be determined by calculation, when the airtightness characteristics of the dwelling are known, or by a test that actually measures depressurization.

Interference with the building envelope

F326 limits the amount of outdoor air that can be brought in relative to the amount of air that is extracted, in recognition of the fact that any excess of intake flow over exhaust flow must be made up by outward leakage through the envelope, which can lead to interstitial condensation. When the ventilation system is operating at full capacity, the amount of outdoor air brought in through intake components (e.g., supply fans) must not exceed the amount of indoor air extracted through exhaust components (e.g., exhaust fans) by more than 0.12 L/s/m^2 of the building envelope's inner surface. This value is based on the historical approach to ventilating houses in which an outdoor air intake duct is connected to the return air plenum of a forced-air furnace; the value represents the flow of air likely to be produced by such a system. This approach has been widely used in Canada without significant problems, even though it can lead to pressurization of the house.

As well as limiting the flow of air, F326 also places a limit of 10 Pa on the positive pressure that can be brought about by the discrepancy between the ventilation system intake and exhaust flows. This requirement is necessary because in a very tight house, even if the flow discrepancy criterion described above is satisfied, there is still the possibility of creating a high positive pressure in the house, which can lead to very high flow at individual leaks, causing local interstitial condensation problems.

1995 National Building Code

The 1995 NBC requires all houses to have mechanical ventilation systems. Systems that comply with F326 satisfy this requirement. However, F326 is a comprehensive standard and is written in performance terms specifically for trained mechanical systems designers. The NBC therefore provides prescriptively described alternatives, which are based on F326 and which can be used by those who are not experts.

These prescriptive alternatives address the issues identified in the description of the ideal system as follows:

Control

The 1995 NBC parallels F326 in that it requires only an on/off switch capable of over-riding any automatic controls.

Capacity

The NBC also parallels F326 in this area, and uses the same table of individual room airflow requirements (that is, the total capacity of the system must equal the sum of the room ventilation requirements shown in Table 1). It also requires the system to be capable of operating at a rate equal to the full capacity as well as at 50% of this capacity.

Distribution

There are basically two prescriptively described approaches in the 1995 NBC — one that can be used in houses with forced-air heating systems and one that can be used in those without such systems (see Figures 1 and 2 for these configurations).

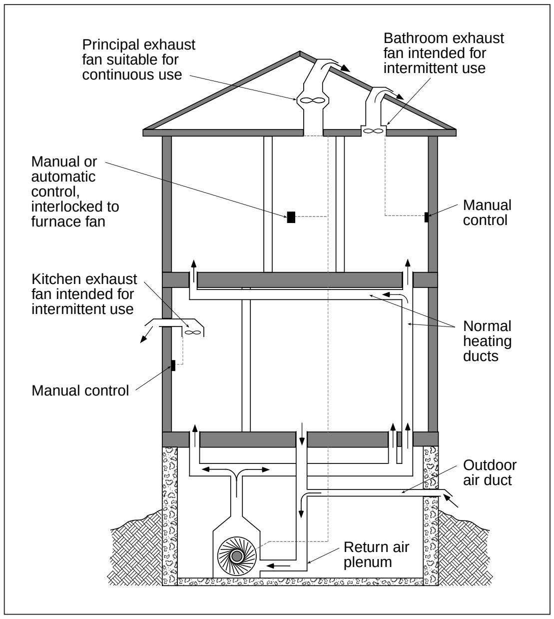

Figure 1. Ventilation system configuration for a house ***with*** *a forced-air heating system*

The main features of the configuration for a house ***with*** forced-air heating are:

The principal exhaust fan. This fan is the heart of the system. It draws air from throughout the dwelling. Although the occupants and their activities determine its operation, the fan should be capable of operating continuously. At this time, however, there is no standard method of testing and designating fans for continuous use. Therefore, such a designation is not yet mandatory.

The principal exhaust fan is expected to provide a relatively low level of ventilation — 50% of the minimum required capacity of the system (such that it can run continuously without excessive noise and without excessive energy penalty). Its control is placed in a central location, such as a living room, family room or hallway, and it is wired directly to the furnace circulation fan so that whenever the principal exhaust fan is turned on, the circulation fan is also activated.

The outdoor air duct. When the furnace circulation fan is turned on, it draws outdoor air through the outdoor air duct. This air is then mixed with return air in the return air plenum in order to increase its temperature before it reaches the furnace heat exchanger and the living areas of the house. (Very cold air passing over the heat exchanger can cause premature deterioration.)

The use of heating ducts to distribute outdoor air. The outdoor air is then distributed throughout the house by the regular heat-distribution (duct) system.

The supplementary fans. These fans (e.g., kitchen and bathroom exhaust fans) make up the discrepancy between the capacity of the principal exhaust fan and the minimum required capacity of the system.

