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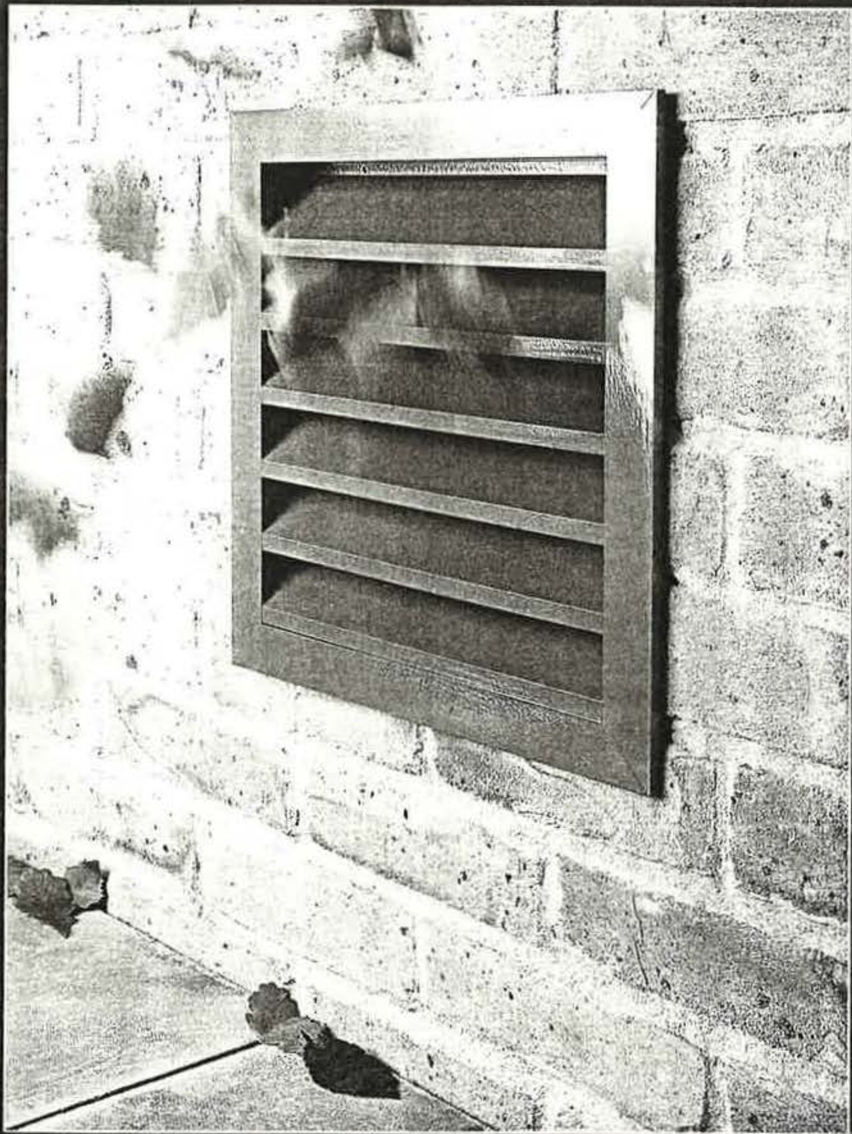
April 1987

Ventilation in commercial buildings



Why ventilation?

The quality of air inside a building – its temperature, moisture level, purity, movement and oxygen content – affects the well-being of those who work, live or visit there.

Air becomes stale or contaminated more or less quickly depending on the use made of the space. People at work will decrease the relative proportion of oxygen in the air and will give rise to body odours, moisture and heat. Tobacco smoke, at best an irritant to non-smokers, may increase the risk of their developing lung cancer. Chipboard furniture and carpet may give off formaldehyde, and other furnishings produce dust and fibres. Other contaminants (see table below for a full list) include fungal spores, germs and radon – a naturally occurring radioactive gas.

Good ventilation provides outside air, removes or dilutes stale contaminated air and controls the movement of air within the space.

Outside air can be filtered to remove dirt, dust and other unwanted impurities and this 'fresh' air used to replace stale air.

The speed and direction of air movement within a space has a marked effect on people's comfort. Too fast, particularly from a single direction, and people will complain of draughts. Not fast enough and the complaint will be about 'stuffiness.' Effective air movement will help to control the rate of heat and moisture loss from the body, and so increase comfort. It will also help to reduce excessive condensation from, for example, kitchens and laundries.

How much ventilation?

The amount of ventilation required in any situation depends on the type of building, the number of people and the use being made of the space. Ventilation must comply with local regulations and the provisions of the Health and Safety at Work Act, but the CIBSE, for example, sets out model recommendations which can be used in the absence of more specific requirements. Ventilation rates can be expressed in two ways: as a number of complete air changes every hour within a space – the most commonly used method – or by a given amount of fresh air per person occupying the space. Air changes must be of outside or fresh air; changing the air by recirculation only will not remove or dilute contaminants.

The rates shown below take into account the occupancy levels and activity for specific locations.

In some situations such as kitchens, laundry etc. where the activity itself is the greatest contributor to the need for ventilation, the rate is usually expressed as number of air changes, not as fresh air per person.

To improve the air quality and further dilute the concentration of contaminants, these ventilation rates can be increased. However, the greater the ventilation rate the more carefully the air direction and movement must be controlled. Unless some form of heat recovery is used, the need for heating and/or cooling due to the increased ventilation rate will increase the building's energy consumption.

