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Mechanical Ventilation Systems for Houses

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Introduction

Adequate ventilation is essential for all houses to achieve an acceptable indoor air quality and humidity level and, in some cases, to ensure an adequate supply of combustion air for fuel-fired heating appliances. In the past, most houses were ventilated by air leakage through cracks and openings in the envelope. However, the demand for energy conservation in recent years has led to the construction of tighter new houses and the tightening of existing houses where air leakage can no longer be relied upon as the sole source of ventilation air. As a result, mechanical ventilation systems are required in these tight houses.

This article presents a brief description of the types of mechanical ventilation systems commonly installed for houses, and the effect of the operation of such a system on the house pressure and the performance of other appliances. It also presents a method for determining the air flow rate of the mechanical ventilation system required for winter operation, which takes advantage of the increased air infiltration in winter, and some guidelines for distributing the ventilation air effectively.

Mechanical Ventilation Systems

There are three basic types of mechanical ventilation system:

- 'balanced'
- supply-only
- exhaust-only

Balanced system

A 'balanced' system consists of a supply fan which draws the outdoor air into the house and an exhaust fan which is supposed to exhaust an equal amount of indoor air to the outdoors. In actual installations, the supply and the exhaust air flows are rarely equal because no attempt is made to adjust the supply air flow rate to account for varying outdoor air density. For this reason alone, the supply air flow rate in winter can be as much as 20% greater than that in summer while the exhaust air flow rate remains virtually unchanged.

In recent years, Heat Recovery Ventilators (HRV) have been installed in many houses in place of conventional 'balanced' systems. Such a device consists of a supply fan, an exhaust fan and an air-to-air heat exchanger. It serves a dual function of supplying ventilation air and reducing the cost of heating the ventilation air. It should be pointed out that a 'balanced' system does not need a heat exchanger to work properly. The sole function of a heat exchanger is to save energy by supplementing the energy required to heat the ventilation air with the heat recovered from the exhaust air. The choice of heat recovery ventilator over a conventional 'balanced' system, therefore, depends on the availability of the device, the cost of having the heat recovery option, the energy saving capacity, and the current and future costs of energy.

Supply-only and exhaust-only systems

A supply-only system consists of a supply fan to bring the outdoor air into a house. The indoor air leaks out of the house through cracks and openings in the envelope. An exhaust-only system consists of an exhaust fan to exhaust the indoor air to the outdoors. The make-up air from the outdoors leaks in through the envelope. Houses with a supply-only system are more susceptible to condensation problems than those with other systems, because the exfiltration of the warm and humid indoor air in these houses occurs mainly through unintentional leakage paths in the envelope. For this reason, a supply-only system is not recommended.

The choice is therefore essentially between a 'balanced' system and an exhaust-only system. Normally, a 'balanced' system is particularly suitable for houses with fireplaces, fuel-fired heating appliances, and also for houses with sources of radon and other contaminants in the building structure. Otherwise, because of its low cost, an exhaust-only system would be preferable.

Interaction Between Mechanical Ventilation System and House

As houses cannot be built completely airtight, air infiltration occurs whenever pressure differences are caused by wind or an inside-outside temperature difference. The ventilation air, therefore, includes both the outdoor air supplied by mechanical ventilation systems and air infiltration; both these components are weather dependent. Measurements made on a two-storey house with a 'balanced' system indicate that the ventilation air supply rate increases as the outdoor air temperature decreases. The ventilation air supply rate also increases with the wind speed, but for cities with cold climates like Ottawa, the effect of wind would be masked by the large inside-outside temperature difference during the winter months. Thus, for wind speeds less than 30 km/h and temperature differences greater than 15 K, the ventilation air supply in a house with a 'balanced' system is primarily a function of temperature difference alone.[1]

Measurements on a similar house with an exhaust-only system indicate that the ventilation air supply rate is relatively insensitive to both wind and temperature difference and remains essentially constant.[1] This is especially true for a system with a high exhaust rate.

