Ventilation Strategies for Small Buildings

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Contents

Small buildings have traditionally relied on air leakage to provide ventilation. Improvements in construction, such as tighter sealing windows, continuous air and vapour barriers and greater attention to details have led to more airtight buildings. As airtightness has increased, air leakage may no longer be able to provide the total ventilation needed in these newer buildings.

This paper is intended as an update on recent developments that affect provision of ventilation air to the building interior for the occupants. It does not address the issue of the combustion air required by various appliances, such as furnaces, water heaters and fireplaces, or dilution air required by their chimneys or exhaust vents. It also does not deal with the make-up air requirements of special appliances that remove air from the building but are not normally regarded as ventilation devices; these include indoor barbeque ranges, central vacuum systems and clothes dryers.

Background information is provided on the trend to airtightness in small buildings, how it is reflected in building regulations and why this issue should interest practitioners. Following this is a discussion of current responses to these issues, namely ventilation systems, and how these systems interact with the building. Finally, some practical design considerations are presented.

The Trend to Airtightness

The perception that trends in construction are producing more airtight buildings has been confirmed. Several surveys have measured the airtightness of Canadian houses of various ages. The most consistent trend is shown by the houses tested in Saskatoon.[1] Figure 1 shows the findings of these surveys plotted as normalized leakage area (NLA).

NLA decreases as the houses become newer. The leakiest group was built before 1945. The next leakiest group was built between 1946 and 1960, followed by the group built between 1961 and 1980. The most airtight group of Saskatoon houses tested are the low-energy homes built between 1977 and 1980. The most recent survey, of new (1989) houses built across Canada,[2,3] shows the most airtight houses, second only to the Saskatoon low-energy houses circa 1980.

Though there is solid evidence to confirm that houses are indeed being built tighter than they used to be, data on non-residential small buildings is scant. Indications are that the trend is not yet carrying over to any great degree to these buildings, regardless of potential advantages for building durability, occupant comfort and energy efficiency.

What are the consequences of more airtight construction? Figure 2 shows the distributions of air change rates, that is, ventilation rates due to air leakage, measured in a survey of Ottawa and Winnipeg area houses.[4] These results are plotted against a measure of each building's relative airtightness (NLAs). Not surprisingly, the plot indicates that the tighter buildings have less ventilation and the leakier buildings more ventilation. Thus, as we build more airtight buildings, something must be done to ensure adequate ventilation.

Normalized Leakage Area

Equivalent leakage area (ELA) is simply a measure of a building's total leakage area, stated in terms of the area (cm^2) of a sharp-edged orifice that has the equivalent flow characteristics of all the leaks in the building envelope. This total leakage area is then stated in terms of what one would expect for a normal or typical area (m^2) of building envelope; that is, NLA is the ELA divided by the area of the building envelope and is stated in cm^2 of leakage area per m^2 of building envelope area. Reduction of the leakage area value to a normal square metre of building envelope area allows comparison of leakage areas for buildings of different sizes.
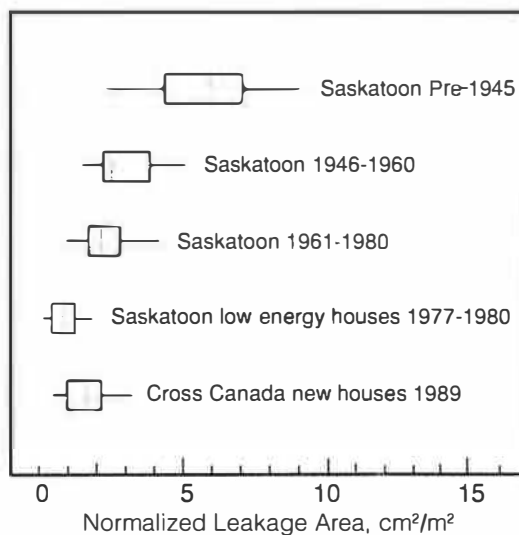

Figure 1   Airtightness survey results

The positions and heights of the "boxes" and "whiskers" on this plot indicate the ranges of air leakage areas (NLAs) of the houses surveyed. The line inside each box indicates the median air leakage area. The two sections of the boxes indicate the range of values within 25% of the median (above or below). The whiskers indicate the outer limits of the air leakage areas measured.

Codes and Standards

The trend to airtightness and the associated concern for ventilation is reflected in recent developments in various building standards and regulations.

Pre-1985 Situation

The National Building Code of Canada (NBC)[5] serves as the principal source of building safety requirements. Prior to 1985, mechanical ventilation requirements for small residential buildings specified in the NBC were limited. Ventilation for small non-residential buildings had to be provided in accordance with accepted procedures of
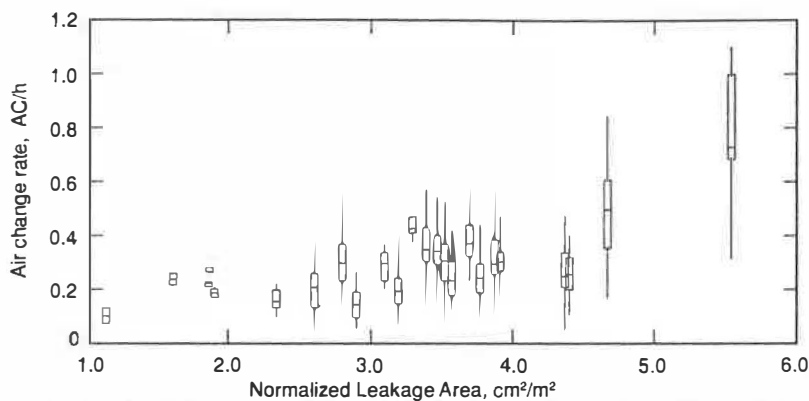
Figure 2 Air change rates compared to normalized leakage area (NLA) The positions and heights of the "boxes" and "whiskers" on this plot indicate the ranges of air change rates measured in each of the houses surveyed. As each house has a fixed NLA, the variation in air change rate depends on a variety of factors including location of openings in the building envelope, indoor/outdoor temperature difference and wind. The line inside each box indicates the median of the air change rates measured. The two sections of the boxes indicate the range of values within 25% of the median (above or below). The whiskers indicate the outer limits of the air change rates measured.

good engineering practice, such as those described in the ASHRAE Handbooks,[6-8] and Standards.[9,10]

No mechanical ventilation was required for small buildings, unless those buildings were residential units heated by other than a fuel-fired system. In those buildings, one or more exhaust fans or blowers were required, having a total capacity of at least 0.05 m^3/s.