The types of contaminants and their probable sources are given in the table below.

Typical air changes per hour or minimum fresh air per person

	Air changes/ hour	Volume of air/ second
Offices	1-2	·005m³/s
Banking halls	2-4	·005m³/s
Cafés	6-8	·008m³/s
Conference rooms	6-8	·012m³/s
Dining rooms/ restaurants	4-6	·012m³/s
Kitchens	12-15	–
Lavatories	10-15	–
Shops	4-6	·005m³/s
Bakeries	15-20	–
Laundries	15-20	–

Pollutants of indoor air and their sources

SOURCE	SMOKING	COMBUSTION	METABOLIC ACTIVITY	FURNISHINGS	BUILDING MATERIALS	AEROSOLS	SOIL	MOULDS & STATIC WATER	EQUIPMENT	EXTERNAL AIR
Odour			✓			✓				✓
Particulates	✓	✓			✓	✓	✓			✓
Moisture		✓	✓			✓			✓	✓
Mites				✓				✓		✓
Micro organisms and allergens			✓	✓				✓		✓
Radon					✓		✓			
Asbestos					✓				✓	
Man made fibres				✓	✓					
Carbon monoxide	✓	✓								
Methane							✓			
Hydrogen sulphide							✓			
Oxides of nitrogen	✓	✓								
Sulphur dioxide		✓								
Carbon dioxide		✓	✓							
Formaldehyde		✓		✓	✓					
Various chemicals inc. fluoro & hydro carbons, ammonia etc				✓		✓	✓			

Types of ventilation

Natural

Ventilation in buildings can be provided by natural means through infiltration, open windows or other purpose made openings.

Infiltration is caused by outside air passing through gaps in windows etc, porous building materials and the opening of doors.

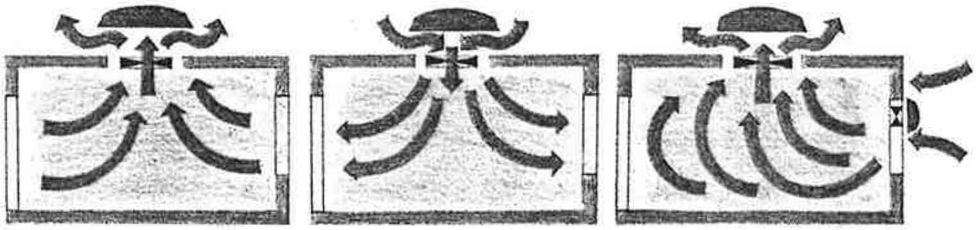
Infiltration may provide all or part of the ventilation that takes place but it is uncontrolled and rarely affects the area where it is most needed. To provide additional natural ventilation, windows can be opened. This is the method which is most likely to be adopted where the ventilation is considered insufficient or where some, albeit inadequate, control of the temperature of the environment is sought.

Unfortunately those nearest the window will suffer draughts and general discomfort so that those farthest away from the window can feel some benefit. The alternative is purpose designed openings within the structure. These are more easily controlled by a form of damper but the ventilation they provide is mainly proportional to the size of opening, and there is a limit to the size and number of such openings in a building.

By any criteria, natural ventilation is a hit and miss operation which also precludes the treatment of incoming air, where this is necessary.

To ensure the correct amount of ventilation, regardless of the outside wind or weather conditions, an electrically powered fan is required either on its own or as part of a comprehensive central ventilation system. Each has its own place depending upon the application and size of the building.

Controlled



EXTRACT INLET COMBINED

Each of the three basic systems of controlled ventilation shown here has its own advantages for different applications. Note that ducting can be used for an improved distribution of air in certain buildings and larger systems. It may also be worth installing heat transfer devices in larger systems to recover heat that would otherwise be wasted in colder weather. Regular cleaning and maintenance of all installations, including outlets, are essential for efficient operation.

Extract system

This is a simple and inexpensive technique, using extractor fans to draw out hot or stale air, contaminants, steam and odours. Replacement air is drawn in at other openings – though 'short-circuiting' may sometimes spoil the general distribution of fresh air. Extract ventilation is useful in ensuring that contamination is confined to one part of a building. For instance, by using it in kitchens, cooking smells are prevented from spreading to other rooms.

Inlet system

Air is 'pushed' into the room by an inlet fan and stale air passes out through other openings. This provides a uniform airflow throughout the area and helps prevent draughts. It is also beneficial to the safety and proper functioning of boilers or other flued equipment. Filters can be used for removing dirt from the incoming air. One advantage of this system is that a proportion of the heated air can be recirculated thus saving heat without having to reduce the rate of air movement.

Combined extract/inlet system

This is the most efficient system and allows the fullest control of ventilation. Normally the input volume should be greater than the output to improve distribution and prevent draughts and infiltration of dust or contaminants. But in a kitchen, for instance, a greater outlet volume is needed to prevent cooking smells from spreading inside the building.

Equipment for controlled ventilation

Each basic type of system has its advantages for different types of application and will consist of individual fans or ducting from centrally sited fans.

Window and wall mounted fans are a cheap, easy to install solution to the problem of ventilation. Depending on the direction of rotation, the fans can provide either inlet or extract ventilation. If a number of units are installed, they can be designed to form a system of combined ventilation.

There are fans which act as an inlet through one side of the unit and extract through the other. Such window fans are often combined with heat recovery so that the outgoing air transfers heat to the colder incoming air.

