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MECHANICAL VENTILATION

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As insulation standards improve, heat loss by ventilation becomes a larger proportion of the total heat loss from a house. With natural ventilation this heat loss is also largely unpredictable since it depends on the way the house is used. If ventilation is to be under the control of the householder, a tight house is necessary so that casual leakage ventilation is minimised. This has implications for house design, choice of building components and standards of workmanship. The requirements of a mechanical ventilation system are that water vapour and odours are removed at source and that fresh air is supplied to living rooms and bedrooms. The preferred way of achieving this is to have ducted supply and extract air streams with a linking heat exchanger which reclaims about 60% of heat which would otherwise be wasted. Economics are attractive when compared with the energy loss caused by opening windows.

INTRODUCTION

In winter the interior of a house is heated to 10°C to 20°C above the outside air temperature. The energy required to maintain this temperature difference depends not only on how the house is constructed but also on how it is used. Field trials on groups of identical houses show typically a 2:1 variation in energy bills. Much of this variability is attributed to losses from different ventilation rates. Controlled ventilation systems provide an opportunity to achieve comfortable conditions at a predictable cost.

HOUSE HEAT LOSS

A typical 200 m^3 house may have a fabric heat loss of about 4 to 5 kW for a design temperature difference of 18°C. Using well known insulation techniques it is possible that this could be reduced to less than 2 kW.

Heat is also lost by ventilation because hot air escapes from the house and the cold air coming in to replace it must be heated to comfort temperature. This heat loss depends on the temperature difference between the air which is thrown away and the air entering the house. If we assume again that the inside to outside temperature difference is 18°C then the heat loss from ventilation is

$$\frac{200 \times (\text{air change rate per hour}) \times 18 \times 990 \times 1.25}{3600 \times 1000}$$

$$= 1.24 \text{ kW per air change/hour}$$

where the density of air = 1.25 kg m^{-3} and the specific heat of air = 990 J $kg^{-1}K^{-1}$.

It can be seen from these figures that if the fabric heat loss is reduced below 2 kW and if the ventilation rate is allowed to increase much above one air change per hour, then the ventilation heat loss would become the main heat loss from the house. Control of the ventilation rate is thus seen to be essential if a 'low energy' house is to work. However, the comfort and convenience of the people living in the house must not be sacrificed, and if possible it should be improved.

WHY VENTILATE?

Obviously the ventilation heat loss can be minimised simply by reducing the ventilation rate but there are limits to this approach. People want 'fresh air'. So why is ventilation needed? There are five main reasons:

(1) to supply oxygen for breathing,
(2) to remove exhaled carbon dioxide

PRACTICAL EXPERIENCE

Examples of various systems have been tested in an unoccupied test house. Ventilation measurements showed that the mechanical ventilation added on to what would be expected by natural ventilation but the flow rates in the ventilation system itself were unaffected by the wind. However, this emphasises the necessity of having a tight house with a very low background ventilation rate.

About 60% of the ventilation heat loss is recovered and is used to preheat the fresh air to the living rooms.

Air speeds measured in the rooms (∿0.1 m/s) would be unlikely to produce draught complaints.

Insufficient evidence is available yet to know whether window opening in winter is discouraged by having a ventilation system installed in the house.

ENERGY COSTS

Ventilation is normally controlled by opening and closing windows. However, quite moderate window opening can result in enormous increases in ventilation rate even in other rooms of the house where the windows are closed. Ventilation rates have been measured continuously in a three bedroom semi-detached house with one bedroom window open by various amounts. The windows were pivoted at the mid-point of the vertical edges. Window width was 700 mm and height 900 mm. By measuring the ventilation rate continuously the influence of the weather was followed and wide variations of ventilation rate were measured, up to seven air changes per hour throughout the house when there was a strong wind directly onto the open window. The house was heated continuously to 19°C internal temperature with results as given in the following table:

Window condition	Mean whole house ventilation rate ac/h	$\frac{\text{Measured ventilation heat loss}}{\text{Total heat loss}}$ %
all closed	0.30	10
one bedroom window open 4°	0.73	21
one bedroom window open 11°	3.0	45

This house was built to 1975 Building Regulations and is comparatively tight, having a fairly low background ventilation rate of 0.3 air changes/hour. This explains why the ventilation heat loss is only 10% of the total when the windows are closed. However, opening one window increases the ventilation tenfold; the ventilation heat loss then becomes nearly half the total heat loss.