Separate from formal codes and standards, the R-2000 Super Energy Efficient Home program began to develop a set of standards for overall performance of these specially constructed homes. These included limitations for allowable leakage area and provisions for mechanical ventilation. Much of the research work carried out in support of the R-2000 program has contributed to developments in the NBC requirements for airtightness and ventilation.

1985 Requirements

The 1985 edition of the NBC, for the first time, required that mechanical ventilation equipment with a flow capacity of 0.5 AC/h be installed in all single dwelling units. It did not, however, contain any requirements for the operation of the mechanical system or for air distribution to ensure the effectiveness of the mechanical ventilation.

Other small buildings and multiple dwelling units were required to conform to principles of good engineering practice under Part 6 of the Code. Part 6 defines such principles as those contained in the HRAI[11] and ASHRAE design handbooks, guidelines and standards. Part 6 allowed for meeting a building's ventilation requirements without mechanical assistance, though the onus was on the building's designer to demonstrate that a non-mechanical system would provide adequate ventilation.

1990 Requirements

The 1990 Code requires that every dwelling unit in a Part 9 building have mechanical ventilation equipment with a capacity of at least 0.3 AC/h, averaged over a 24-hour period. It still does not specify requirements for air distribution systems or the operation of the mechanical ventilation system.

Except where the mechanical ventilation system consists of simple exhaust fans that do not share a central duct system, the 1990 Code specifically requires all mechanical ventilation systems to conform to Part 6. As in 1985, Part 6 allows for meeting non-residential building ventilation requirements without mechanical assistance, though again, the onus is on the building's designer to demonstrate that a non-mechanical system will provide adequate ventilation.

Comparing the measured infiltration rates from the study of Ottawa and Winnipeg houses with the 1985 and 1990 Code ventilation requirements (Figure 3), we see that the natural ventilation rates in many of the houses tested fall short of those Code requirements. Thus air leakage in many houses, both old and new, is not sufficient and requires some mechanical assistance. Some non-residential buildings are subject to lower indoor moisture and pollutant loads. For these buildings, natural ventilation may still be adequate.

CSA Standard F326 and Future NBC Directions

The Canadian Standards Association is developing standard F326 "Residential Mechanical Ventilation Requirements."[12]
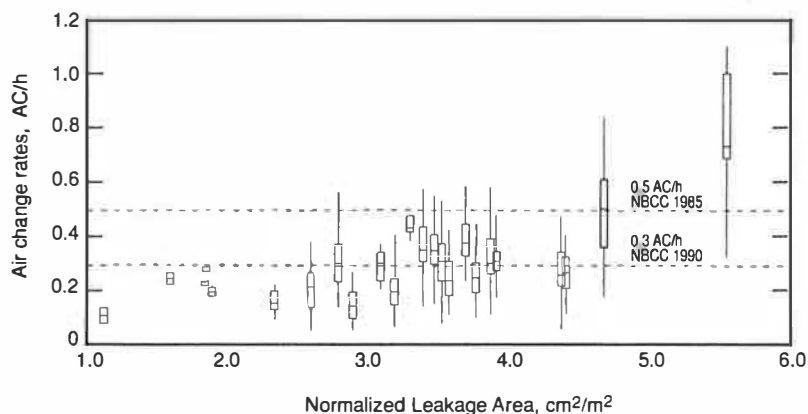
Figure 3   Measured air leakage rates compared to Code requirements

Currently in preliminary form, it specifies air supply rates for each room, the total for the house to be a minimum of 0.3 AC/h. The standard limits the imbalance between exhaust and supply flow rates and also limits the indoor/outdoor pressure difference caused by such imbalance to 10 Pa pressurization and 5-10 Pa depressurization, depending on the type of heating system used. This standard is based on the ASHRAE standard 62-1989 "Ventilation for Acceptable Indoor Air Quality,"[10] in its specification of ventilation rates for individual spaces in residential and non-residential buildings. It has been proposed that the 1995 NBC reference the CSA standard once it is released in its final form.

Factors Motivating Change and Implications for the Building as a System

Lest one be left with the impression that these various code and standard requirements have been developed solely as impediments to builders and designers by detached officials, consider the factors that have led to these changes. Reconciling sometimes conflicting requirements of various building subsystems that affect energy conservation, occupant health, safety and comfort, and building durability is a difficult task.

From an energy conservation standpoint, the air change rate in most small buildings should be reduced as much as possible, since the energy required for heating the supply air can amount to 30 percent or more of the total energy consumption in occupied buildings. A perfectly airtight building, shut up like a sealed plastic bag, could be very inexpensive to heat.

The plastic bag approach, however, would create a totally uninhabitable building. Some air change is required to prevent the accumulation of indoor air pollutants and to provide air for breathing. From the perspective of occupant health, the ventilation rate should be as large as possible. When the outdoor air supply is fresh and unpolluted, this will reduce the concentrations of indoor air contaminants to a minimum. Large fresh air supply rates also avoid stuffy conditions, odour problems and uncomfortable high humidity. Conversely, excessive ventilation rates may lead to cold drafts, occupant discomfort and excessively low humidity levels.

For improved building durability, interior moisture levels must be controlled and the migration of moisture into wall and roof cavities should be prevented. A large ventilation rate can reduce levels of interior moisture and other air contaminants. However, high exfiltration air leakage rates can carry moisture into wall and roof cavities. There the moisture can condense and cause material degradation problems, such as rot and mould growth. On the other hand, too little ventilation and inadequate heating can lead to condensation and mould growth on interior wall and ceiling surfaces.