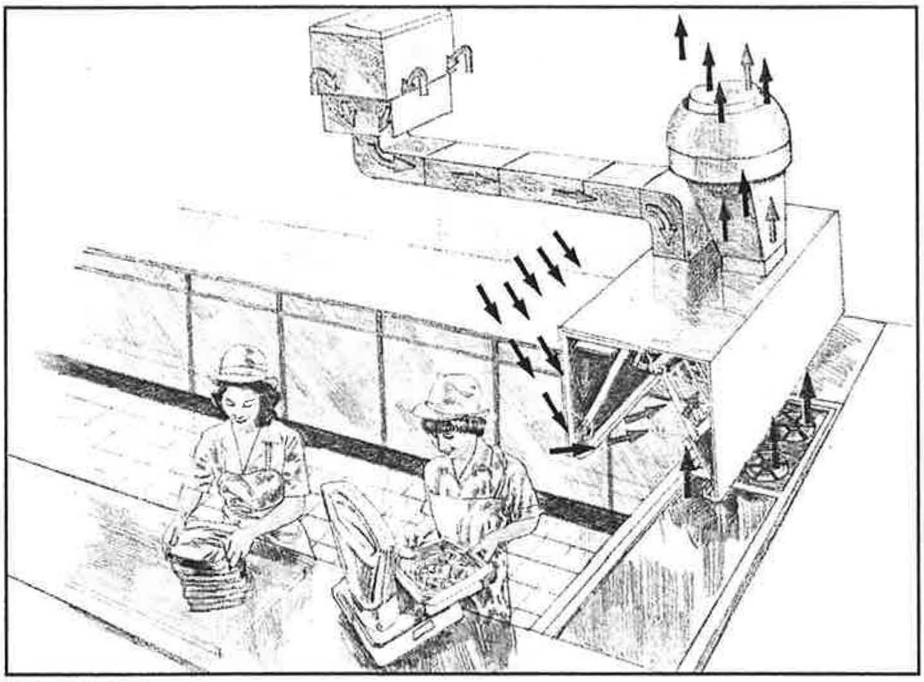
The disadvantages of window fans are their appearance, noise and the limited control they give over air movement. They also make air treatment such as filtration difficult and costly. Their main use would be to provide extract ventilation, thus avoiding the need for filtration and control of air direction. They are, therefore, ideal for a small extract application from, for example, an individual office or similar space.

Larger applications will require a ducted system from a centrally sited fan. Alternatively, a number of individual fans, normally located on the roof of the building, can be ducted to the areas where ventilation is needed. With a ducted system, grilles or diffusers are used to control the volume and direction of the entering air, enabling proper air distribution to be maintained. Air enters the space at velocities of between 1 and 3 m/sec in such a way that its velocity within the space is about 0.2 m/sec giving a pleasant sensation of 'fresh' air, without feeling draughty.

Extract grilles remove stale or contaminated air and can be placed in convenient positions in relation to the inlets and the occupants. By taking the extract or exhaust air to the same location as the incoming air, heat recovery is easily achieved by using an appropriate heat exchanger and/or heat pump. Such systems are ideal for all larger applications especially those in multistorey office blocks. The inlet can be placed to avoid street level contaminations.

proprietary heat recovery kitchen hoods which allow exhaust heat to be recovered and re-used. Consideration should be given to the energy savings benefits of such equipment.

Where fish fryers or similar equipment are present, replaceable grease filters or traps must be used. Similar hoods can be used in laboratories for fume removal. However, if the fumes are toxic or of a very high concentration, a fume cupboard with extract ducts would be preferable.



In a busy kitchen, heat, grease, moisture and cooking smells should be removed by an extract ventilation system at the cooking or wash-up source. A heat recovery system, incorporated in the ventilation equipment allows exhaust heat to be recovered and re-used.

The previous examples are those requiring general or non-specific ventilation. Often there is a need to remove a particular contaminant or a high concentration of several contaminants. In such cases it is better to remove these at source with a completely separate system.

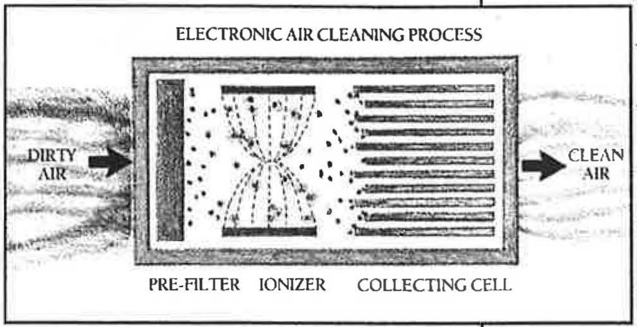
High concentrations of heat, moisture, grease and cooking smells in a kitchen are best removed by an extract ventilation system at the cooking or wash up source. Extract hoods are used over the source to pick up all contamination directly. The type and size of the hood depends on the location. For example, with the cooking equipment in the middle of a kitchen an island hood open on all four sides would be used. There are a number of

Care needs to be taken to ensure that these exhaust fumes, or kitchen contaminants are not discharged into or near the inlet to either the kitchen or main ventilation system. There is no point in removing the smells at source if they are then going to be spread throughout the building.