Figure 1 shows the contributions of air infiltration, mechanical ventilation system and chimneys to the ventilation air supply of a two-storey house, as measured on a calm day with an indoor-outdoor temperature difference of 28 K. With no mechanical ventilation (Figure 1a), the outdoor air pressure was greater than the indoor pressure at the lower levels and the reverse was the case at the upper levels of the house. At a level slightly above the floor level of the second storey, the interior and exterior pressures were equal. This level is called the neutral pressure level. Below this level, air infiltration occurs, and above it, air exfiltration occurs. The ventilation air was supplied by air infiltration alone at a rate of 0.25 ac/h. With a 'balanced' system delivering an air flow rate of 0.5 ac/h (Figure 1b), the ventilation air rate increased to about 0.7 ac/h. The pressure pattern was similar to that without the mechanical ventilation system. With an exhaust-only system (Figure 1c), the ventilation air rate was equal to the exhaust rate of 0.5 ac/h and the neutral pressure level was located at the ceiling level of the top storey. There was essentially no air exfiltration through the envelope.

Figure 1d shows the same house with a chimney. It indicates that, similar to an exhaust-only system, the presence of a chimney moved the neutral pressure level upwards to somewhere near the middle of the second storey, resulting in an increase in the ventilation rate from 0.25 to 0.3 ac/h. If a 'balanced' system were added, the ventilation air supply rate would increase but the house pressure, and hence the venting capacity of the chimney, would not be significantly affected.

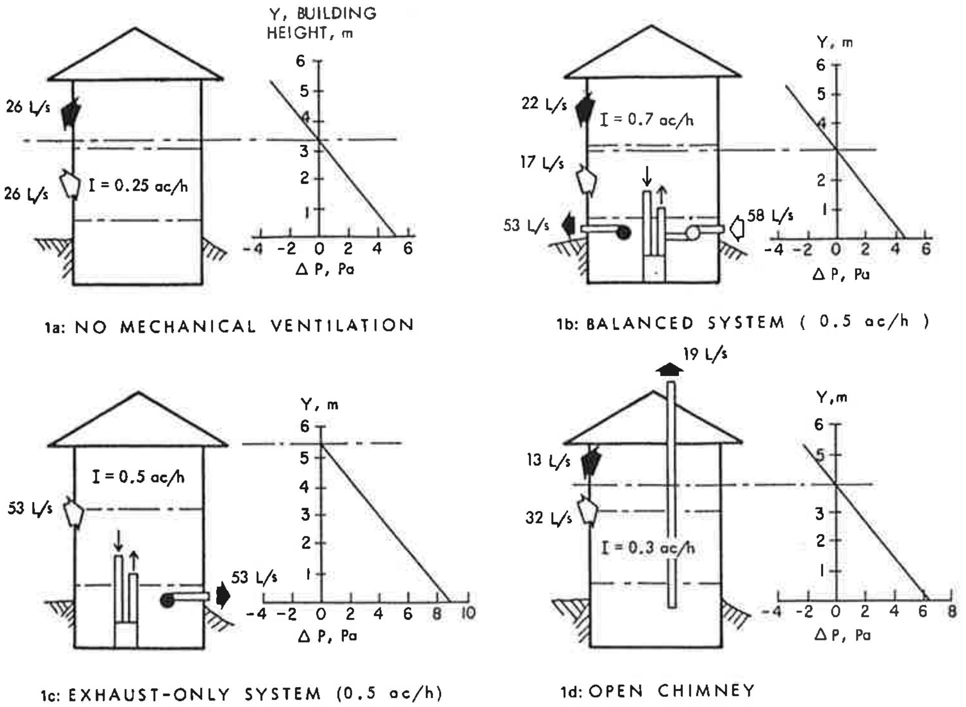

Figure 1: Air flow pressure patterns induced by temperature difference, chimney and mechanical ventilation systems.

With an exhaust-only system, the neutral pressure level would move upwards, causing a reduction in the house pressure and also in the venting capacity of the chimney. The effect of chimneys annd exhaust fans on the ventilation air supply and house pressure is further illustrated in Figure 2. Two different types of chimney were studied: a 12.7 cm open chimney of a conventional gas furnace and an 8 cm wall mounted exhaust vent of a medium efficiency induced draught gas furnace. The results indicate that the amount of outdoor air leaking into the house increases linearly with the neutral pressure level as the house pressure decreases due to the operation of a chimney or an exhaust fan. This linear relationship is expected to be valid until the neutral pressure level reaches the ceiling level of the top storey. In the region slightly above the ceiling level, a sharp increase in the air leakage occurs due to the increased pressure difference across the ceiling where a significant proportion of leakage openings is located. As the exhaust air flow rate of the fan further increases, the pressure difference across the house envelope depends only on the exhaust fan. The amount of outdoor air leaking into the house varies with the nth power of the fan induced pressure difference. Figure 2 also indicates that the gas flow through the chimney of the conventional gas furnace decreases slowly as the fan exhaust rate increases and the neutral pressure level moves upwards. Measurements indicated that the chimney backdraught occurred when the neutral pressure level reached approximately seven times the building height above ground level.