When energy conservation came to the public fore after the first large energy cost increase in 1973, building owners started to tighten buildings, to reduce their air change rates and save on space conditioning energy. Airtight construction did save energy and also improved control over moisture migration into the building envelope. However, concerns soon arose that the resulting reduction in ventilation rates also meant a deterioration in the indoor air quality. Mechanical ventilation was seen as the way to increase ventilation rates in a controlled manner and thereby improve indoor air quality, while retaining the other benefits of a more airtight building envelope.

Neutral Pressure Level – What it is and what it means

The concept of the neutral pressure level (NPL) helps in understanding the impact of a ventilation system on a building's air pressure distribution. It is related to the mechanism that drives warm air up a chimney and draws cold air in at the bottom. This mechanism is referred to as stack effect.

When a temperature difference exists between the inside and outside of a building, a pressure distribution results (Figure A). The NPL is the elevation at which the pressures inside and outside the building are equal, in conditions of low or no wind. Below the NPL, the pressure difference drives air into the building; above the NPL, the pressure difference drives air out of the building. In a building without vents, flues, or a mechanical ventilation system, the NPL is typically located near or just above mid-height.

The NPL indicates the separation between regions of the building envelope where there is infiltration from those where there is exfiltration. The actual location of the NPL will depend upon the distribution of leakage openings in the building envelope.

Figure B illustrates this effect. Exfiltration of warm moist air from the upper region of the building has resulted in condensation and frost build-up on the higher windows. The infiltration of cool dry outdoor air through the lower regions of the building has kept the lower windows clear. The NPL is clearly located two thirds of the way up the first floor windows.

In a building with a flue (Figure C), the flue acts as an additional leakage site in the upper portion of the envelope. This both raises the NPL and increases the air infiltration and the total air leakage rate. That is, raising the NPL reduces both the portion of the envelope where there are outward acting pressures and the exfiltration air flow caused by those pressures. The air flow out through the flue makes up the difference between the infiltration and exfiltration air flows. These flue effects are probably the reason why houses heated by natural draft combustion appliances generally have far fewer moisture problems than electrically heated houses, which have no flue.

Exhaust fans raise the NPL and increase infiltration; supply fans lower the NPL and increase exfiltration.
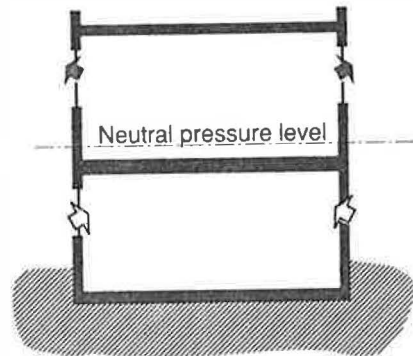
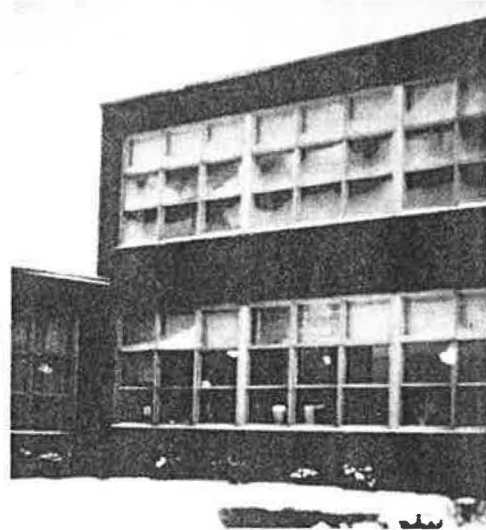

Figure A   Neutral pressure level

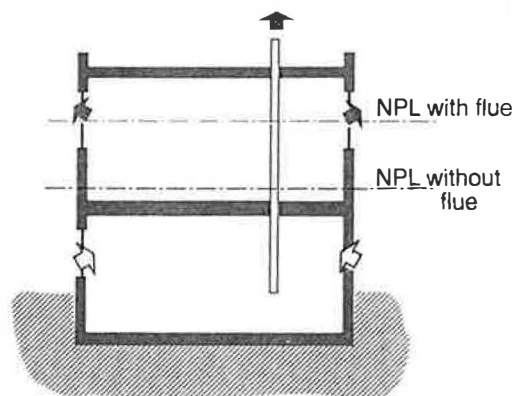Figure B   Neutral pressure level shown by frost on windows

Figure C   Neutral pressure level affected by a flue

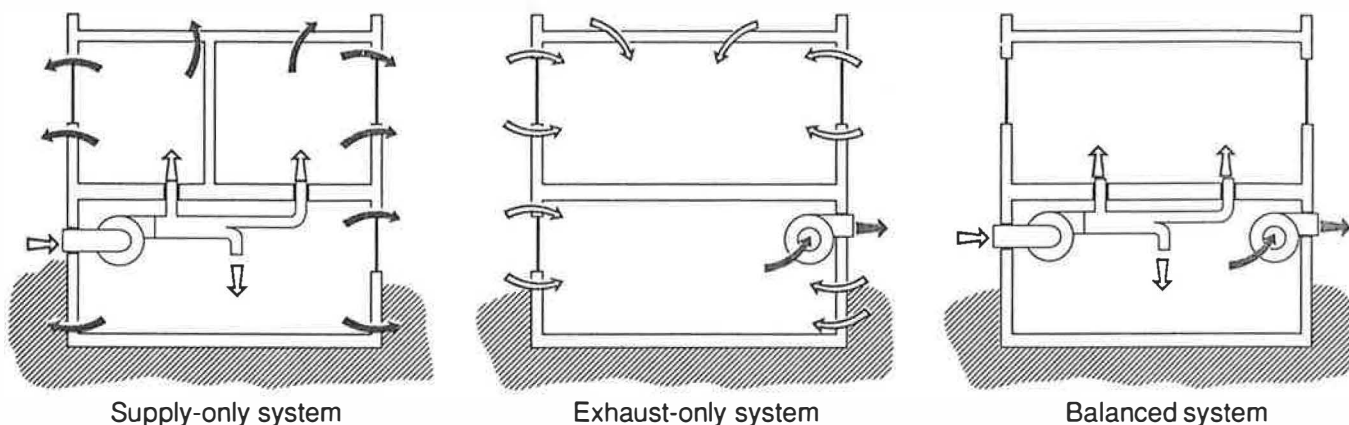Supply-only system   Exhaust-only system   Balanced system

Figure 4   Three basic types of mechanical ventilation systems

Responses – Ventilation Systems

There are three basic types of mechanical ventilation systems (Figure 4):
- supply-only
- exhaust-only
- balanced.