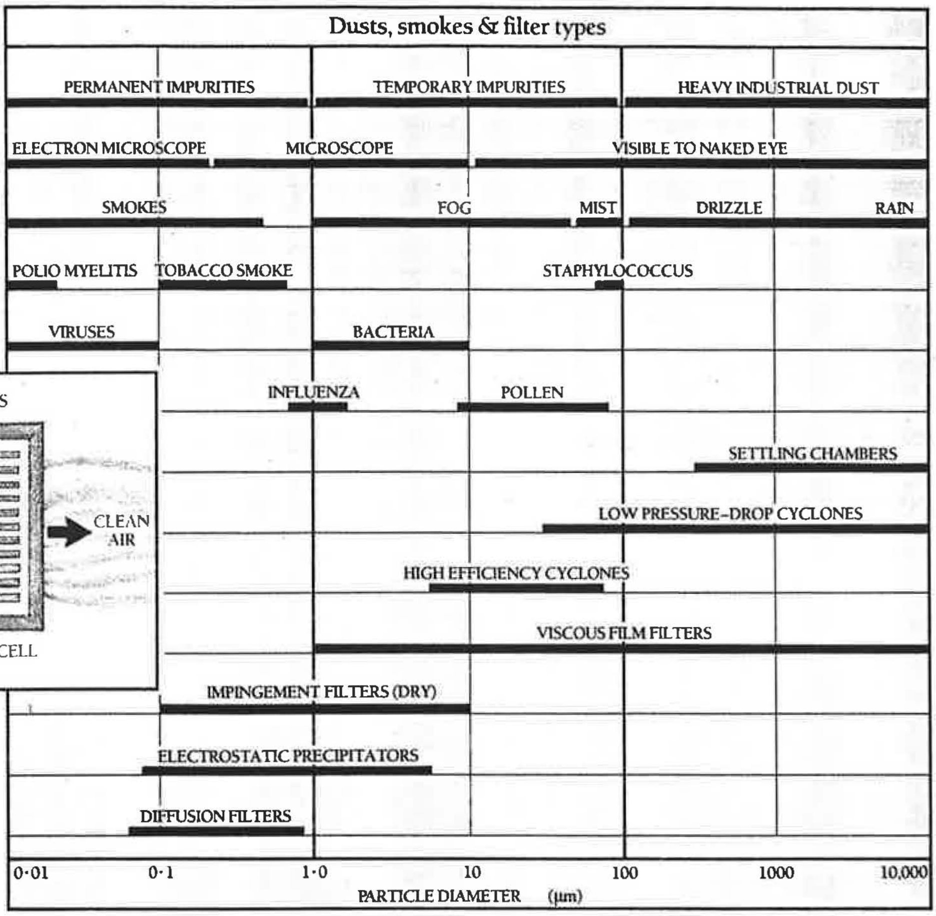
The advantage of central ventilation is that it can be combined with other forms of air treatment to make a better environment.

Filtration

Incoming air can be cleaned by one of the many types of filter available. For example, renewable activated carbon filters can remove strong odours, and electrostatic filters are capable of extracting very fine particles such as cigarette smoke or pollen from the air.



Where the contamination is from chemicals such as ammonia from printing processes, special treatment is required. The adjacent table shows the types of filter suitable for removing particular impurities.



Cooling

Although ventilation alone can help to reduce the internal temperature, especially when the outside air temperature is low, and so-called free cooling can be used, it has certain limitations. The internal temperature cannot be reduced below the outside temperature. In fact, it is often difficult to reduce the temperature to lower than 3°C above outside temperature. Depending on the internal loads, excessive air change rates in the order of 10/20/hour will be required with a subsequent increase in fan power. A combination of heat exchanger/heat pump (see page 6) may be the answer but even this solution has its limitations. Also, although the temperature can be reduced by ventilation during the spring and autumn it is unlikely that the humidity will be reduced. In a maritime climate such as that of the UK, excessive humidity in spring, summer and autumn is as much a problem as temperature.

The process of cooling air will also dehumidify it, and cooling equipment can be designed to remove the right amount of heat and moisture as required. If dehumidification only is required, then a specific dehumidifier can be incorporated in the ventilation system.

Heating

Heating can be provided by incorporating an electric heater battery in the system or by putting heaters at each inlet to enable individual control.

Humidification

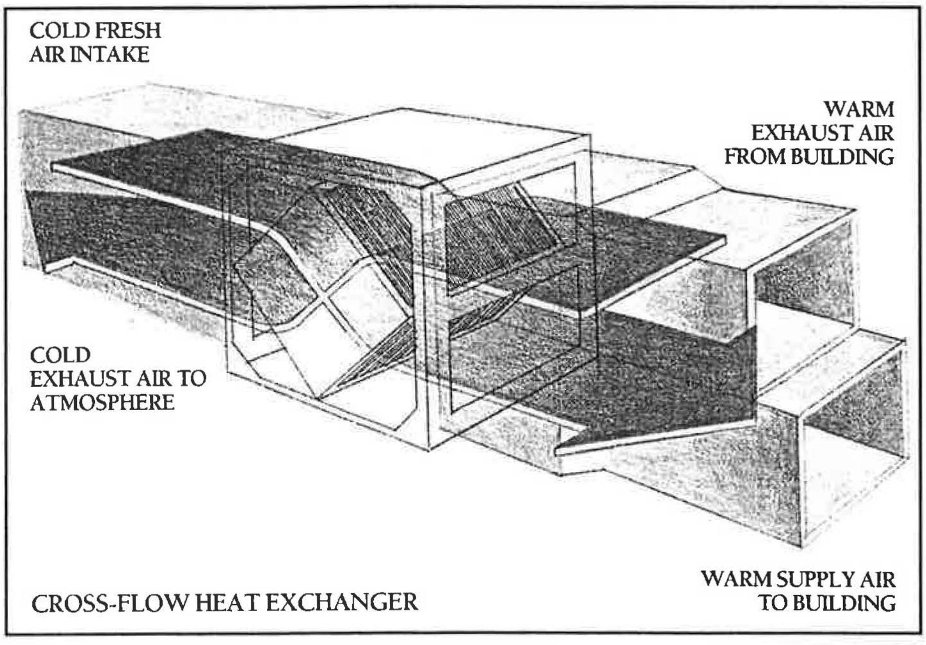
There are occasions when the conditions within a commercial building are such that humidification (the addition of moisture to the air) is required.