If this house was insulated to reduce the fabric heat loss to 40% of its present value, which is possible using available techniques, the absolute value of the ventilation heat loss would remain the same but with one window open it would now represent 67% of the total house heat loss.

ECONOMICS OF MECHANICAL VENTILATION

If a house is ventilated at 0.5 to 1.5 air changes per hour with windows closed, then installation of a mechanical system would result in excessive ventilation and would never be economic. Intermittently used local extract fans would however still be applicable.

Fortuitous ventilation must be reduced to less than about 0.2 air changes per hour before a mechanical system can be economic.

Assuming the resulting ventilation rate averages 1 air change per hour, the annual ventilation heat loss, for a mean internal temperature of 18°C, is about 4000 kWh per year, which can be reduced to 1600 kWh if 60% of the heat is reclaimed. The apparent saving by heat recovery is 2400 kWh, about £65 (assuming electric heating, 75% of units at 5.33p and 25% at 1.82p). For an investment of over £1000 this does not look very attractive. However, the true saving is much greater because the alternative is to rely on opening windows.

Measurements have shown mean ventilation rates of 3 air changes per hour with one window open and around 10 air changes per hour if windows are open on both sides of a typical house. If the ventilation rate was 3 air changes per hour throughout the winter then the ventilation heat loss would be 12000 kWh per year.

IMPLICATIONS FOR HOUSE DESIGN

Modern houses with all windows and external doors closed have natural ventilation rates of 0.5 to 1.5 air changes per hour. The addition of any extra mechanical ventilation will add to this figure and result in excessive ventilation for much of the time. Therefore, before the ventilation can be controlled by windows or mechanical ventilation, the house structure must be 'tight'. Fortunately house tightness can be measured easily by a pressurisation test and the same test also shows that the leakage gaps in a house occur at every corner and joint, especially where timber meets brickwork, i.e. around the outside of window frames, where floor joists rest in holes in the inner leaf of the external wall. The now common practice of dry lining instead of wet plastering can also provide more leakage paths.

Thus, before controlled ventilation can be achieved, the details of how houses are built must be looked at very carefully to see where fortuitous leakage can be avoided. Seals must be provided between window frames and brickwork. Holes where services penetrate the envelope must be made good. Loft hatches must be draughtstripped. Joist hangers should be used. New ideas in architectural detailing and probably improved on-site supervision are required until the new techniques become established.

Having obtained a tight house envelope the ventilation openings must then be provided where required. Since ducting may have to be concealed above the ground floor ceiling, the floor joist direction may be critical and it is important that the mechanical ventilation system should be incorporated into the house design at the earliest possible stage.

Room to room return air paths will normally take place through internal doorways and if the doors are unusually tight fitting it will be necessary to provide transfer grilles or slots for this purpose.

VENTILATION SYSTEMS

The simplest mechanical ventilation system is an extract fan in the kitchen. This may be supplemented by extract fans in WC and bathroom with timers so that they operate only when required. These systems are common for intermittent use, contaminants are prevented from spreading from utility to living rooms but the ventilation rate is not controlled when the fans are off, which is most of the time.

If a house can be made relatively 'tight' then the provision of extracts in kitchen, bathroom and WC, together with air inlets in living rooms and bedrooms, will ensure that as well as removing contaminants at source, fresh air is supplied where it is most needed. For this system to succeed the fortuitous leaks in the house structure must be much smaller than the air inlet slots, otherwise short circuiting will occur and rooms will be unventilated. Conventional cooker hoods and extract fans are relatively noisy which would be very undesirable for a continuously running system. A quieter and neater system is achieved using a central fan connected to a cooker hood and ceiling extracts in the bathroom/WC by ducting. Commercially available systems have flow rates of about 200 m^3/h with a 70 watt fan, having at least two speed capability.

