NOTES

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4.0 Introduction

Ventilation is the replacement of stale air in a building with fresh air. Ventilation is a vital requirement for the comfort and health of building occupants (see IP10). The reasons why ventilation is so important can be Listed as;

- to supply oxygen for breathing (respiration)
- to dilute pollutants such as body odours and exhaled carbon dioxide.
- to remove unwanted heat from the building.
- to supply air for combustion appliances.
- to lower the relative humidity and so avoid condensation.
- to clear smoke in the event of fire.

There are two ways of stating the quantity of ventilation supplied to a space. The first relates to the occupants of a building and is specified as the number of litres of fresh air that is delivered to the room per second per person (l/s/p). Each of the functions of ventilation listed above require different rates of air supply. For example the need for respiration can be satisfied by supplying air at a rate of 0.2 l/s/p. Dilution of body odours from sedentary occupants requires 8 l/s/p. Dilution of odours such as tobacco smoke requires much higher ventilation rates. For very heavy smokers 32 l/s/p is required. For estimation of typical ventilation requirements the value of 8 l/s/p is used.

The second method of quantifying ventilation is to use the air change rate. The air change rate is the number of times the air in a room is completely changed by fresh air every hour. The units are therefore air changes per hour (ac/h). The recommended air change rate in a typical mechanically ventilated office is in the range 4 to 6 ac/h. For dining halls and restaurants the recommended air change rate is between 10 and 15 ac/h. The CIBSE Guides give recommended air change rates for a range of situations.

4.1 Domestic Ventilation

Ventilation of domestic buildings is mostly provided by infiltration. Infiltration is the movement of air in and out of the building via cracks and gaps in the building envelope. Air movement is driven by natural forces such as wind pressure and differences between inside and outside temperatures. Unfortunately infiltration is uncontrollable and, in windy conditions, can lead to excessive ventilation rates resulting in draughts and high ventilation heat losses. Conversely it can also lead to inadequate ventilation on still, warm days. To avoid these problems a four stranded strategy is recommended :-

- The building envelope should be built as air-tight as possible to reduce uncontrolled infiltration (see p62). This can be achieved by sealing known infiltration routes such as the gaps between doors/window frames and the masonry, the jambs of door and window openings, around service entries and loft hatches.
- Purpose built openings should be provided to supply background ventilation. Trickle slot or tube ventilators which provide an air movement path through the wall or window heads are suitable. These devices should be fitted with a manual damper to adjust the size of the ventilation opening. Some trickle ventilators are fitted with dampers which close automatically if the airflow rate through the ventilator becomes excessive on windy days.
- Windows should be openable to provide short term rapid ventilation of rooms.
- The building regulations section F1 requires that extract fans are used in rooms where moisture and odours are created such as bathrooms, kitchen and toilet. The fan should be sited close to the source of

IP10 - INDOOR.AIR.QUALITY

The occupants of a building are protected against the extremes of climate, noise pollution and to an extent external air pollution by the building fabric. However the internal environment itself acts as a collector and concentrator of a range of pollutants which are known to be harmful to health. Since the majority of people spend over 90% of their lives indoors the quality of indoor air is of great importance for a healthy life. The range of problems that are encountered range from discomfort to death. The former being due to the presence of odours and the latter due to the presence of airborne carcinogens. Cigarette smoke is a source of both categories. Table IP10 lists some of the pollutants found in indoor air.

Category	Example/Quantification
Fibres	Asbestos fibres, no longer used but materials using asbestos still exist in older buildings. Inhalation causes lung disease and cancer. Quantified as number of fibres per litre of air (f/l).
Gases	Carbon Monoxide, produced by incomplete combustion of gas in heating and hot water appliances. In sufficient quantities causes asphyxiation and death. Quantified as a fraction of air volume using parts per million (ppm).
Radiation	Radon gas, a radioactive gas arising from uranium in the ground. Inhalation of radon decay products causes lung cancer. The problem is greatest in houses built over granite. Quantified using radioactivity (Bequerels)per cubic metre of air (Bq/m^3).
VOC's	Formaldehyde. A vapour given off by the binding agents in chipped wood products. Inhalation causes irritation and may lead to allergic reactions such as asthma. Quantified using ppm.
Pathogens	Legionella bacteria. Grows in poorly maintained water based air conditioning and hot water services. Inhalation causes a flue like infection which can lead to pneumonia and death.

