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Construction Technology Update, 1998-05-01

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Construction Technology Update No. 14

Why Houses Need Mechanical Ventilation Systems

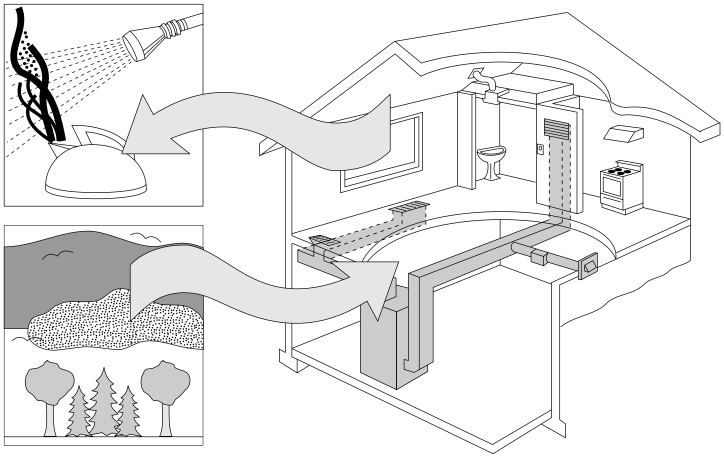
by J.C. Haysom and J.T. Reardon

This Update is the first of two that discuss mechanical ventilation systems in houses. It explains why houses need to be mechanically ventilated, and examines the main characteristics of an ideal system from the standpoint of design and installation.

The Need for Mechanical Ventilation

History of Ventilation in Houses

Houses need to have an indoor/outdoor exchange of air to replenish oxygen used by the occupants and to remove pollutants generated by breathing, household activities and emissions from building materials and furnishings. For many years, houses were constructed without mechanical ventilation systems and relied on air leakage through the building envelope to provide this indoor/outdoor air exchange during the winter months.



Canada Mortgage and Housing Corporation, "Complying with Residential Ventilation Requirements in the 1995 National Building Code" (1996), cover photo

In the past, this natural form of ventilation worked fairly well. Houses built before the 1960s tended to be quite leaky and pressure differences between the inside and outside, caused by wind or temperature difference, were sufficient to provide a significant amount of air exchange most of the time. However, a leaky building envelope does not always guarantee adequate air exchange. The movement of air requires both a pathway (e.g., a leak) and a pressure difference, and even a leaky house will experience periods when there is no indoor/outdoor air exchange. These periods are most likely to occur during the spring or fall, when winds are light and there is little or no indoor/outdoor temperature difference that can create a stack effect. The leakier the house, however, the less frequent the periods of inadequate air exchange.

Since most fuel-fired systems consume air from the house, and this air must then be replaced by leakage from outdoors, the operation of fuel-fired systems promotes some indoor/outdoor air exchange. The chimneys associated with these systems also provide a major leakage point, thus promoting air exchange even when the heating system is not operating. As well, a chimney tends to raise the level of the neutral pressure plane, thus reducing the outward pressure difference across the building envelope and, with it, the

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potential for interstitial condensation (i.e., condensation that occurs within the building envelope) caused by air leaking out of the house.

In houses built prior to the 1960s, the amount of air exchange provided by leakage was generally regarded as sufficient. But in the ‘60s, a number of factors changed this picture, including the increased use of electric heating in houses. Unlike fuel-fired systems, electric heating systems do not require the replacement of air, nor do they require chimneys. Consequently, electrically heated houses have a greater tendency to experience high humidity levels, interior surface moulds and interstitial condensation.

In the early 1970s, in response to these problems associated with electrically heated houses, Canada Mortgage and Housing Corporation (CMHC) took the step of requiring all NHA-financed electrically heated houses to incorporate exhaust fans, a requirement that was eventually incorporated into the National Building Code. By the mid-70s, these problems had became so apparent that CMHC contemplated not allowing electric heating in houses financed under its National Housing Act mortgage insurance program.

In addition to the increase in the use of electric heating, the 1960s brought the construction of houses that were much more airtight as a result of new products and practices, which included the substitution of panel sheathings, such as plywood and waferboard, for board sheathing; the replacement of paper-backed insulation batts by friction-fit batts and polyethylene film; improved caulking materials; tighter windows and doors; and more efficient heating systems.

When the energy crisis developed in the early 1970s, considerable emphasis was placed on reducing air leakage in order to conserve energy. The use of electric heating systems was encouraged and higher efficiency furnaces were developed further reducing air-change rates in buildings. This trend towards greater airtightness and higher efficiency furnaces gave rise to concerns that the exchange of air in houses by natural means might be insufficient in some instances to provide adequate air quality thus increasing the risk of health problems among the occupants. Condensation problems resulting from higher humidity levels were also a concern.

How Much Indoor/Outdoor Air Exchange Is Necessary?

The air-change needs of houses are not uniform. Not only do they vary from house to house according to the number of occupants, and the presence and strength of various pollutant sources, but, for any given house, they also vary with time as occupants come and go, and pollutant sources wax and wane. Nevertheless, ASHRAE Standard 62, Canadian Standards Association Standard CAN/CSA-F326 and the National Building Code of Canada (NBC) have all established levels of air change that can be expected to meet the peak or near-peak needs of a majority of normal households. (The latter two are based to some extent on ASHRAE Standard 62.)

All three approaches suggest an air change rate of about 0.3 air changes per hour (ach). This is the level of air change used internationally as the norm in terms of analyzing the success of various ventilation schemes. Again, it is recognized that few, if any, houses require constant air change at the rate of 0.3 ach. However, if a house is so tight that leakage fails to provide this level of air change for significant periods of time, it is likely that many such periods of shortfall will coincide with periods when this level of air change is required. When this happens, poor indoor air quality, high humidity, surface moulds and interstitial condensation can result.