The extract only systems, while cheap and simple to install, may still suffer some wind-dependence of individual room fresh air ventilation and also all of the heat in the extracted air is being thrown away. It is then but a small step to install a heat exchanger in the path of outgoing air and use it to preheat the incoming air, which of course must now be ducted to each room. This more than doubles the complexity and cost of the ventilation system but gives lower running costs because of heat recovery and more positive ventilation which is independent of the weather.

Schematic diagrams of both systems are shown in Figure 1. There are two main variations depending on whether the fans and heat exchangers are incorporated into an enlarged cooker hood in the kitchen or remotely sited in the loft. The former has the advantage of accessibility for cleaning and maintenance whereas equipment in the loft may not receive regular attention; however, the extra ductwork in the kitchen takes up a lot of space.

It is generally recommended that fresh air supply into rooms is at high level to avoid draughts. An alternative is at low level behind or below panel heaters. The kitchen extract ducting to a remote fan is usually 150 mm diameter, as are the main supply and extract ducts for the whole house. 80 mm ducting is adequate for individual room air supplies. Acoustic dampers are usually necessary between the fresh air fan and the room diffusers.

The main problem in system design is fitting the ducting into the house structure with the minimum of intrusion into the living space. Components and ducting in the loft must be thermally insulated.

(3) to remove water vapour (avoiding condensation and 'stuffiness'),
(4) to remove odours,
(5) air supply for combustion appliances.

These requirements are summarised in British Standard 5925: 1980, e.g., if three people (non-smokers) are considered to be seated in a 30 m^3 room then fresh air supplies for (1), (2) and (4) are required as follows:

	l/s	ac/h
oxygen supply	0.3	0.04
CO_2 removal	2.4	0.3
odour removal	15.0	1.8

It is seen that fresh air requirements for breathing are minimal; the main reason for ventilation is to remove odours.

Combustion appliances are a special case which will not be considered here.

Water vapour removal and control of humidity are an important function of ventilation which cannot be dealt with as simply as odours. This is because water vapour sources within the house are generally localised and intermittent, for example:

Sleeping adult produces 0.04 kg/h of water vapour		
Cooking	~0.5 kg/h)	
Clothes washing	~0.2 kg/h)	very variable
Clothes drying	~1 kg/h)	

This shows that the main sources of water vapour are predictable and localised and require special provision. Water vapour from people at a rate of 0.04 to 0.05 kg/h will not be a problem if the ventilation criterion for odours is satisfied, e.g., assume 3 people in a 30 m^3 room as above, water vapour is being produced at a rate of 0.15 kg/h and ventilation is at a rate of 1.8 ac/h. The equilibrium concentration of water vapour in the room from respiration is only 0.00035 kg/kg air, which is sufficient to raise the relative humidity by 2% at 20^{o}C or 4.5% at 10^{o}C.

Odours arising from smoking are stronger than normal body odours and will often require higher ventilation rates. BS 5925 gives an average requirement of 7 litre/second per smoker.

HOW TO VENTILATE?

Ventilation in houses can be described as fortuitous when all windows and external doors are closed, entering through numerous cracks in the house, and deliberate when windows are opened. Both are described as natural ventilation and both the ventilation rate and route will depend on the weather for any given set of openings, but the fortuitous ventilation cannot ever be controlled. By diligent opening and closing of windows as the weather and internal conditions change, it is possible that economical and efficient ventilation can be achieved but it is more likely that windows will be opened when the house feels 'stuffy' and left open until someone feels a draught. As will be shown later the ventilation rates and corresponding heat losses may be far more than is necessary for comfort.

Control of ventilation implies the provision of openings in the house envelope at appropriate locations and a method of controlling the rate and direction of air flow through these openings.

In general the fresh air flow into a house will take place on the windward side especially downstairs and air will leave the house on the leeward side especially upstairs. While this may seem to imply a general flow of fresh air through the house, this is not strictly true because much larger interchanges of air between rooms arises as a result of internal temperature differences, if doors are open.

