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7.4 Humidifiers

The amount of moisture in a given volume of air is most often stated in terms of its relative humidity (RH). This is a measure of how much water vapour there is in the air sample compared to its saturated state. Completely dry air would have a relative humidity of 0% . Air which is saturated would have a relative humidity of 100%. For human comfort the relative humidity of the air in a room should be between 40 and 70% RH. If the air is below 40% RH the air will feel dry and lead to discomfort through dry eyes and throats. It is also known that the risk of static shocks and problems with VDU screens increases in dry atmospheres. Relative humidities above 70% result in discomfort due to clamminess and overheating. This is because the body's normal mechanism for cooling itself down, sweating, cannot operate effectively in a humid environment. Prolonged relative humidities above 80% can lead to mould growth in buildings.

In addition to human comfort, some industries require stable relative humidities for the production and storage of materials without degradation. Examples are the high relative humidities required in the textile industry, typically 65% in wool processing and 75% RH in cottons, to avoid problems such as electrostatic build up and yarns breaking. 50-55%RH is required in the print industry to prevent sheet papers curling and breaks in newspaper webs. At the other end of the scale, low relative humidities are required by some industries such as in car panel manufacture to avoid corrosion.

Low relative humidities occur when cold outside air is brought into the building and is heated. For example the relative humidity of outside air at 0°C and 90%RH drops to 23%RH when heated to 20°C. The problems associated with this can be overcome by adding moisture to the airstream (humidifying it). High relative humidities occur when warm summertime air is cooled or in spaces with open bodies of water such as swimming pools. Problems associated with high relative humidities can be avoided by removing moisture from the airstream (dehumidifying it). Dehumidification is discussed in the next section.

This section will discuss methods for humidifying a space. Humidification systems are categorised by the way they deliver water vapour to the air in a room. The two categories are direct and indirect humidification.

Direct humidification is used in industrial situations and involves adding moisture directly into the air of the room in which humidification is required.
Indirect humidification is used in buildings with central air conditioning systems. The air is humidified within the air handling unit and is then delivered to the room using ducting.

There are two general methods of humidification. These are; wet humidification and steam humidification.

WET HUMIDIFIERS

Wet humidifiers work by encouraging liquid water to evaporate. This creates water vapour which mixes with the airstream to humidify it. For the water to evaporate it must absorb heat from its surroundings. As a result wet humidifiers cause the airstream temperature to fall during the humidification process. To overcome this problem, in air handling units, a pre heater initially warms the incoming airstream. The warmed air then passes through the humidifier but becomes cooled in the humidification process. The air must then pass through a reheat coil to bring the airstream up to the required temperature.

Wet humidifiers can take a number of different forms. The common feature of each is that they all aim to increase the surface area of water over which evaporation can take place.

Air washers are used mostly in industrial humidification. As the name implies they provide the dual function of humidifying the airstream and at the same time washing out some dust and odours. The airstream is made to flow smoothly by passing between baffle plates (figure 7.10), it then passes through a fine mist of water droplets created by a spray head. This provides the contact between the liquid water and the air necessary for evaporation to take place. Spray eliminators are placed downstream from the humidifier to prevent the carriage of liquid water further down the ducting.

Evaporation of the water cools the airstream, if this is desirable, further cooling can be obtained by using a

chilled water spray. During periods of warm weather the water in the sump may remain still for a long period. It is important that this water is treated to avoid bacteriological growth which could lead to infection of the building occupants. For example, Humidifier fever, an industrial disease with flue like symptoms, is commonly associated with humidifiers with reservoirs. However, care should be taken in the choice of biocide and that it is not carried by the airstream into the working environment.

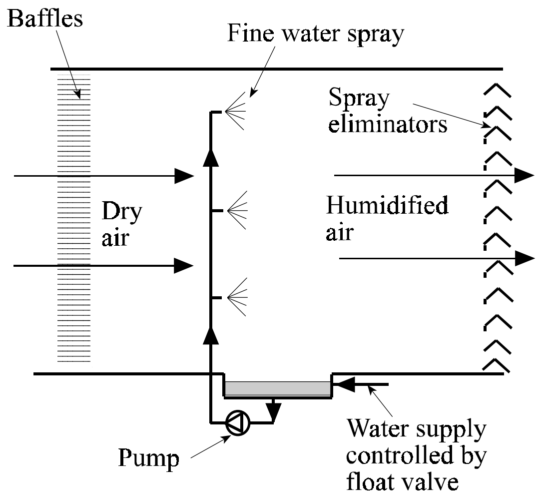

Figure 7.10 Air washer

Capillary washers are humidifiers with a better humidification effectiveness than the basic spray air washer. The greater effectiveness is obtained by directing the spray onto a matrix of metal, glass or plastic fibre cells (figure 7.11). The spray coats these cells resulting in further spreading out of the water due to capillary action. The airstream passes between the gaps in the cells and hence over the wetted surfaces. In this way close contact is obtained between the airstream and extended water surface. The airstream can be in the same direction as the spray or in the opposite direction to the spray, termed parallel and contra flow respectively.