The supply-only system uses one or more fans to supply air to the building interior, relying on exfiltration leakage to remove air from the building. The exhaust-only system uses one or more fans to remove air from the building interior, relying on infiltration to provide the make-up air supply required. The "balanced" system uses a fan to supply air to the interior and another fan to remove air from the interior.

Canada Mortgage and Housing Corporation is publishing guidelines[13] to assist designers, builders and owners in complying with the 1990 NBC ventilation requirements for houses. Four basic approaches are recommended:
- point exhaust systems
- central supply systems
- central exhaust systems
- balanced systems [with optional heat recovery ventilators (HRVs)].

All four apply to buildings with forced-air heating systems. With some modifications, they can also be installed in buildings with other forms of heating systems, such as hydronic (hot water) systems and electric baseboard heating. All can be applied to any building covered under Part 9 of the NBC, though some are more or less appro-priate for non-residential buildings. With the exception of the point exhaust system in houses, all these ventilation systems are subject to Part 6 requirements for proper design.

These four ventilation system options are discussed below in the context of their interactions with the building as a whole.

Point Exhaust Systems

The point exhaust ventilation system is the most common approach to house ventilation, and will probably continue to be for the foreseeable future. This is the one mechanical ventilation system for houses that Part 9 of the NBC exempts from having to satisfy Part 6 requirements. It uses one or more exhaust fans, for example, a bathroom fan and a range hood fan, to provide the total ventilation needs for the building (Figure 5). This approach might also be applied in other small buildings, for example, an exhaust fan in a paint booth or a small work-shop. However, non-residential systems would have to satisfy Part 6 requirements for good engineering practice by meeting the requirements of, say, ASHRAE Standard 62-1989 and the appropriate ASHRAE design handbooks and guidelines.

The system works by drawing air from the building interior out through one or more exhaust fans, relying upon infiltration or intentional air intake openings for the make-up air supply. This tends to depressurize the interior and raise the neutral pressure
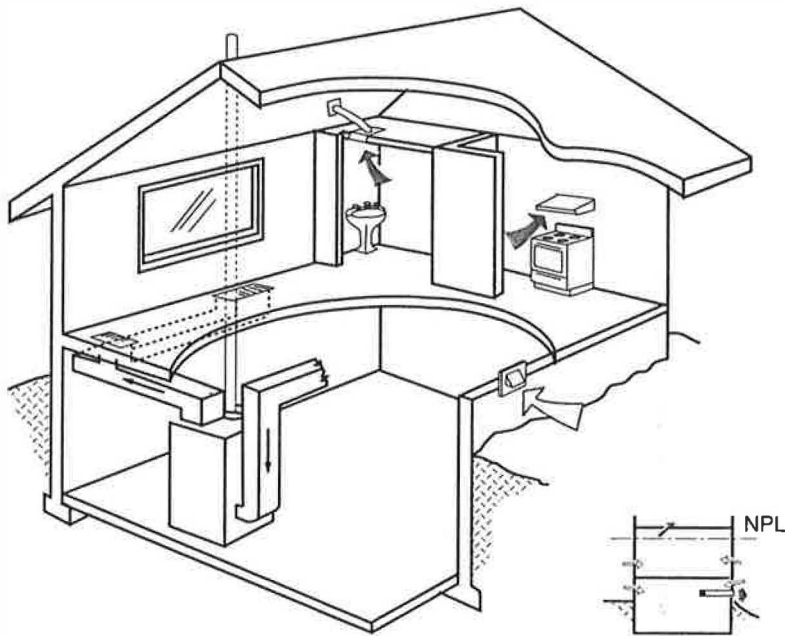
Figure 5   Point exhaust ventilation system

level. Depending upon how much the neutral pressure level is raised, exfiltration air flow is either reduced or eliminated entirely (if the NPL is raised above the uppermost heated ceiling).

Advantages of point exhaust systems

The point exhaust ventilation system has several advantages. It is simple and rela-tively inexpensive. For houses, it is ex-empted from NBC Part 6 requirements for a proper engineered design. The Part 9 total ventilation rate is considered to be satisfied if the sum of the fan capacities totals or exceeds 0.3 AC/h. This approach is suit-able for new building construction and can be implemented relatively easily as a retrofit measure. By raising the neutral pressure level and reducing or eliminating exfiltration, the design can reduce the potential for wall and roof moisture problems.

Disadvantages of point exhaust systems

This ventilation approach is not without its disadvantages, however. The point exhaust system tends to suffer from poor air distribu-tion, since air is not exhausted from all spaces and leakage is relied upon for the fresh air supply. Make-up air supplied by infiltration or air intake openings can also produce cold drafts, since it is, by definition, uncontrolled. The make-up air ducts may need heaters in colder regions of the country.

Two important disadvantages have health implications. Combustion flue spillage or backdrafting may occur during exhaust fan operation, and soil gas entry may be encouraged, bringing radon, moisture, and other pollutants into the building interior.

This approach also requires several penetrations of the building envelope, with the usual problems of caulking and sealing.

Central Supply Systems

The central supply system is another commonly used approach to small building ventilation. In its simplest form, in residential or non-residential buildings, it consists of a fresh air supply duct connected from the outside to the return plenum of a forced air furnace (Figure 6). The furnace fan draws outdoor air into the system and distributes it throughout the building. Air leaving the building must do so by exfiltration.