Table IP10 Examples of indoor air pollutants

THE SOURCES OF POLLUTION

The sources of indoor air pollution are;

- The materials used to construct the building e.g. volatile organic compounds (VOC's) used as glues to bind materials together such as chipboard
- The building occupants themselves e.g. body odours and carbon dioxide
- Processes being carried out in the building e.g. ozone, pigments and solvents emitted from photocopiers, faxes and computer printers
- External sources e.g. traffic pollution from nearby roads

Humans spend 90% of their lives indoors. The quality of indoor air is therefore of great importance for comfort and health

SOLVING THE PROBLEM

- Avoid using materials or processes which give off pollutants
- Use extract ventilation to remove pollutants at source
- Use supply ventilation to dilute the quantities of pollutants down to acceptable levels
- Use filtration methods to remove pollutants from the air (see section 7.1)
- Seal the envelope to avoid unwanted ingress of polluted air

moisture or pollution and operate to give the specified extraction rate. For example these rates are 15 and 30 litres per second for bathrooms and kitchens respectively. The extract fan should be fitted with appropriate controls to limit the time it runs. One example of control is to fit a humidistat to the bathroom extract fan. When the relative humidity rises over a set threshold the fan will operate. When the humid air is cleared the relative humidity will fall and the fan will switch off. This will stop heat loss caused by the unnecessary extraction of warm dry air.

Most domestic extract fans are simple propeller fans fitted through the window or wall, possibly incorporating a short length of ducting.

Heat recovery extract fans are a method of extracting stale air and supplying fresh air to single rooms without wasting all the heat contained in the exhaust air. The unit incorporates two fans one to extract air through the unit and the other to bring fresh air into the building in the opposite direction (figure 4.1).

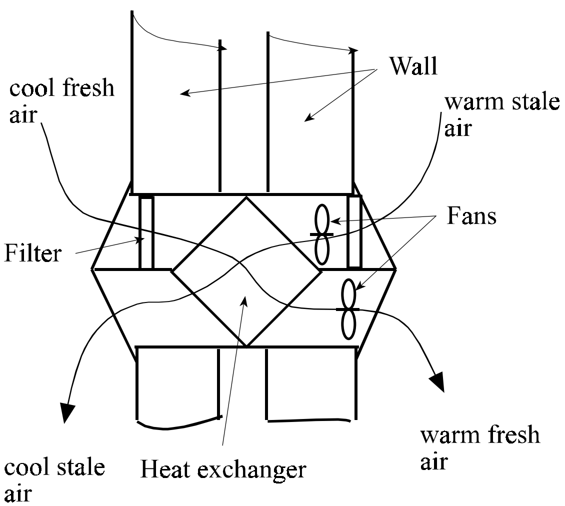

Figure 4.1 Ventilation unit with heat recovery

Both airflows pass through an air to air plate heat exchanger. The two airflows are kept separate and only come into thermal contact with each other. Heat from the outgoing warm stale air passes through thin separating plates in the device and warms the incoming cool fresh air. More details are given in section 4.4.

Whole house heat recovery. The single room unit described above can be extended to provide ventilation and heat recovery to all the rooms of the house (figure 4.2). A fanned heat exchange unit is sited in the loft or within the cupboards above the cooker extract hood. Warm stale air is extracted from all the rooms of the house and passed outside through the heat exchange unit. Incoming air is passed through this unit and is therefore pre-heated before being discharged into each room using ducting.