Vents are commercially available for installation through walls or window frames which progressively throttle as the wind pressure increases but only a fan will be able to move air out of a house against the wind pressure.

Having accepted that a mechanical extract is desirable, it is then relatively simple to arrange for removal of kitchen and bathroom contaminants at source and then a relatively modest ventilation rate will suffice for the living rooms in the house.

The mechanical system removes the possibility that this could happen and results in a predictable ventilation heat loss of only 1600 kWh per year, thus the system could save as much as 10400 kWh or about £280 per year.

In practice, the saving is somewhere between these two examples because houses are generally not heated 24 hours a day and windows will not be open all the time.

The increased comfort which will result from removing smells and moisture from kitchens and bathrooms, avoiding condensation in bedrooms, and supplying fresh air to bedrooms and living rooms is not easy to express in terms of money but is real nevertheless.

The cost of running the system which has two 60 watt fans is about £26 per annum for a heating season from October to April inclusive, but about 50% of that will be returned to the house as heat because the supply fan is in the fresh air stream.

CONCLUSIONS

Ventilation control is necessary to minimise heating energy consumption in houses. While passive systems and those requiring occupant participation may give satisfactory results, only a mechanical system can provide predictable ventilation rates and routes at all times.

An extract only system is attractive because of its low initial cost but it is difficult to ensure fresh air ventilation throughout the living rooms of the house.

A complete supply and extract system with heat recovery is expensive to install and requires careful design to ensure convenient duct runs but the performance is predictable.

The pressurisation tests can be used to test houses for leakiness before installing a ventilation system.

Compared with opening windows a full ventilation system appears to be a reasonable investment and the running costs are predictable.

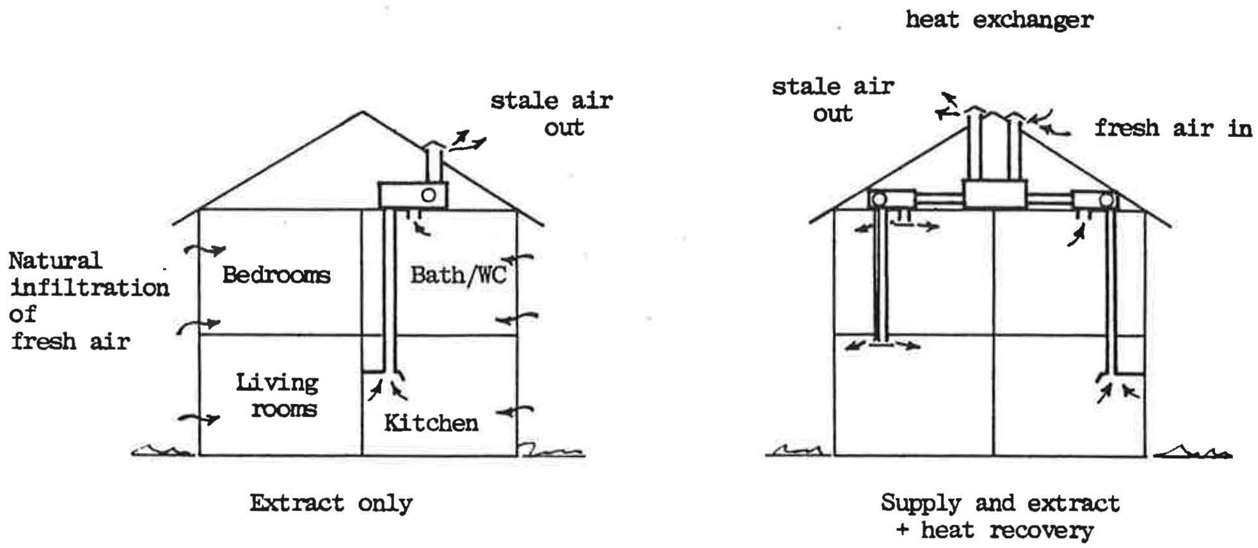

Figure 1. Mechanical ventilation systems