This system tends to pressurize the building interior and lower the neutral pressure level. By lowering the neutral pressure level, it reduces both the envelope area subject to infiltration and the inward pressures that drive infiltration airflow. The total inward air
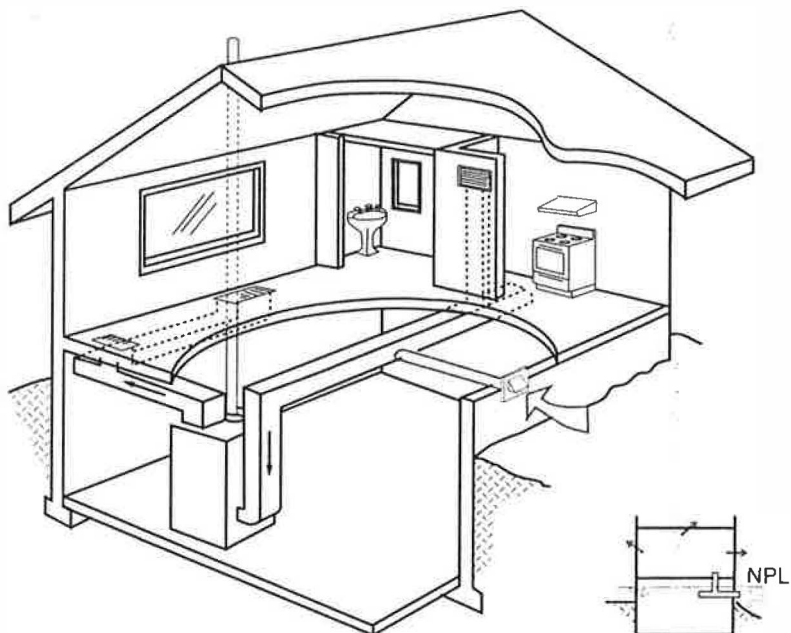

Figure 6   Central supply system

leakage may be reduced or eliminated (if the NPL is lowered beneath the basement floor). However, the outward pressures and the envelope area subject to exfiltration are increased, which tends to increase the total exfiltration airflow. For both residential and non-residential buildings, this system must meet the requirements of Part 6 for a prop- · erly engineered design.

Advantages of central supply systems

Among the advantages of the central supply system are its relative simplicity and low cost. Provided the building has a central forced-air heating system, it can be implemented as a retrofit measure, as well as being suitable for new building construction. One particular advantage of this approach is its good distribution of fresh air throughout the building interior. Its tendency to pressurize the building also reduces the potential for flue spillage and soil gas entry. This system requires only one penetration of the building envelope, for the supply duct.

Disadvantages of central supply systems

One serious disadvantage of this approach is its increased potential for driving moisture-laden interior air into the wall and roof cavities, where it can condense and cause problems such as mould growth, rot, and peeling paint. This system should therefore only be used in a building with a very good air barrier. The approach may not be practical for retrofit applications, where it may not be easy to ensure that the air

barrier is adequate to prevent moisture problems.

In colder regions of the country, the fresh air supply duct may require a duct heater to preheat the fresh air to prevent condensation on the furnace heat exchanger and cold drafts on the building's occupants. If the supply inlet is improperly located, sound can be transmitted into the building through the ventilation system.

Central Exhaust Systems

The central exhaust ventilation approach (Figure 7) requires a separate duct system which connects all the exhaust vents to a central fan unit with sufficient capacity to meet the total ventilation requirements for the whole building. Like the point exhaust system, the central exhaust system works by drawing air out from the building and mainly relies upon inward air leakage for its make-up air supply. This system also raises the neutral pressure level and reduces or eliminates exfiltration through the building envelope. The system and its required make-up air provisions must be properly engineered to meet Part 6 requirements and to ensure satisfactory operation.

Advantages of central exhaust systems

Like the point exhaust system, a central exhaust system shares the advantage of reducing the potential for wall and roof moisture problems. With one central fan unit, this type of system can be controlled automatically using centralized controls and sensors, such as humidistats or a carbon dioxide-based demand controller. The central exhaust fan can be located away from quiet areas in the building, thereby reducing the potential for noise problems. Judicious location of exhaust air pick-ups can provide better distribution of supply air. If energy conservation is important, and in certain non-residential occupancies where high ventilation rates are required to handle high pollutant loads, this system can also incorporate an exhaust air heat recovery heat pump, whose output energy can help to heat the hot water supply or indoor air. For its exhaust duct, this system requires only one penetration of
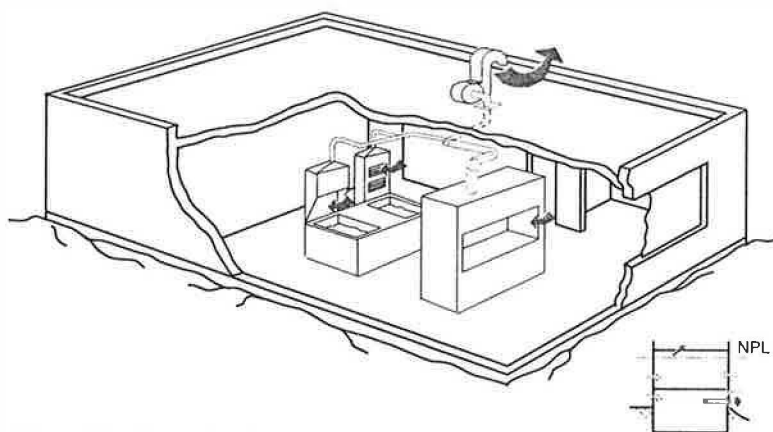

Figure 7   Central exhaust system

NPL

the building envelope, reducing potential sealing complications and problems.

Disadvantages of central exhaust systems

This type of system can be significantly more expensive than the previous two. It also shares the major disadvantages of the point exhaust approach indicated earlier, namely the increased potential for flue spillage and soil gas entry into the building interior. This system can increase the potential for cold drafts, due to its depressurization effect, and, unless exhaust pickups are judiciously placed, tends to likewise provide poor air distribution. Also, if the make-up air requirements are extensive, several additional penetrations of the building envelope may be necessary.