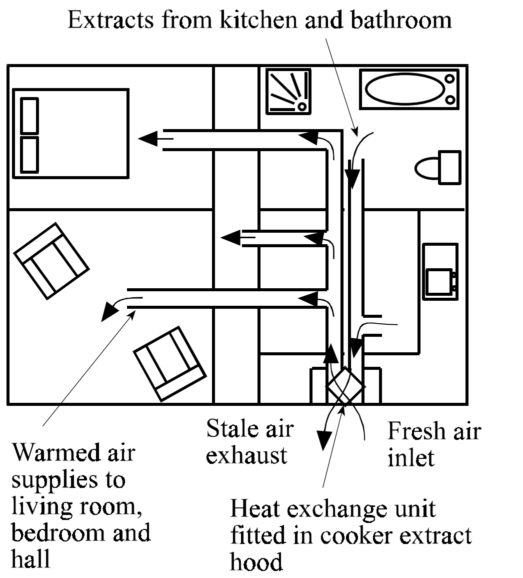

Figure 4.2 Whole house ventilation with heat recovery

4.2 Ventilation of Commercial Buildings

Ventilation of small commercial buildings is carried out in the same way as that for domestic buildings. However as the building size and complexity increases the demand for mechanical ventilation becomes more necessary. A number of situations can be identified where mechanical ventilation is essential these are;

- Densely populated rooms, where the space per occupant is less than 3.5 m^3 per person
- Deep plan buildings. Natural cross ventilation

6 Keeping tabs on energy efficiency

Airtightness of buildings

The motto for ventilation and air leakage is 'build tight – ventilate right'. Adequate ventilation is very important, but too much uncontrolled air infiltration causes discomfort and energy waste.

Airtightness can be measured by pressurising buildings and measuring how much they leak. Ideally, most buildings should leak less than 7.5 m^3/h for each m^2 of envelope area when pressurised to 50 Pascals (Pa). Testing shows that a figure of twice this value is typical, and some buildings are four times as leaky.

Airtight buildings improve occupant comfort, save energy and reduce risks of structural damage. As buildings become better insulated, an increasing proportion of the heat loss is through infiltration.

Benefits of airtight buildings

Occupant benefits

- Occupants will not have any discomfort caused by draughts.
- In very leaky buildings internal temperatures might not even reach comfort levels during the winter.
- It is likely that the productivity of the work force will improve since staff feeling comfortable in their working environment will get on with their work, while those who are not will continue reacting to their discomfort.
- With a well-designed mechanical ventilation system contaminants from the outdoor air will be filtered etc.

Energy and environmental benefits

- Energy costs and the resulting carbon emissions will be much higher than necessary in buildings with high air infiltration rates.
- The reduction of air infiltration in a building will allow designers of HVAC systems to reduce the size of the plant and even the size of the plant rooms.

Further information

Further information on building-related energy-efficiency measures is available from the Energy Efficiency Best Practice programme on the Environment and Energy Helpline 0800 585794

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

is difficult to achieve through buildings deeper than 15m from outside wall to outside wall. Single sided natural ventilation is also ineffective beyond 6m from an outside wall.

· Where windows cannot be opened for example due to external traffic noise or pollution.

· Rooms where accurate control of temperature or humidity is required.

· Rooms where pollution is created at a faster rate than can be cleared by natural ventilation.

· Where pressurisation of rooms is required e.g. in clean rooms to keep dust laden draughts out.

· Tall buildings which are sealed because wind and stack driven natural ventilation would be excessive

VENTILATION SYSTEMS

There are three methods by which buildings can be mechanically ventilated. These are:

Extract ventilation. This method of mechanical ventilation is used to remove pollutants such as moisture, odours and heat from occupied spaces. A propeller fan is used, mounted in a window pane or through the wall in a short length of ducting, to drive air out of the building. The fan must be sited near the source of pollution so that it can be removed directly from the building without it crossing the occupied space. Whenever air is mechanically removed from a building fresh air will enter to replace it. This make up air will normally enter through cracks and gaps in the building fabric. Alternatively purpose built perforations can be made. In this case the incoming air can be heated using a heater across the path of the incoming airflow. Controls should be fitted to the extract fan to limit its duration of operation to those times when it is needed.