Ultrasonic humidifiers create an extremely fine mist of water droplets by passing liquid water over a ceramic plate which is made to vibrate at ultrasonic frequencies using the piezoelectric effect (figure 7.12). The small droplet size results in quick and effective evaporation

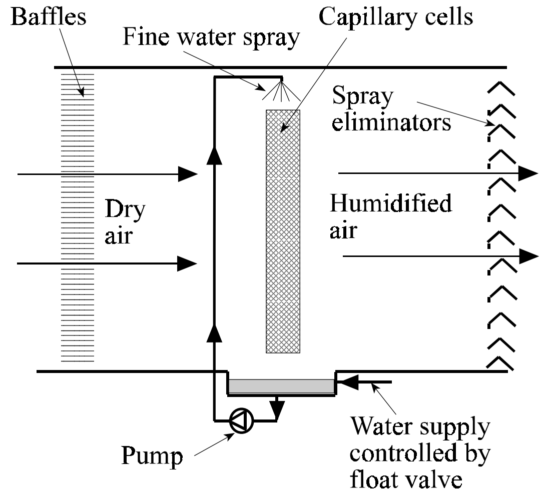

Figure 7.11 Capillary washer

of the water. The consequence is a rapid adjustment in relative humidity in response to a call for humidification from the controls. The excellent evaporation characteristics of the device make it very efficient in energy terms and ultrasonic humidifiers have an extremely low energy consumption for a given humidification load.

However, ultrasonic humidifiers must be supplied with demineralised water. This is to avoid scale build up which would otherwise lead to clogging.

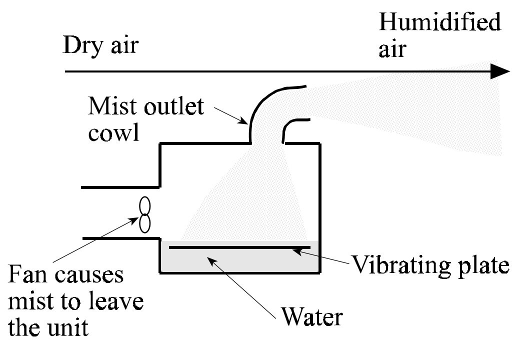

Figure 7.12 Ultrasonic humidifier

Atomising nozzle humidifiers produce a fine spray of cold water directly in the air or within air handling units. Droplet size is small so evaporation and hence

IP22 - PSYCHROMETRIC.CHART-USES

In information panel 21 the structure of the psychrometric chart was explained. The psychrometric chart is used to illustrate the relationships between the temperature and mosture content of air. The first of these is to show, graphically, the condition of air in a room. This is achieved by placing a point on the chart representing the state of the air. This point appears where the variables intersect. It can also be used to visualise the changes which take place following heating, cooling or humidification.This information panel gives an example of each of these uses. Firstly to determine a full set of variables describing the current condition of the air in a room and secondly to track changes in moisture content,temperature and relative humidity.

DETERMINING AIR CONDITIONS

The current condition of the air in a room can be illustrated on the chart if two of the four variables wet bulb temperature, dry bulb temperature, relative humidity or moisture content (wbt, dbt, RH or mc) are known. For example assume the wbt and dbt of outside air are 4°C and 5°C respectively. These values can be used as two coordinates to create a point (A) on the chart (see IP23). Having got this point the chart allows us to determine the other two variables i.e. RH and moisture content. They are found by tracking the point back to the relevant axis along the lines of constant value. In this case they are 85%RH and 0.0046kg/kg (4.6g/kg) respectively.

FOLLOWING CHANGES TO CONDITIONS

For illustration we can assume that the air described by point A on the psychrometric chart is outside air in winter.