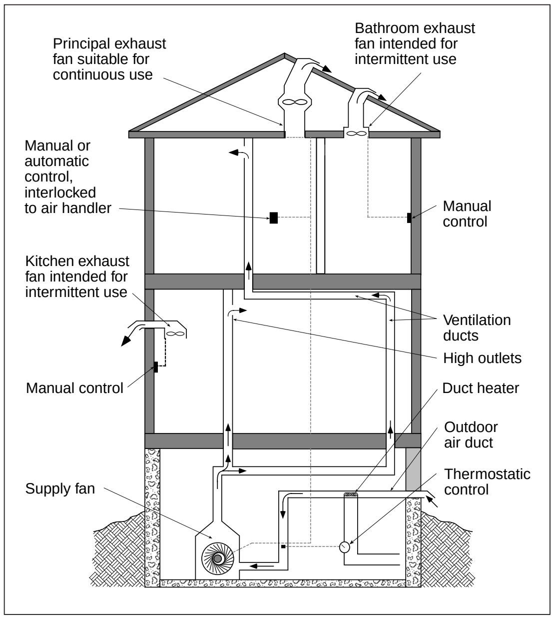

Figure 2. Ventilation system configuration for a house ***without*** *a forced-air heating system*

The main features of the configuration for houses ***without*** forced-air heating systems are:

The principal exhaust fan. This fan performs the same function as the fan in a house with forced-air heating and is sized and controlled in the same ways. However, its control is wired to the supply fan rather than to a furnace circulation fan.

The supply fan. This fan has the same capacity as the principal exhaust fan and operates whenever the principal exhaust fan operates, drawing outdoor air in through the outdoor air duct.

The outdoor air duct. When the supply fan is turned on, outdoor air is drawn in through this duct. Since, in this case, there is no return air to temper the outdoor air, another means must be used to warm up this air before it is circulated to the living areas.

The duct heater. This heater warms up the incoming outdoor air before it reaches the supply fan.

The use of ventilation ducts to distribute outdoor air. The outdoor air from the supply fan is distributed through a rudimentary system of small ducts installed for this purpose. These ducts must go to each bedroom and to any storey without a bedroom. Unlike heating ducts, they can be of combustible materials.

The supplementary fans. These fans have the same sizes and functions as those in a house with a forced-air heating system.

Sound level

The 1995 NBC requires all fans constituting part of the ventilation system to have sound ratings not exceeding 2 sones (53 decibels) with the exception of kitchen exhaust fans, which are permitted to have sound ratings of 3.5 sones (60 decibels).

Interference with other systems

The portion of the system that is suitable for continuous use includes the principal exhaust fan along with either the furnace circulation fan or the supply fan (in houses without forced-air heating). When operating in this mode, the system is balanced since the volume of air extracted by the principal exhaust fan is approximately equal to that brought in by the other fans.

The portion of the system that operates infrequently, for short periods of time, (known as the “high rate or episodic” portion) includes the supplemental exhaust fans, which operate when the principal exhaust fan is not able to provide an adequate rate of air change. When operating in this mode, the system is unbalanced, although it does not usually depressurize the house significantly unless other exhaust devices (e.g., a clothes dryer) are used at the same time. However, if there are other large exhaust devices (e.g., a stove-top barbecue) in the house, high levels of depressurization can occur if these devices are operated on their own. For this reason, in houses with spillage-susceptible combustion appliances, any such large exhaust devices (i.e., greater than 75 L/s exhaust capacity) must be provided with make-up air.

In the past, the NBC and other codes and standards tended to rely on the passive supply of make-up air through openings provided for this purpose. This is no longer felt to be a reliable approach for a simple, prescriptively described system because it does not have sophisticated depressurization controls (such as those provided in F326). According to the 1995 NBC, make-up air must be provided by a supply fan that is automatically activated whenever the exhaust device requiring make-up air is activated. If spillage-susceptible combustion equipment is not used, make-up air does not have to be provided.

Even at the relatively low level of depressurization likely to occur when the ventilation system is operated at its “high rate or episodic” level, an open fireplace operating in its “die-down,” or smoldering, stage can spill products of combustion into the house. In the absence of more sophisticated controls to prevent such levels of depressurization (such as those provided in F326), the only available safeguard is the installation of a carbon monoxide detector in any room that has an open solid-fuel-burning device. Where this is not a viable option, the prescriptively described alternatives must be abandoned in favour of a system that complies with F326.

Interference with the building envelope

Because these configurations are either pressure-neutral (when only the principal exhaust fan is operating), or mildly depressurizing (when other fans are operating), they are not likely to pressurize the house and therefore not likely to increase the potential for interstitial condensation in the building envelope.

The Distribution Problem

In the two configurations described above, the distribution of outdoor air to the rooms or spaces where it is needed is relatively simple in houses with forced-air heating systems but somewhat more problematic in houses with other types of heating systems.