Specialist extract systems for kitchens, laboratories and other industries are available which use fume collection hoods or cabinets. These are connected to outside using ducting and therefore require the use of an axial flow or centrifugal fan.

Supply ventilation works in the opposite sense to extract ventilation in that a fan is used to drive air into the building. The air supplied dilutes pollutants but it cannot directly remove them from the building. The fresh/stale air mixture leaves the building via cracks and gaps in the building envelope.

Supply systems deliver fresh air to the building at high speeds. This is acceptable in summer when high air speeds have a cooling effect but in winter the rapid movement of cold outside air into the building would cause discomfort. This discomfort can be avoided by passing the incoming air over a heating coil before it enters the occupied space. Supply ventilation pressurises the space it is serving, this is useful where entry of draughts and odours from outside needs to be prevented.

Balanced ventilation is a combination of both supply and extract ventilation. Each space is served by supply and extract ducts. The air movement through which is fanned. This system allows a consistent supply of fresh air to be supplied to each room using a configuration similar to the indirect warm air heating systems discussed in section 2.0 and air conditioning systems described in section 7.0.

By making the supply fan more powerful than the extract fan the space will be pressurised avoiding ingress of dust laden draughts. The most important advantage of balanced ventilation systems is the ability to carry out heat recovery between the exhaust and supply air streams.

Air to air heat recovery systems are described in section 4.4.

4.3 Fans

Air movement in warm air heating, ventilation and air conditioning systems is made possible by the use of fans. A fan creates air movement using a rotating vane driven by an electric motor. The casing in which the impeller rotates also has an effect on the air movement characteristics. There are two basic configurations of fan available each with different operating characteristics.

7 Keeping tabs on energy efficiency

Energy efficiency in mechanical ventilation

The amount of energy consumed by mechanical ventilation systems can be substantial but is often overlooked – in offices, fans and pumps typically use as much electricity as lighting.

Key design issues

- Do not use unnecessarily high air velocities in ductwork. High velocities result in high fan pressure requirements and thus high powered fans.
- Do not supply more air than is needed – or at times when it is not needed.
- Select an efficient fan.

Early design decisions on space allocation for ducts can be critical.

Lower air velocities mean quieter systems and bigger and more expensive ducts. Typically, choosing a low velocity rather than medium velocity will reduce running costs by 70%. The additional ducting cost will be recovered in about five years.

Supplying the correct amount of air is partly a question of design air volumes and partly one of providing appropriate controls.

A useful way of checking the efficiency of a mechanical ventilation system is to calculate the specific fan power. This is the power of the fan in kW divided by the flow rate in m^3/s.

System energy efficiency	Specific fan power
High efficiency	<1.5
Medium efficiency	1.5 to 4
Low efficiency	>4

Further information

Further information on building-related energy-efficiency measures is available from the Energy Efficiency Best Practice programme on the Environment and Energy Helpline 0800 585794

BEST PRACTICE PROGRAMME
ENERGY EFFICIENCY

Axial flow fans have the impeller connected directly to the drive shaft of the motor (figure 4.3). This means that the airflow passes over the motor and is parallel to the axis of the fan.