How Airtight Are Recently Built Houses?

In 1989, a study to determine the airtightness of recently constructed houses in various regions of Canada was conducted. Airtightness was measured by carrying out fan-depressurization tests on nearly 200 houses throughout the country. The test results were analyzed to estimate the indoor/outdoor air change rate that could be attributed solely to the air leakage likely to be experienced by each house over a typical heating season. The results of the study allowed the researchers to make the following predictions:

- More than 70% of the surveyed houses would have an average air-leakage rate of less than 0.3 ach over the entire heating season.

- Almost 90% of the surveyed houses would have at least one month during the heating season when the average air-leakage rate was less than 0.3 ach.
- Virtually all of the surveyed houses (99%) would have at least one 24-hour period over the heating season in which the average air-leakage rate was less than 0.3 ach.

These results seem to indicate that a majority of houses being built in Canada using normal construction practices are close enough to being airtight that air leakage through the envelope cannot be relied on to provide the rate of air change deemed necessary to maintain adequate indoor air quality in a typical household. While the rate of air change through the building envelope may be adequate most of the time, it may not be all of the time. Therefore, to ensure that a satisfactory rate of air change is attainable at all times throughout the heating season, these houses must be provided with mechanical ventilation systems.

Characteristics of an Ideal Mechanical Ventilation System

Currently available technology is not able to provide an ideal mechanical ventilation system for houses. But before looking at the methods of mechanically ventilating houses that are available today, it is helpful to identify the characteristics of an ideal system:

Operate when needed
The system would operate whenever additional indoor/outdoor air exchange is needed and would do so without the need for occupant intervention.

Operate only when needed
This is important since a mechanical ventilation system has costs associated with it — the cost of the electricity to run it and the cost of heating the outdoor air that the system brings in. (The latter can be reduced by incorporating heat-recovery capabilities in the system, but cannot be eliminated altogether.) Therefore, the system should not operate during those periods when no indoor/outdoor air exchange is required. The length, timing and frequency of such periods vary from household to household. Air exchange is not required when:

- there are no occupants in the house
- there are no activities or processes underway that generate pollutants
- there is sufficient air exchange due to wind or stack effect to meet the household's needs.

Provide needed amount of air exchange
The system would be able to deliver enough outdoor air to meet the probable maximum needs of the household. It would also be capable of modulating delivery so that it did not deliver more outdoor air than required at times of reduced need. A system that does not have this capability is likely to provide too much outdoor air most of the time it is in operation, resulting in excess energy costs and low humidity. As well, a system that is unresponsive can annoy the occupants, possibly to the point that they simply turn it off altogether.

Distribute outdoor air where needed
It is not enough that the mechanical ventilation system change the air in the house as a whole to meet the standard of 0.3 ach. The system must also be able to deliver the outdoor air to those parts of the house where the occupants are likely to spend most of their time — the living room, the kitchen and the bedrooms.

Be quiet
The system would be quiet enough so that the occupants would not be tempted to turn it off to reduce noise.

Not interfere with other systems
There is significant potential for mechanical ventilation systems to interfere with the operation of other systems, such as certain types of fuel-fired heating systems. Under these circumstances, if the ventilation system creates a high negative pressure in the house, the products of combustion (which can be harmful to the occupants) can spill into the house rather than flowing up the chimney to the outdoors.

Not interfere with the building envelope
The system would not create significant positive pressure in the house since this could drive humid air from the house through the building envelope, resulting in interstitial condensation.

Demand-Controlled Ventilation

The first two characteristics of the ideal mechanical ventilation system described above are related to the issue of control. A system that embodies these characteristics is known as a "demand-controlled ventilation system." Such a system would ideally be controlled by an array of sensors — one for humidity and one for every possible pollutant that the ventilation system would have to respond to, including carbon monoxide, carbon dioxide, formaldehyde, volatile organic compounds, etc. The system would bring in outdoor air and/or extract indoor air until all of these sensors determined that specific pollutants were at, or below, predetermined safe levels. Whenever a sensor detected a pollutant above its safe level, the ventilation system would operate.

A less-than-ideal demand-controlled ventilation system would have at least one sensor. For example, many ventilation systems are controlled by dehumidistats: the system operates until the dehumidistat has determined that the humidity in the house is at a safe level. Excess humidity is one of the main reasons that ventilation is required, but not the only one. The amount of ventilation required to control humidity may not be sufficient to control other pollutants since this depends on the activities of the occupants, on the relative strengths of other pollutants and on the level of humidity.

Carbon dioxide (CO_2) sensors are sometimes used to control ventilation systems in large buildings, and this technology is just now becoming available for residential use. Increasing CO_2 concentration is usually a good indicator of decreasing air quality but it may not be adequate in cases where there are unusual pollutants, such as those generated by certain hobbies.

The ideal system requires the full array of sensors mentioned above. However, at present this ideal is not attainable because:

- there is insufficient knowledge and information to determine
  - which pollutants should be monitored, and
  - what the acceptable levels for a particular pollutant are.
- practical, reliable and economical detectors for all pollutants of concern are not available.

While research and development is underway in many countries to try to address these issues, breakthroughs are not expected in the near future.

For a discussion of current approaches to mechanical ventilation systems for houses, please see Construction Technology Update No. 15.

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May 1998
ISSN 1206-1220

"Construction Technology Updates" is a series of technical articles containing practical information distilled from recent construction research.

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