A humidifier can be included within the ventilation system or as a separate unit in the area affected. Steam humidifiers which are self sterilising should be preferred. If spray humidifiers are used, the water reservoir must be kept clean.

Humidification uses a disproportionate amount of energy compared to its benefits unless it is used only when low humidities (below 35% RH) are regularly experienced. Such relative humidities do not generally occur throughout the whole of a commercial building.

Heat recovery

To avoid wasting the energy needed to



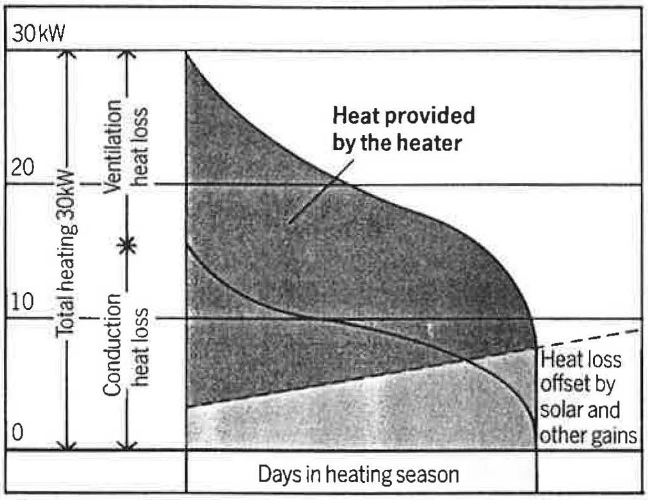
CROSS-FLOW HEAT EXCHANGER

heat incoming air, especially where it is necessary to increase the ventilation rate, heat recovery should be considered. Heat recovery can be by means of a thermal wheel, cross-flow heat exchanger (see figure on previous page) or many of the other active and passive heat exchangers explained in the Electricity Council publication: Heat recovery with heat exchangers. EC 4395.

Alternatively, heat pumps can be considered for heat recovery, either on their own or in conjunction with cross-flow heat exchangers. Their use in both methods is described in the Electricity Council publication – Heat recovery with electric heat pumps. EC 4634.

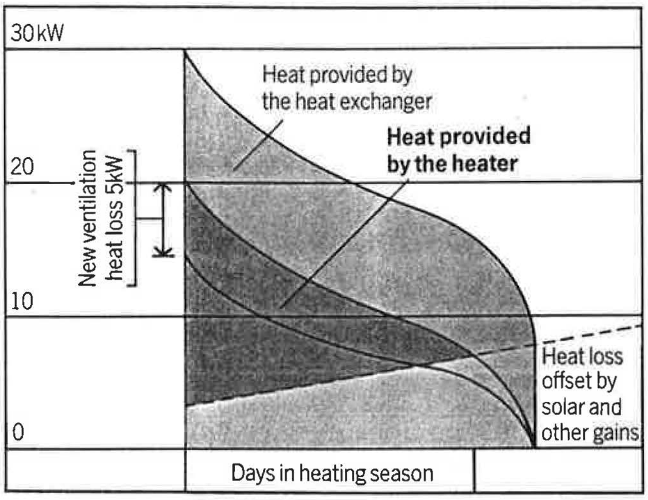
Where heat pumps are used, they can be reversed to provide some cooling during the summer.

The following heating analysis charts show the savings in energy that can be achieved by using heat exchangers, or combined heat exchangers and heat pumps, to reduce the ventilation losses.



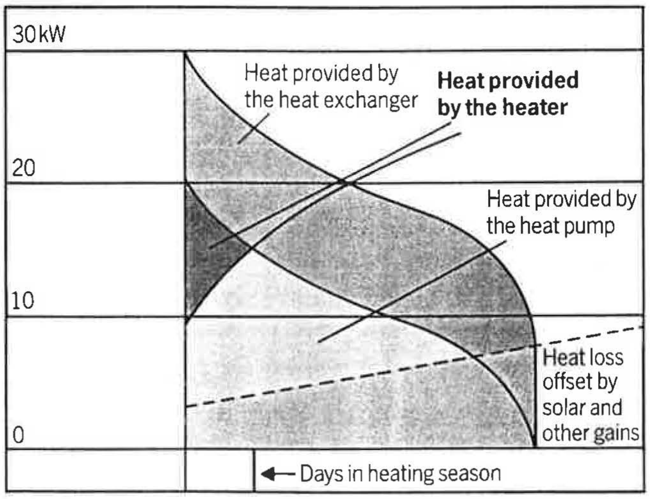
Without heat recovery

A building needs 30kW of heat to maintain the internal environment at 20°C. The inlet air is raised from 0°C to 30°C by means of a heater and a similar volume of air is exhausted from the building at 20°C. The heating analysis chart shows the heat provided to the building over the heating season with the coldest days shown on the left. When the heat gains from the sun, people, light, etc, are taken into account, the red shaded area represents heat being provided by the heater.