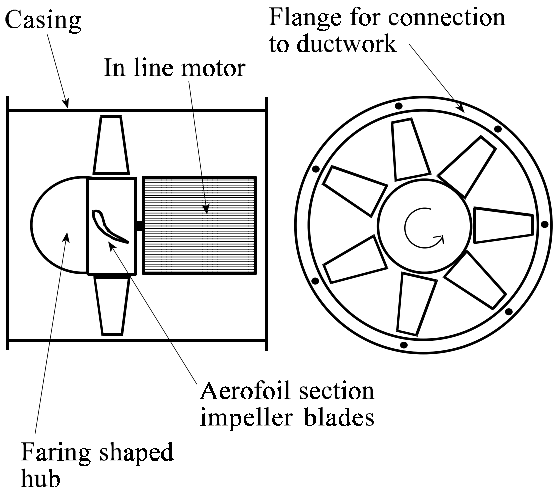

Figure 4.3 Axial flow fan

The impeller blades can be one of two types. The first is a simple propeller where the blades have a uniform cross section throughout their length but are twisted so that when the impeller rotates the air that it comes into contact with is pushed from the leading to trailing edge of the blade. The momentum built up carries the air out of the fan. The volume of air moved depends on the speed of rotation of the fan and the number of blades. Rotational speed is however kept below 30m/s blade tip velocity as the noise generated by the fan becomes unacceptable. Propeller fans do not generate a large pressure difference and so they cannot move air through ducting longer than approximately 45-55 cm. However they are effective at moving air through free openings such as window extract units or wall extract units incorporating short lengths of ducting.

The second blade arrangement is more complex having an aerofoil cross section and twisting from one end to the other. In the same manner as an aircraft wing, the aerofoil bladed impeller generates increased air movement over its upper surface. This creates a greater pressure difference and so the fan can move air along a system of ducting. The efficiency with which the aerofoil bladed fan converts electricity into air movement is higher than the propeller fan but can be further increased using stationary radial guide vanes across the inlet or exit of the fan. This reduces swirl and so gives a more even flow of air.

Centrifugal fans have a completely different impeller and casing arrangement to axial fans. The impeller blades rather than being perpendicular to the axis of rotation are parallel to it and are arranged into a drum like configuration (figure 4.4). Air is drawn into the fan parallel to the axis of the impeller. The rotation of the impeller causes the air to leave the fan at right angles to the direction of entry. The air being driven by centrifugal force and collected by the volute casing. Changing the arrangement of blades within the impeller changes the characteristics of the fan. For slow, low pressure applications such as is required in noise sensitive environments, the leading edge of the blades faces backwards, away from the direction of rotation. For maximum pressure generation such as is required for moving air through very long lengths of ducting, the leading edge is made to face forwards.

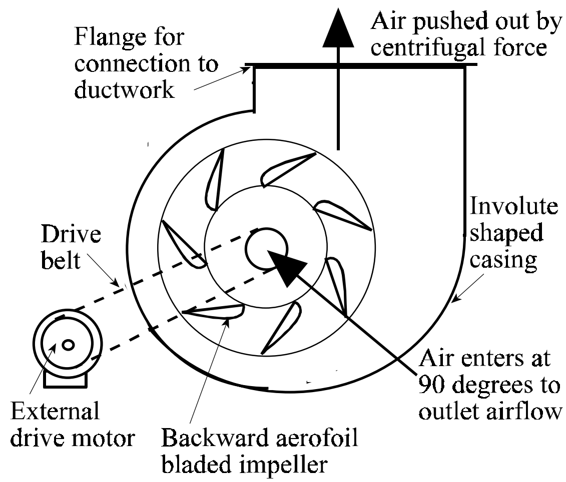

Figure 4.4 Centrifugal fan

4.4 Heat Recovery

Mechanical ventilation gives good control of ventilation rates and hence air quality. However, the air removed from the building carries with it the energy used to warm it up to room temperature. It therefore repre-

IP11 - THE.FAN.LAWS

Three factors of fan performance are of interest to us, these are;

What is the volume of air moved by the fan? (determines the volume of air the fan can extract or deliver)

What is the pressure difference created by the fan? (determines the pressure drop, caused by resistance to air movement in the ducting, that the fan can overcome)

How much energy is the fan using? (determines cost of operating a ventilation system)

The performance of fans in use is predicted by a set of laws which govern them. These laws can be placed into two groups; those that predict the changes arising from varying the speed of the fan and those which predict what happens when varying the size (diameter) of the fan (see also p64).