Balanced Systems

The balanced flow supply-exhaust ventilation system incorporates a central supply fan, a central exhaust fan and a system of supply and exhaust ducts (Figure 8). The system may also include an air-to-air heat exchanger to recover heat energy from the exhaust air flow to warm the fresh air supply. The exhaust air is collected by a duct system independent from the forced-air heating system, and expelled from the building by the exhaust fan. The supply air, which is drawn into the building by the supply fan, may be integrated into the return air plenum of a forced-air heating system, or in the case of a non-forced-air heating system, distributed through an independent supply duct system. Balanced systems are

only suitable for more airtight buildings where mechanical assistance is required to both supply and exhaust air; that is, where the building envelope is sufficiently tight to reduce air leakage to a level where it cannot provide adequate supply air by infiltration or exhaust flow by exfiltration.

When this type of system operates in a balanced condition, it has no net effect on the building's pressure distribution or the neutral pressure level, neither raising nor lowering it. However, conditions often result in a "balanced" system operating in an unbalanced way, as a net-exhaust or net-supply system. For example, if the inlet screens of the supply fan become partially blocked, a net-exhaust situation may result. If the incoming air is very cold, it will warm up and expand as it enters the living space, resulting in a larger effective supply flow rate and a net-supply situation. Where the exhaust duct of an air-to-air heat exchanger becomes partially obstructed by frost build-up, the exhaust flow rate would be reduced and a net-supply situation would also result.

An air-to-air heat exchanger to be incorporated into a balanced ventilation system should be selected with care. In the past, many such products have had serious problems due to frost build-up and inadequate design provisions for defrosting and resistance to frost damage. Many products are on the market, so only devices that have been properly designed, tested and proven reliable for your particular climate should be chosen.

Advantages of balanced systems

This type of system can provide high ventilation rates without large heating costs, if heat recovery ventilators are incorporated in the ventilation system. Though the system does not affect the building's pressure balance, the larger ventilation rates possible with this type of system can reduce the indoor humidity levels and thus the potential for wall and roof moisture problems. The larger and continuous ventilation rates can also help reduce the potential hazard from radon entry and chimney spillage, should they occur, by diluting the resulting indoor air contaminants. This type of system provides very good air distribution, and is par-
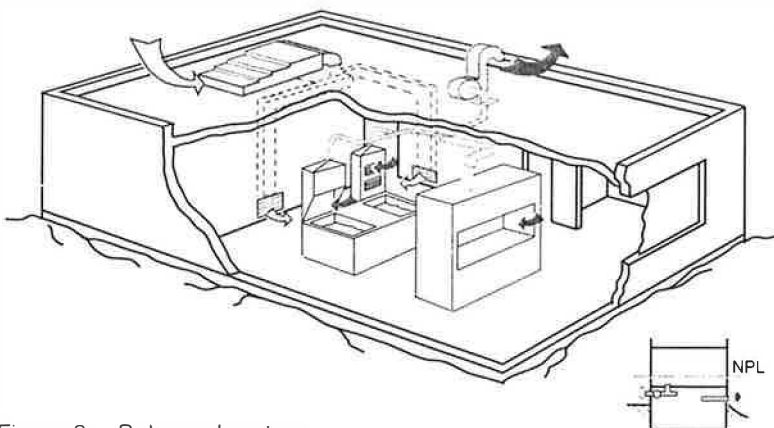

Figure 8   Balanced system

ticularly suitable for automatic controls. A balanced ventilation system has no additional need for a make-up air supply, so extra penetrations of the envelope are not necessary.

Disadvantages of balanced systems

The balanced system, with its independent exhaust air duct system and the optional heat exchanger, is the most costly and most complicated of those presented. The system is difficult to balance and may require a certified installer, further increasing the cost. Its maintenance requirements (inspection and cleaning) are extensive so operating costs can also be quite high. This system is suitable primarily for new building construction; the envelopes of older buildings tend to be sufficiently leaky that natural infiltration and exfiltration would short-circuit the mechanical system. Its installation as a retrofit measure is usually not practical.

Combined Systems

In actual applications, various combinations of these basic systems are often used. One example is a building with a central supply system (fresh air duct to furnace return air plenum) in combination with point exhaust devices, such as bathroom and kitchen exhaust fans. Such a system may function very much like a balanced ventilation system, as far as the building pressure

distribution and neutral pressure level are concerned. Another example would be a balanced ventilation system which still includes point exhaust devices (e.g., a store with a photographic darkroom which has its own exhaust fan to eliminate chemical odours). Some combined systems are designed and installed to meet special applications, while other combinations are commonplace.

Design Considerations

The following is a discussion of some practical design considerations for mechanical ventilation systems and their components. Much of the material is a review of what constitutes good engineering practice, and is not necessarily new information. It has been drawn from many sources.[6-11,13]

Intake and Exhaust Hoods

Figure 9 indicates the required separations and clearances for intake and exhaust vent openings. Vents should be at least 1 m from any corner of the building to minimize wind effects. Intakes should be at least 450 mm and exhaust vents at least 200 mm above the ground to avoid snow blockage and contamination by ground care products such as herbicides. Intakes and exhaust vents should be separated vertically or
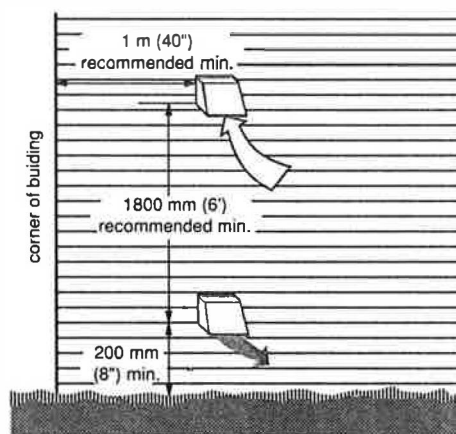
a) Vertical separation of intake and exhaust vents
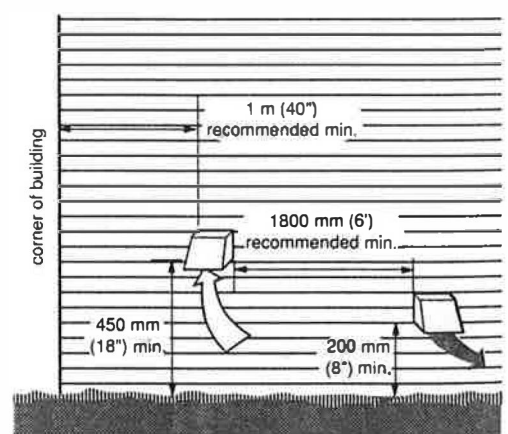
b) Horizontal separation of intake and exhaust vents

Figure 9   Locations for intake and exhaust hoods

horizontally by at least 1800 mm to minimize the potential for cross contamination.