With heat recovery using heat exchanger

Compared with the previous example, if a heat exchanger is placed in the inlet and exhaust air streams, heat can be transferred to the inlet reducing the exhaust air temperature to 5°C. The inlet air before entering the heater is raised to 15°C and the heater can be reduced in size to 15kW. This can be demonstrated on the heating analysis chart.



Heat recovery using combined heat exchanger and heat pump

When the heat pump is used in conjunction with a heat exchanger, the combination is more energy efficient.

By being able to reduce the exhaust temperature, less exhaust heat is wasted and hence the ventilation heat loss is effectively reduced.

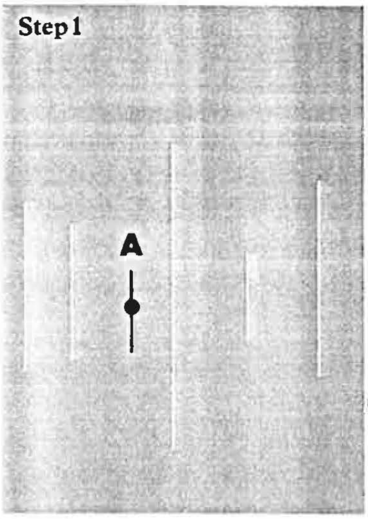
The use of a combination system also means that the heating load is reduced to the point where the use of central fuel-fired plant may no longer be justified and the electric heater will be a cost-effective alternative.

Ventilation or air conditioning?

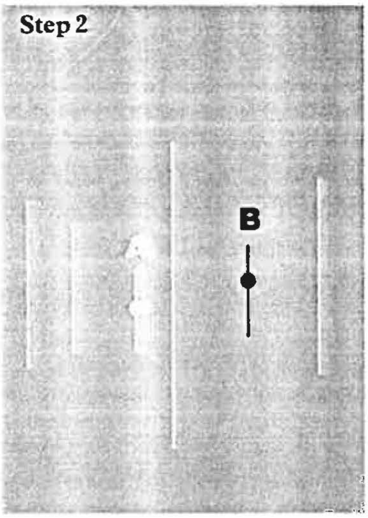
There comes a point in environmental control when ventilation alone is not enough and cooling and dehumidification must be provided by an air conditioner or heat pump.

Often, the power of the combined refrigeration units and fans is near to that of ventilation fans alone but with much better conditions, especially if the fresh air is of the right quality.

The benefits of air conditioning are given in the Electricity Council publication: EC 3967 and the use of energy efficient heat pumps is explained in the Electricity Council publication EC 4327.



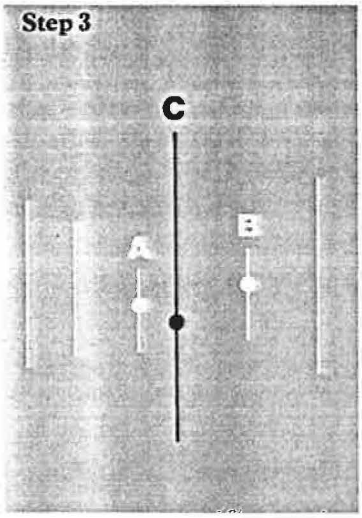
Start with line 'A'.
First decide the maximum internal temperature you are prepared to tolerate. From this, subtract 24°C (a typical outside temperature on a summer day). Mark the temperature difference on line A. Note that it can rarely be less than 2 deg C because of internal heat gains from people, lights, etc.



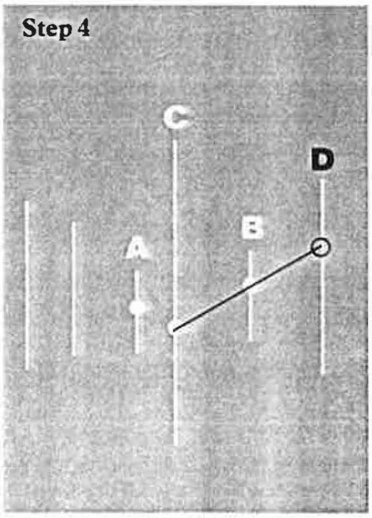
Go on to line 'B'.
Select the heat gain condition which best fits your room:

No outside walls	30 W/m³
One outside wall	40 W/m³
Two outside walls	50 W/m³
High level of lighting or solar gain	60 W/m³

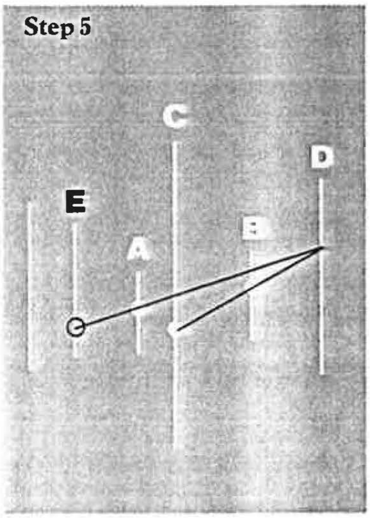
If the temperature difference you've worked out (line 'A') is between 5 and 10 deg C, subtract 10 W/m³. If it is between 11 and 16 deg C subtract 20 W/M³. Mark the resulting value on line 'B'.