SPEED CHANGES (size kept constant)

Law 1. *Increasing the fan speed increases the volume of air drawn into the fan.* This is a direct relationship, so for example, doubling the speed of the fan doubles the air volume drawn into the fan.

Law 2. *The pressure difference generated across the fan inlet and outlet increases with increasing fan speed.* This is a square relationship so doubling the fan speed will quadrouple the pressure difference created by the fan.

Law 3. *The energy used by the fan increases as the fan speed increases.* This is a cubic relationship so doubling the fan speed will increase the electrical use by a factor of eight.

Without fans mechanical ventilation and air conditioning systems cannot operate. Optimal operation depends on a knowledge of the factors that affect fan performance.

SIZE CHANGES (speed kept constant)

Law 1. *As the fan size increases the volume of air drawn into the fan increases.* This is a cubic relationship so doubling the fan diameter increases the input by a factor of eight.

Law 2. *The pressure difference created across the fan increases as the fan size increases.* This is a square relationship so doubling the size of the fan increases the pressure difference by a factor of four.

Law 3. *As the fan size is increased the energy required to operate it increases.* This is a cubic relationship so doubling the fan size will increase the energy consumption by a factor of eight.

Manufacturers produce fan characteristic curves (figure IP11) which graphically illustrate changes which occur as the volume flow rate changes. This characteristic is for an individual fan.

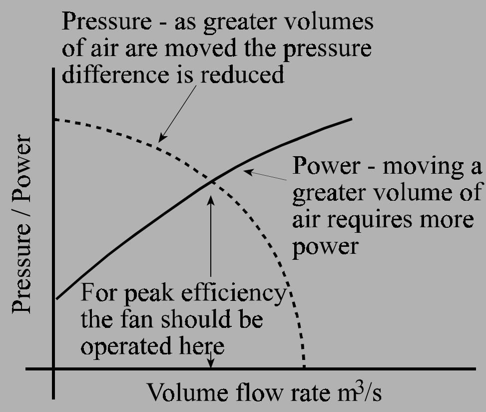

Figure IP11. Fan characteristic (radial bladed centrifugal fan) sents a source of heat loss from the building. Mechanical ventilation has an advantage over natural ventilation in that systems can be put in place to recover most of the heat normally lost along with the extract air. The systems are known as air to air heat recovery units. Each method of heat recovery involves transferring energy from the exhaust airstream to the supply airstream. There are a number of ways of achieving this as described in the following sections.

Air to air plate heat exchangers are used for both domestic and commercial heat recovery. The remaining systems, because of their cost and complexity, are restricted to commercial use.

Plate heat exchangers are used where the exhaust and supply airstreams are arranged to flow alongside each other (figure 4.5). They are composed of a cubical sandwich of thin metal or plastic plates. These plates allow the exhaust and supply airstreams to pass each other but remain separated. Heat passes from the hotter to the cooler airstream by conduction through the thin plates (figure 4.6).

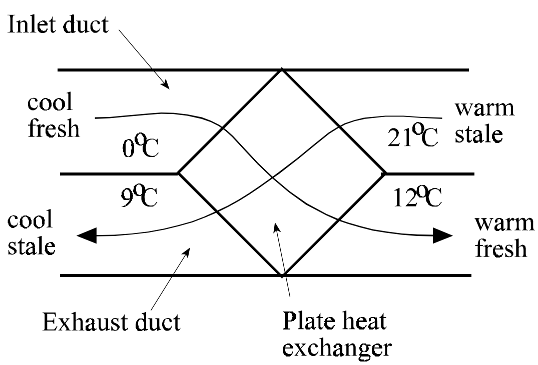

Figure 4.5 Location of plate heat exchanger in the ducting

Plate heat exchangers have a number of advantageous features;

- They have no moving parts which would require maintenance.