These vents should be located where they are shielded from the direct impact of the wind, and away from sources of potential contamination, such as vehicle parking, loading bays, and fuel or chemical storage. In addition, intake vents can conduct noise and so should be located away from sound sources, such as mechanical equipment, fans, and air-conditioning condensing units.

Exhaust ducts should be installed with backdraft dampers to prevent them from functioning as intakes when they are not powered. All intake and exhaust openings should be provided with hoods and non-corroding screens to protect them from weather and entry by insects and small animals.
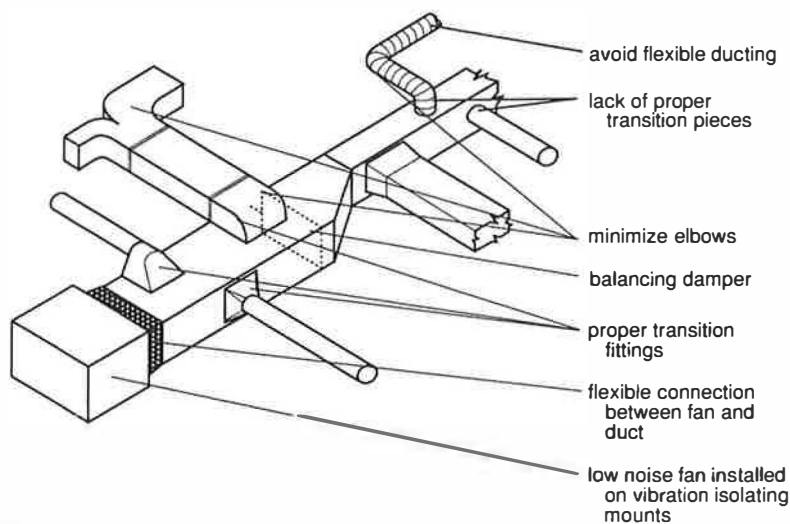

- avoid flexible ducting
- lack of proper transition pieces
- minimize elbows
- balancing damper
- proper transition fittings
- flexible connection between fan and duct
- low noise fan installed on vibration isolating mounts

Figure 10 Ductwork

Ductwork

For ductwork design and installation (Figure 10), the following principles should apply:
- Duct runs should be kept as short as possible, to minimize flow resistance and noise.
- Proper fittings, elbows and transition pieces should be used throughout.
- Ducts should be properly sized for their length of run and their flow rates.
- The use of flexible ducting should be avoided wherever possible and the total

number of elbows should be minimized to reduce flow resistance and noise.
- Balancing dampers should be installed in trunk lines to facilitate proper adjustment of the system operation.
- Ductwork should be non-combustible.
- Exhaust air ducts should lead directly outside and not terminate in enclosed spaces such as attics or crawlspaces.

Fans

For the selection and installation of fans, the following principles should apply:
- Low noise fans (with a Sone rating less than 2.0) should be used. Typically, centrifugal fans are quietest.
- Fans should be installed using vibration isolating mounts and flexible connections to the ductwork to prevent sound transmission to the building structure or through the ductwork.
- Fans with capacities rated at 25 Pa backpressure are required by the NBC. Fans should be sized to correspond to the calculated pressure drop in the duct system.
- Fans should be installed as far away as possible from quiet areas such as private offices, bedrooms, and libraries.

Ventilation System Components -- General

Some additional general design and installation principles are as follows:
- Fresh air supply ducts should be insulated and wrapped with vapour retarder, and exhaust ducts running through unheated spaces should be insulated to at least RSI 0.4 (R-2) to prevent condensation.
- Supply air diffusers and return air grilles should be located to assist their function and minimize cold drafts. For example, return grilles should be located as high as possible on interior walls to assist natural air flow patterns.
- Range hoods and clothes dryers should not be connected to a recirculation air duct, but should be vented directly outdoors.
- Interior doors should either have grilles installed or be undercut 40 mm to allow
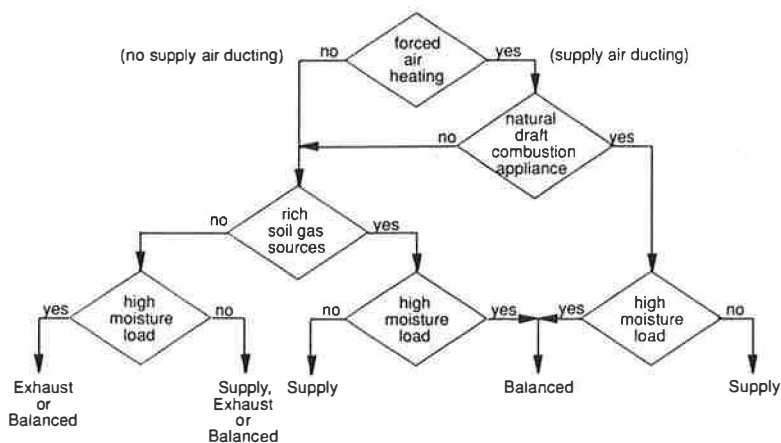
Figure 11   Mechanical ventilation system decision tree

proper interior air circulation in rooms without both supply and return grilles.

- Kitchen exhaust ducts must have a grease filter on their inlet or be installed such that their entire length can be cleaned.