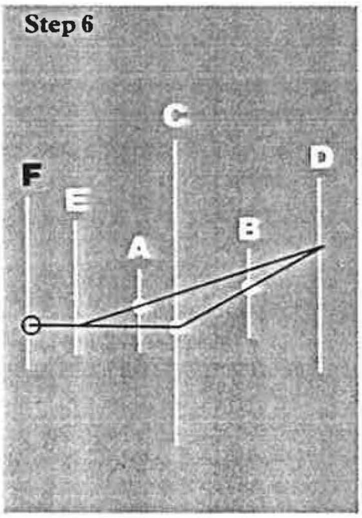
On line 'C', mark the volume of your room in cubic metres.



Draw a line from the room volume (line 'C') through the heat gain (line 'B') to cut the transfer line (line 'D').

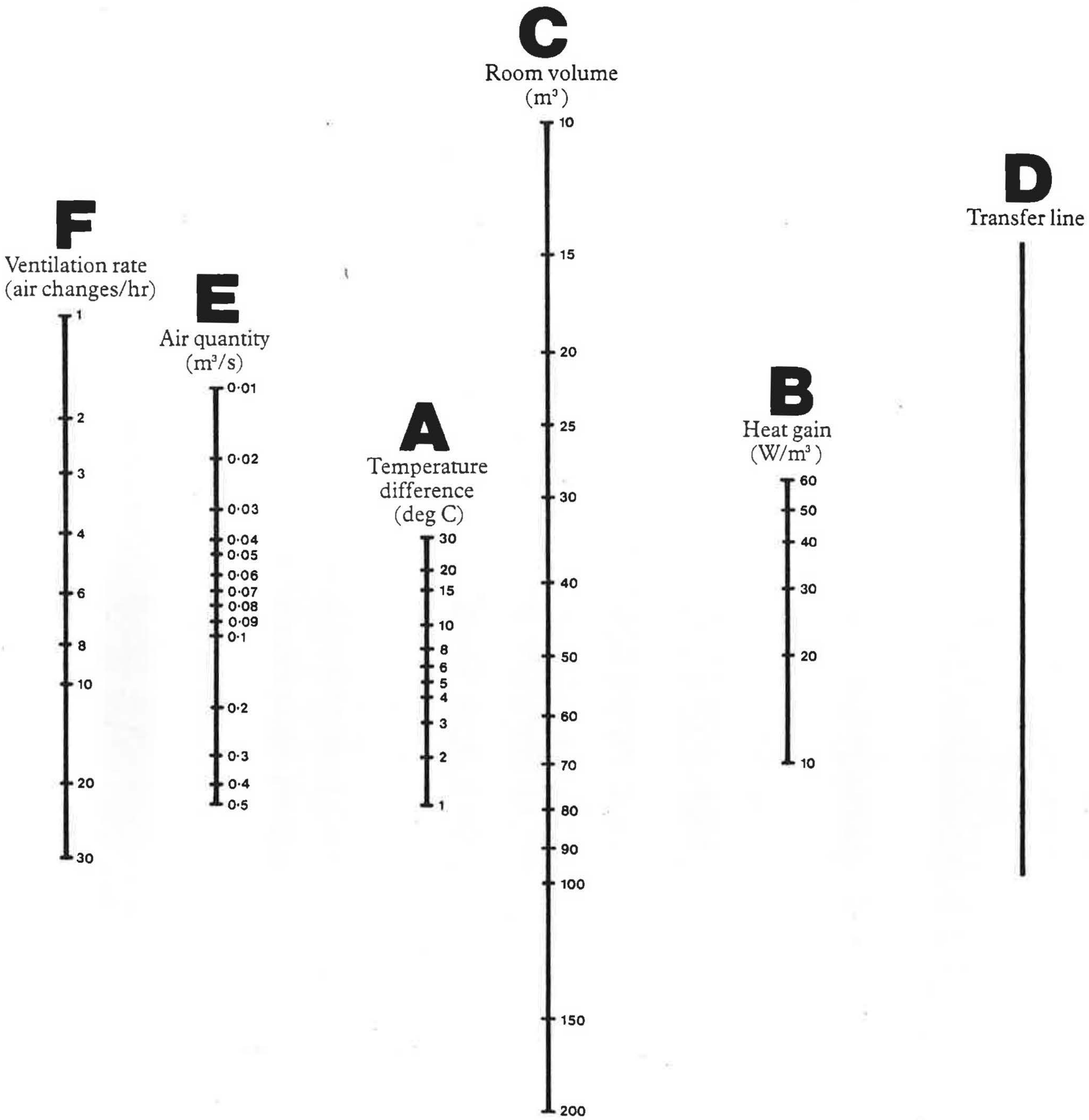


Draw a line from the transfer line (line 'D') through the temperature difference (line 'A') to cut line 'E'. This gives you the amount of air to be handled by the fan(s).



Finally, draw a line from the room volume (line 'C') through the air quantity (line 'E') to cut line 'F'. This point on line 'F' is the number of air changes required to reduce the room temperature to the level chosen. If this is more than the recommended value (see page 2) only air conditioning will be sufficient to provide comfortable conditions.