- They keep the airstreams separate so no cross contamination can occur.

- No energy is required for their operation although fan power may need to be increased to overcome air friction through the unit.

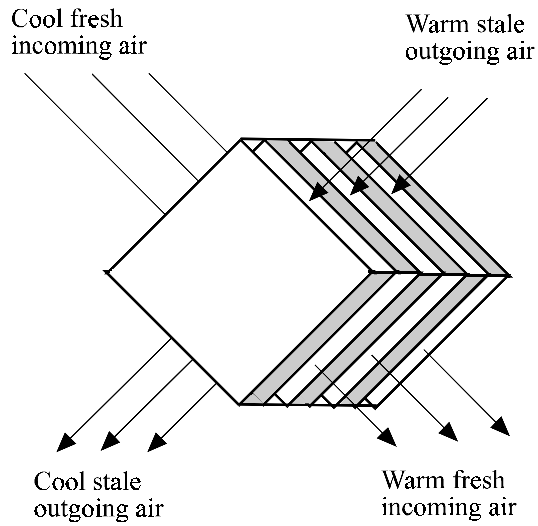

Figure 4.6 Air to air plate heat exchanger

Thermal wheels are composed of a circular matrix of tubes through which air can flow (figure 4.7). The wheel is positioned across the inlet and exhaust ducting so that inlet air passes through the upper half of the wheel and exhaust air passes through the lower half. As the exhaust air passes through the wheel the matrix heats up. The wheel rotates and slowly brings this heated section into the path of the incoming airstream. The incoming airstream is warmed as it passes through the thermal wheel matrix.

The thermal wheel requires an electric motor to drive it and so the energy consumption of this needs to be considered in assessing the heat recovery efficiency. Thermal wheels should not be used in areas where cross contamination of airflows would be a problem such as hospital operating theatres. This is because it is not possible to fully seal between supply and exhaust airflows.

Run around coils are heat recovery devices which can be used when supply and exhaust airflows are not run close together. A finned coil is situated in the path of the exhaust air (figure 4.8). Air passing through the coil heats up a water and antifreeze mixture circulating

I P 1 2 - E C O N O M I C S . O F . H E A T . R E C O V E R Y

Heat recovery devices represent a capital cost which must be recovered in the value of energy savings made. Economic viability usually depends on recovering this capital cost within a certain period of time known as the payback period. Determination of payback periods involves a comparison between capital and running costs on the one hand and value of energy savings on the other.

It is not always economical to use heat recovery devices. Capital and running costs must be weighed up against the value of energy saved.

Simple payback period calculations can be made using the following formula. For retrofitting of heat recovery devices a simple payback period of three to four years is usually considered economically viable.

$$\text{Payback period(y)} = \frac{\text{Capital Costs (£)}}{\text{Energy savings (£/y) - running costs (£/y)}}$$

PAYBACK FACTORS

Initial costs involve the capital and installation costs of the heat recovery device. However, some of this may be offset by savings arising from reductions in the size of boiler plant, made possible by the availability of recovered heat.

Running costs involve a debit in terms of electricity used by fans, pumps and motors and also maintenance costs. The credit is in the value of recovered energy. Running costs and credits are strongly dependent on the hours run by the system and availability of energy for recovery. For example cost effectiveness will be greater in winter when differences between inside and outside temperatures are at their greatest. Similarly the cumulative value of energy savings will be greatest in buildings where the ventilation system runs for a large number of hours in the day.

System efficiency varies depending on the rate of flow of air through the device. Figure IP12 shows how the efficiency of a domestic air to air plate heat recovery unit depends on the airflow rate. As the airflow rate increases the heat recovery efficiency decreases. This is because the air does not dwell in the device sufficiently long for heat transfer to take place. It can be seen that the peak efficiency is 75% indicating that three quarters of the heat contained in the extract air can be recovered to the supply air .