In the configuration shown in Figure 2, ducts must be added to a house that would otherwise not need them. For this reason, IRC researchers are investigating alternative methods of ensuring proper distribution of outdoor air in houses without forced-air heating systems. To date, the findings can be summarized as follows:

- Ducted systems can provide adequate distribution of outdoor air.
- Central exhaust fans, such as those in kitchens and bathrooms, used without some other means of distribution, do not provide adequate distribution of outdoor air to bedrooms.
- Distributed exhaust systems that have pick-ups in the upper storey rooms can provide even distribution of outdoor air. An example of this type of system consists of an attic-mounted exhaust fan with manifolded intakes branching to all bedrooms. This system could be combined with a central passive inlet vent to reduce the depressurization of the house and increase total indoor/outdoor air exchange.
- The combination of a central exhaust fan with distributed passive air inlets does not achieve an even distribution of air since the inlets on the upper level become outlets in cold weather as a result of stack effect. Under these circumstances, lower storey rooms receive too much outdoor air, and upper storey rooms too little. This approach might be viable in milder climates in Canada.
- Closed bedroom doors with typically sized door undercuts do not hinder the adequate distribution of air provided by forced-air heating systems when the furnace circulation fan is operating.

Heat Recovery

Because the cold air entering the house must be heated, indoor/outdoor air exchange, whether provided by leakage or by mechanical ventilation, brings with it an energy and a cost penalty. In the past, when this air exchange took place without the whirring of fans, people tended to ignore the energy cost or simply attribute it to the need for the house to “breathe.” But once there is a greater awareness of the air exchange taking place (by means of a mechanical ventilation system) and of the possibilities the system offers for exercising some control over the ventilation of the house, there is a tendency to view the energy cost with some alarm and to seek some means of reducing it.

One way to do this is simply to turn off the ventilation system, or to use it less; however, this can result in poor indoor air quality, mould on interior building surfaces and interstitial condensation in the building envelope. Another approach is to incorporate a means of recovering heat from outgoing indoor air and transferring it to the incoming outdoor air. The heat recovery ventilator is the most commonly used equipment with this capability. (Figure 3 shows how it can be used to satisfy the requirements of the NBC.) However, ventilation systems with heat recovery capability inevitably cost more than those without. Therefore, this extra cost needs to be weighed against the cost of the energy saved.

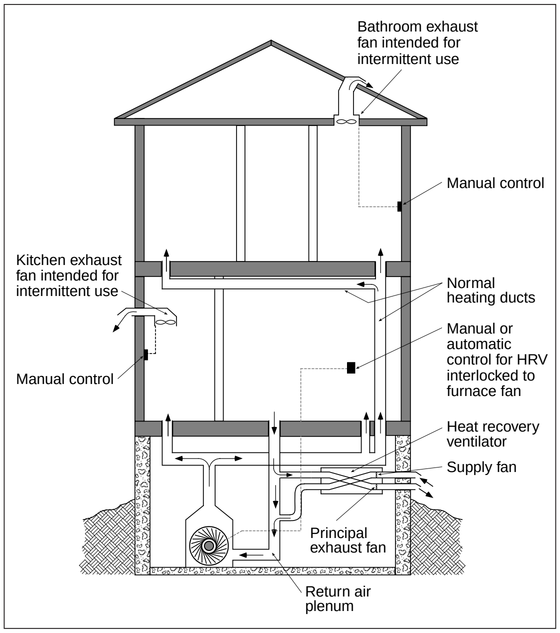

Figure 3. *Ventilation system configuration with a heat recovery ventilator for a house with a forced-air heating system*

This weighing of costs has been done in the Model National Energy Code for Houses, which includes regionally sensitive requirements for all parts of Canada. One such requirement deals with whether or not heat recovery must be incorporated into mechanical ventilation systems. In deciding whether or not heat recovery should be required in a particular region, the committee that developed this code employed extensive life-cycle cost analyses based on regional energy and construction costs. The results can be summed up as follows:

- for gas-heated houses, heat recovery is required only in the coldest regions;
- for oil- and electrically heated houses, heat recovery is required almost everywhere in Canada.

The Future of Mechanical Ventilation of Houses

In time, mechanical ventilation systems will likely approach the ideal (see Construction Technology Update No. 14), as demand-controlled ventilation becomes more practical and economical as a result of research and development. At the same time, it is possible that the amount of indoor/outdoor air exchange required will decrease. This could come about through the introduction of limits on pollutant emissions from building materials and furnishings. However, our ability to identify pollutants of concern and to set safe and practical limits on emissions is still very limited.

Finally, there is growing evidence that houses being built today are even tighter than those tested in the 1989 survey. In light of this evidence, the continued viability of the prescriptively described solutions in the NBC for houses that incorporate spillage-susceptible combustion appliances will have to be re-examined.

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