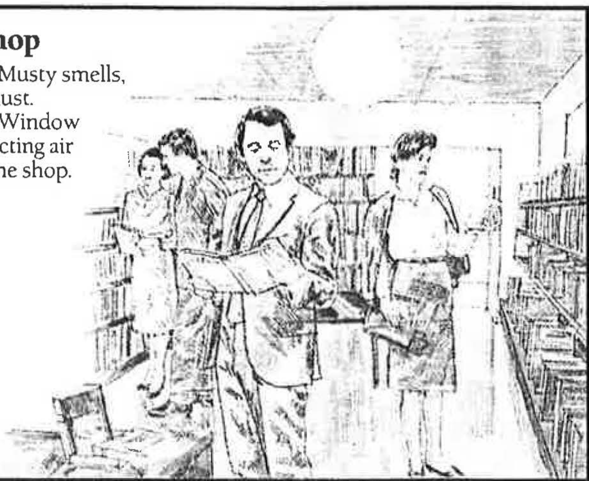
This chart has been specially designed to help you assess if ventilation is sufficient for your needs. The information you require to fill it in is minimal, and the procedure is quite straightforward.



Is your problem here?

Bookshop

Problem: Musty smells, stale air, dust.
Solution: Window fans extracting air through the shop.

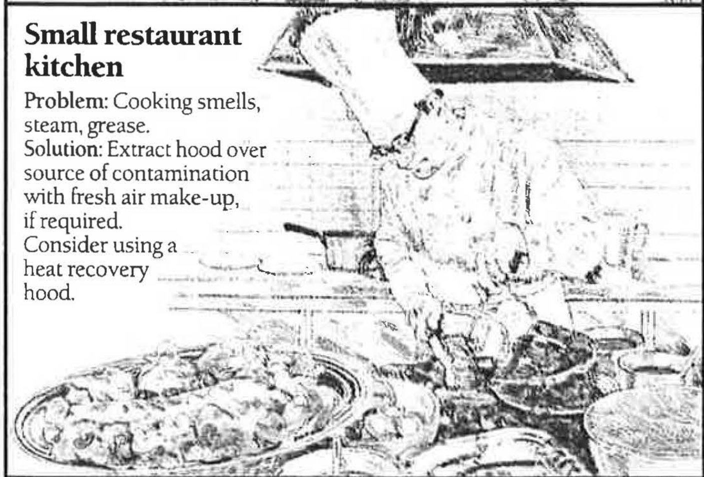


Super-market or small food shop

Problem: Heat from freezer cabinets, food smells, minimum ventilation.
Solution: Roof extract units dealing with individual areas as required.

Small restaurant kitchen

Problem: Cooking smells, steam, grease.
Solution: Extract hood over source of contamination with fresh air make-up, if required.
Consider using a heat recovery hood.



Open plan office

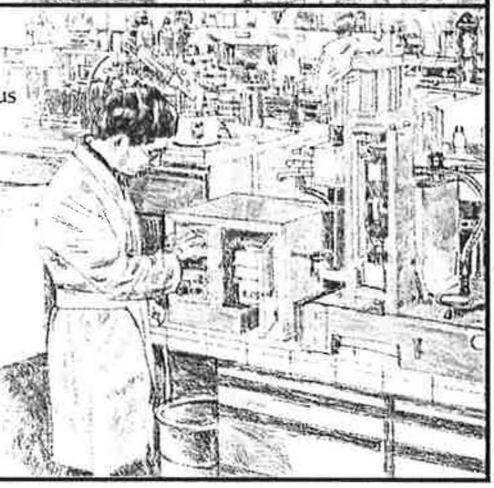
Problem: Lack of natural ventilation through infiltration as buildings become better insulated. Windows cannot be opened.
Solution: Central inlet and extract system with ductwork to all floors. Consider using combined heat exchanger/heat pump with the system.

Disco

Problem: Over-heating because of the activity of many people in a small space. Smoky atmosphere.
Solution: Central inlet plant with roof unit extract. Consider the use of an electrostatic filter to remove smoke.

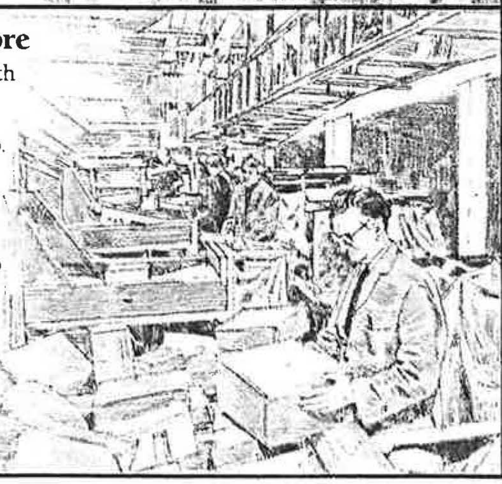
Laboratory

Problem: Noxious odours and dangerous fumes.
Solution: Fume cupboard with specially coated extract fan. The fan's motor is outside the path of the fumes.



Basement Store

Problem: Space with limited access to outside and the possibility of damp.
Solution: Ducted system to nearest outside location. Consider the use of dehumidification to minimise damp.



For expert help and advice about any of your ventilation needs contact the Heat Pump and Air Conditioning Bureau, or the Industrial or Commercial Sales Engineer at your local Electricity Board.

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