If the furnace is not operating and the chimney is cold, backdraught can occur in the chimney as soon as the neutral pressure level reaches approximately the top of the chimney. For design purposes, therefore, the ceiling level of the top storey would be a reasonable choice as the maximum acceptable height of the neutral pressure level for satisfactory chimney venting and for sizing exhaust-only systems.

Sizing Mechanical Ventilation Systems

The capacity of a mechanical ventilation system should be determined on the basis of the design ventilation rate and the air infiltration rate. However, in practice air infiltration is rarely considered because it is difficult to estimate. As a result, the amount of ventilation air received by a house under the combination of mechanical ventilation and air infiltration often exceeds the design ventilation rate, causing an unnecessary increase in energy consumption. The energy consequence is not serious under mild weather conditions because temperature differences are small. This is not the case under winter conditions. For a house with a 0.5 ac/h 'balanced' system and an air infiltration rate of 0.25 ac/h, Figure 1b shows that the amount of ventilation air received by the house can exceed the air flow rate of the mechanical ventilation system by as much as 40%.

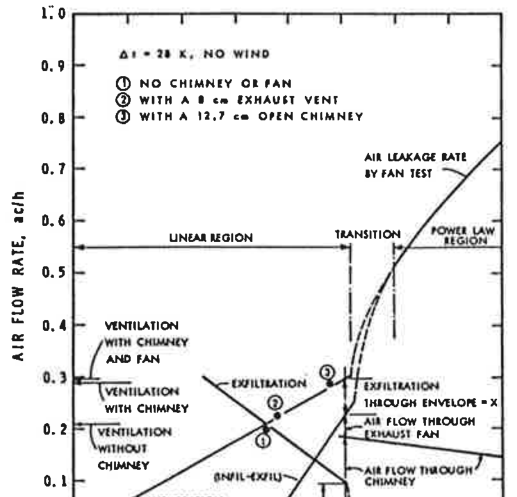

Figure 2: The effect of chimneys and exhaust fans on ventilation air supply and house pressures.

On one hand, to satisfy the ventilation requirement, a mechanical ventilation system should always be capable of delivering the design ventilation rate. On the other hand, to conserve energy, it should be operated under a reduced flow during the winter months to take advantage of the increased air infiltration. Thus, it is suggested that all mechanical ventilation systems be equipped with a flow controller such as a two-speed fan, and operate continuously with the reduced capacity designed for the winter months. A manual switch and/or an indoor humidistat can be used to increase the flow for the quick removal of odours, moisture and fumes during cooking, bathing and cleaning. In addition, an outdoor temperature controller may also be installed to increase the air flow in milder weather.

Air flow rate for winter operation

The air flow rate for winter operation can be determined on the basis of the design ventilation rate and the mean air infiltration rate for the winter months. The recommended design ventilation rate for houses can be found in various standards such as the ASHRAE Standard 62-1981.[2] For typical houses an outdoor air supply rate of 0.5 ac/h would be a reasonable value for the time being. This value has been reduced to 0.35 ac/h in the revised ASHRAE standard to be published shortly.

The mean air infiltration rate for the winter months is proportional to the airtightness of the house which can best be determined by conducting a fan pressurization test. Based on the measurements of 40 houses,[1,3] the range of airtightness values for different types of low energy houses is given in Table 1.

Types	Rating	Air Changes Per @ 10 Pa
Bungalow	Tight	0.13
	Average	0.43
	Loose	0.73
Two-storey	Tight	0.17
	Average	1.05
	Loose	1.93
Others	Tight	0.16
	Average	0.49
	Loose	0.81

Table 1: Range of airtightness values for low energy houses.

Based on the mean air infiltration rate for the winter months estimated from the airtightness value, the air flow rate for the winter operation of a balanced system and an exhaust-only system can be determined from Figures 3a and 3b respectively for various design ventilation rates. Figure 3b also shows the maximum allowable air flow rate for houses with chimneys. If a greater air flow rate is needed, intake openings must be installed in the exterior walls to avoid the possible occurrence of chimney backdraught. Such a remedial measure contradicts the purpose of tightening houses but it is a practical and inexpensive method of providing and distributing the ventilation air to the needed areas for some houses. The optimum degrees of airtightness for new and existing houses have yet to be determined.