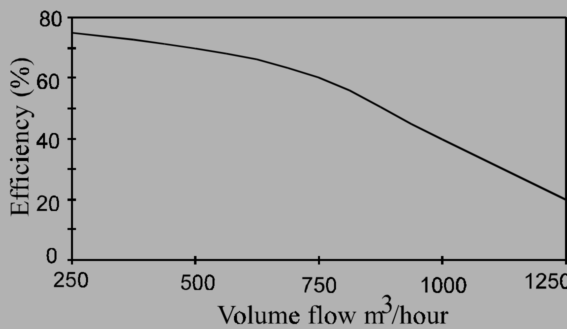

Figure IP12 graph of efficiency against airflow rate

ENVIRONMENTAL BENEFITS

Falling energy costs following privatisation of the fuel utilities means that it is increasingly difficult to justify energy saving devices in terms of financial payback. This is because the value of recovered energy has fallen. There are, however, considerations to be made beyond financial paybacks. Energy usage represents a cost to the environment. Heat recovery will result in a reduced need for heat generation and hence a reduction in the emission of pollutant gases such as carbon dioxide. Unfortunately no formal carbon payback methods exist.

in the pipe work. A pump circulates this heated solution to a similar coil installed in the supply duct. The supply air will become heated by passing through this coil. Topping up and maintenance of the system will need to be considered in economic analyses.

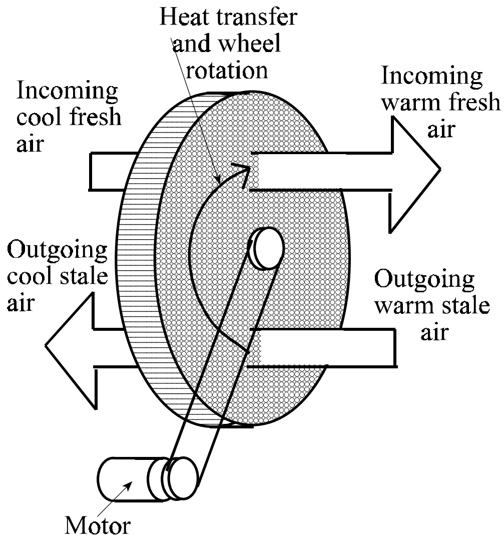

Figure 4.7 Thermal wheel

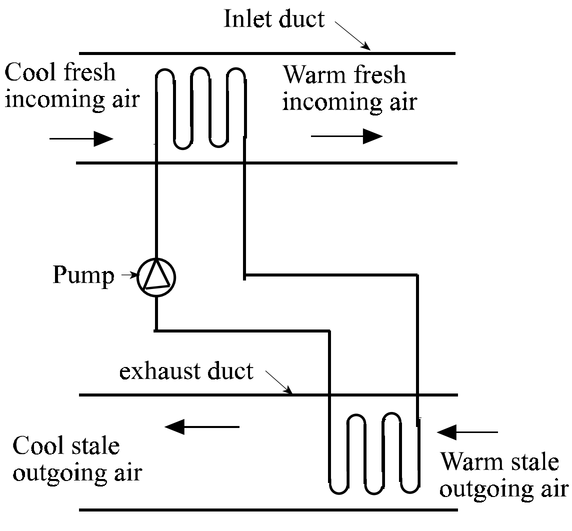

Figure 4.8 Run around coil

Heat pumps are similar to run around coils in that they can exchange heat between ducts which are separated by distance. However the pipework is filled with a refrigerant which evaporates in the coil situated in the exhaust duct. As the refrigerant evaporates it absorbs heat. The refrigerant vapour then flows to the coil in the supply duct where it condenses and in doing so releases the heat it has absorbed. The pipe work is fitted with a compressor and pressure reducing valve which enable the evaporation and condensation of the refrigerant to take place. A more full description of heat pumps is given in section 5.1.1.