Summary – Mechanical Ventilation System Decision Tree

To summarize much of the material presented in this paper, a "decision tree" (Figure 11) will help in the selection of a ventilation system for a small building. The order of priority used to construct this flowchart is occupant health, followed by building durability. Energy conservation has not been included, because its economic advantage depends heavily on energy costs, which vary from place to place.

Perhaps the largest financial decision rests on the choice of heating system. If forced-air heating is to be installed, then the largest part of the ventilation system investment, the air distribution system, has already been selected. If the building is to have a natural draft combustion appliance (furnace, water heater, or fireplace) then the viable options are either a central supply system, if the moisture loads are not high and likely to cause condensation problems, or a balanced supply-exhaust system.

If there is to be no spillage-susceptible combustion appliance, then the next issue is whether soil gas entry poses a potential problem. If the soil gas is rich in radon,

methane or other contaminants, its entry must be prevented, or at least not encouraged by the ventilation system, such as would occur with an exhaust-only system. If the building also contains high moisture loads, a supply-only system would probably cause moisture problems in the building structure and a balanced ventilation system should be selected. If however, interior moisture loads are not a potential problem, then a supply-only ventilation system could be selected, and it would actively discourage soil gas entry.

If, on the other hand, soil gas entry does not pose a potential problem, then the one remaining concern is potential moisture problems in the building envelope. An exhaust-only ventilation system will actively discourage moisture migration from the interior into the wall and roof cavities, and is appropriate regardless of the interior moisture loads. A balanced ventilation system can lower the interior humidity levels and, thereby, indirectly reduce the potential for moisture problems in the walls and roof.

In this summary, the exhaust-only and supply-only options are promoted because they tend to be less expensive than a balanced ventilation system. However, if cost is less important than other considerations, a balanced supply–exhaust system should be the ventilation system of choice because of its excellent air distribution characteristics, resistance to weather effects and generally higher dependability and ventilation rates.

Appendix

Allowance for Air Infiltration Contribution to Total Ventilation Rate

Unless a building is completely airtight, air leakage will almost always make some contribution to the total air change rate. This contribution can be especially significant at the colder times of the year, when stack effect is strong. This was illustrated in the measured air leakage rates reported earlier,[4] where, in several cases, the entire

Code-required ventilation rate was provided by air leakage.

While the NBC requires that the mechanical ventilation system be capable of providing the total ventilation needs in a building, it does not require that the system always operate at its full capacity. This allows a mechanical system to be operated at a lower flow rate when air infiltration is able to contribute part of the building's ventilation needs. A simple technique is to use a multi-speed fan whose top speed meets the total ventilation requirement. When air leakage is contributing part of the ventilation, the fan can be operated at a reduced speed. The following methods allow the designer or building manager to determine what is an acceptable lower fan capacity.

Balanced Systems

To use the graph in Figure A1,[14] the airtightness value of the building must either be measured or estimated accurately. The minimum design ventilation rate, as required by the NBC, is selected on the horizontal axis. A vertical line is drawn from this value to intersect the airtightness curve for the building. A horizontal line from this point to the vertical axis will indicate the reduced wintertime flow rate in air changes per hour.
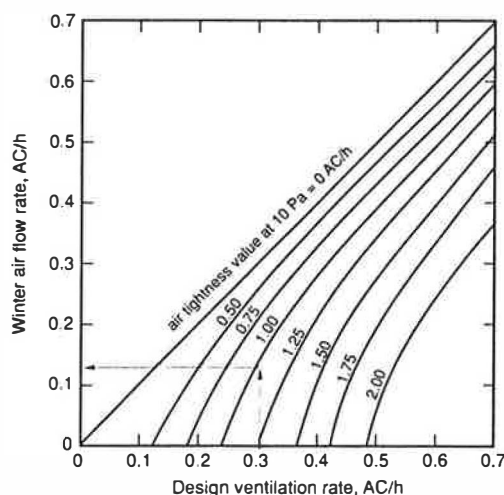

Figure A1   Graph for determining reduced winter ventilation rate for a balanced system

Figure A1 includes an example of a balanced ventilation system, in a building with an airtightness value of 1.0 AC/h at 10 Pa and requiring 0.3 AC/h in total. According to the figure, the ventilation system could be operated at 0.12 AC/h during the winter.

Exhaust-Only Systems

Figure A2 was developed for an exhaust-only ventilation system. It has one additional feature which is notably different from the graph for the balanced system. The curves
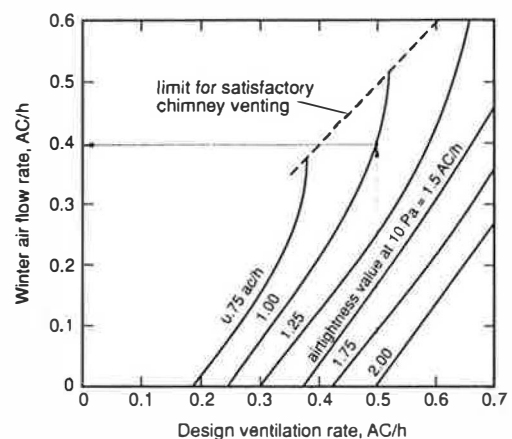

Figure A2   Graph for determining reduced winter ventilation rate for an exhaust-only system

on the graph end at a dashed line, indicating the safe limit of exhaust-only ventilation to avoid chimney spillage caused by excessive depressurization of the building interior. As the building becomes more airtight, this restriction is more severe. The exhaust-only system has to work against the flow restrictions of the leakage openings in the building envelope for its make-up air supply. Therefore, since inward air leakage is already providing the make-up air supply, infiltration does not have much potential for providing extra ventilation. This effect is more pronounced in tighter buildings.

Figure A2 also includes an example. Consider the same house as before, with a measured airtightness value of 1.0 AC/h at 10 Pa, but with a design ventilation rate of 0.5 AC/h. For winter operation, the mechanical exhaust-only system should be operated at a flow rate of 0.4 AC/h.

This illustrates the different effects on the two systems. The balanced system was permitted a 60 percent wintertime reduction due to infiltration, whereas the exhaust-only system's winter cutback allowance is only 20 percent.

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