Air Distribution

In spite of an adequate supply of ventilation air for the whole house, there can be a room or rooms where the ventilation air is inadequate, because of poor air distribution. For houses with a forced air heating system, the most effective and economical way of distributing the ventilation air is to use the existing air distribution system. This can best be achieved by connecting the supply air duct of a 'balanced' system to the return duct of the forced air heating system (if such an installation is permitted by the prevailing building codes and standards). Otherwise, the supply duct should be terminated near a main return air grille of the forced air heating system. For houses without forced air heating systems, an air distribution network might be necessary for a 'balanced' system. An alternative would be to use an exhaust-only system with intake openings installed in the exterior wall of the areas requiring the proper distribution of outdoor air.

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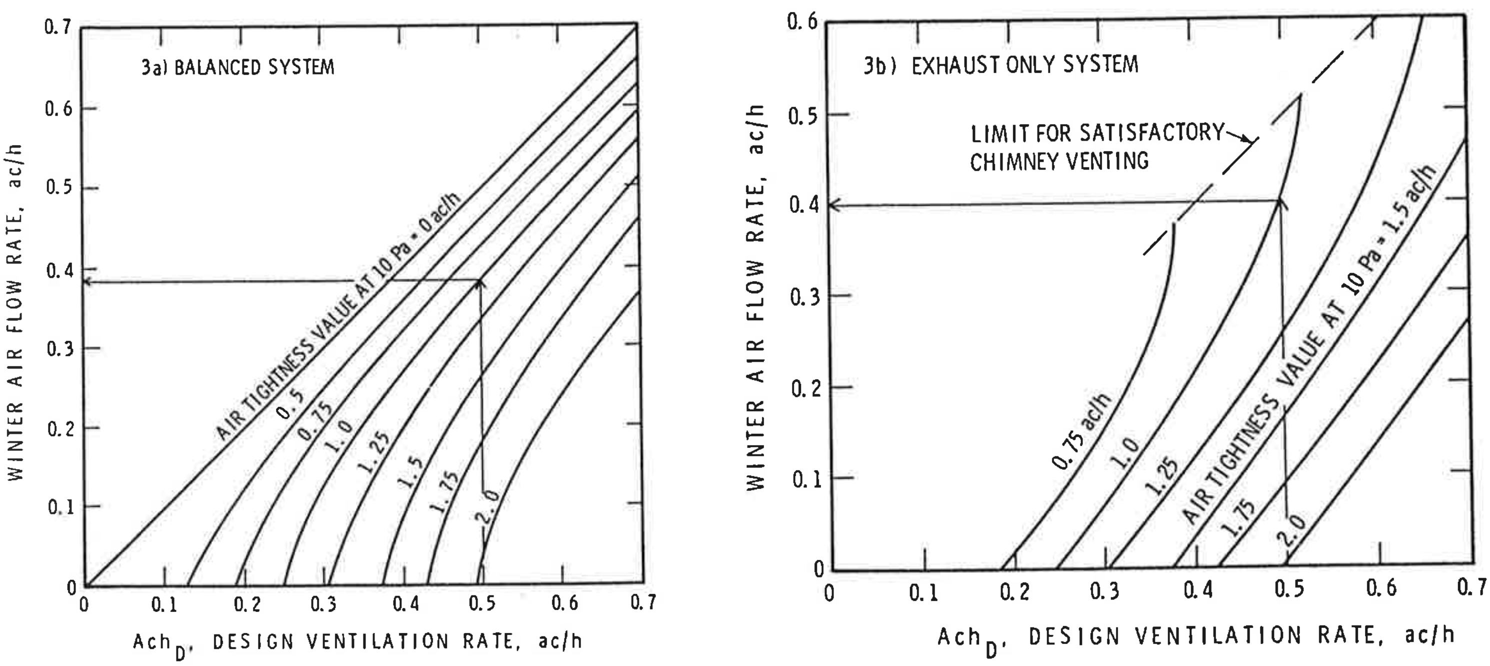

Figure 3: Air flow rate of a mechanical ventilation system required for winter operation.