A to B - Heating

If this air is used to ventilate a building either through infiltration or mechanical means it will come into contact with a heating appliance such as a radiator. This will raise its temperature to 21°C. As a result the condition of the air changes. This is illustrated by a move from point A to B on the chart. The most striking change is the fall in relative humidity from 85 to 29% RH. Note the relative humidity has changed but the moisture content is has not. It remains at 4.6 g/kg.

B to C - Addition of moisture

If the heated room air described by point B comes into contact with a source of water vapour such as human breath, a kettle boiling or a humidifier it will absorb moisture. If we assume 5.4 grammes of water vapour per kilogram of dry air are added, then the condition of the air changes from point B to C on the chart. Three variables have changed these are;wbt to 16.8°C, mc to 10.0g/kg and RH to 64%, the dbt stays the same at 21°C as no heat has been added or removed from the air.

C to D cooling

Now imagine that the air is cooled in some way. It may for example be cooled by an air conditioning unit or it may simply come into contact with a cold window. If the air is cooled by 7°C to 14°C then the condition of the air moves from point C to D. The most noticable change is that the RH has increased to 100%. The air is said to be saturated. The values of dbt and wbt are the same. The temperature at which this occurs is known as the dew point temperature as it is the temperature at which condensation is just starting to occur.

D to E Further Cooling and Condensation

If the air is cooled by a further 4°C the air condition cannot leave the boundaries of the chart and so runs down the saturation curve to point E. In practice this means that 2.5 grams of moisture per kilogram of dry air will be condensing on the cold surface. This is how condensation occurs on cold windows and is the basis of moisture removal from the air by heat pump dehumidification.

The structure of the chart is shown on page 96, the chart itself showing the above examples is on page 108.

humidification is rapid. Water is supplied directly from the mains, avoiding any contamination risk, and compressed air is used to create the spray. The small size of the atomising nozzle means that it can easily be blocked by mineral build up. To avoid this a needle built within the nozzle head periodically cleans the orifice automatically. When used in air handling units all of the spray released from the nozzle evaporates removing the need for water recirculation and chemical treatments. Atomising nozzle humidifiers provide close control of humidity at low running cost and with low maintenance requirements.

STEAM HUMIDIFIERS

Unlike wet humidifiers, steam humidifiers do not chill the airstream during the humidification process. This is because the moisture is delivered to the airstream already in the vapour state (as steam) having been created by a heating element.

Electrode-boiler humidifiers (figure 7.13) are the most widely used type of steam humidifier in direct and indirect humidification due to their low cost and ease of installation.

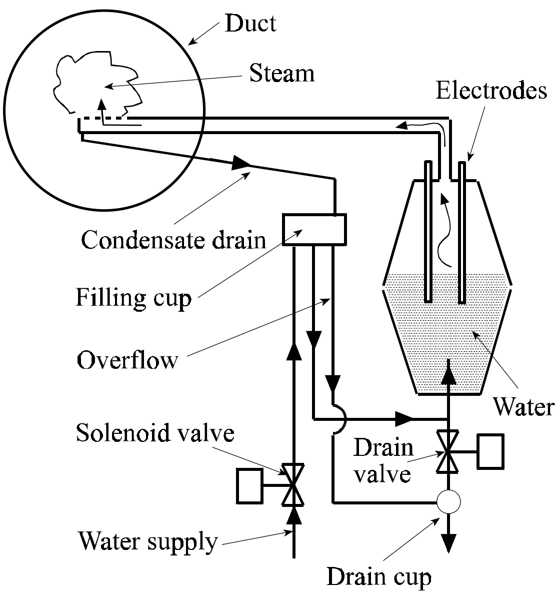

Figure 7.13 Electrode-boiler humidifier

The core element is a small boiler comprised of a non-conductive polypropylene tank fitted with three or more bare steel electrodes. When the tank is filled with water the electrodes become immersed. Electrical connections are made to the electrodes and current flows directly through the water causing it to heat up and boil. Output of the unit is controlled by varying the depth of water in the tank. Continual boiling of the water causes the concentration of minerals in the tank to build up. To avoid this there is an automatic cycle of emptying and re-filling the tank with fresh water. When the boiler eventually scales up it is simply replaced or opened and de scaled. The primary disadvantage of this system is high running costs and the need to regularly replace boilers.

Resistive element humidifiers (figure 7.14) are like small kettles boiling the water within them using an electric element. Regular drain and refill cycles prevent excessive scale build up. Switching off individual elements and modulating the power supply provides very close control of steam output, making them the preferred choice for close control applications.

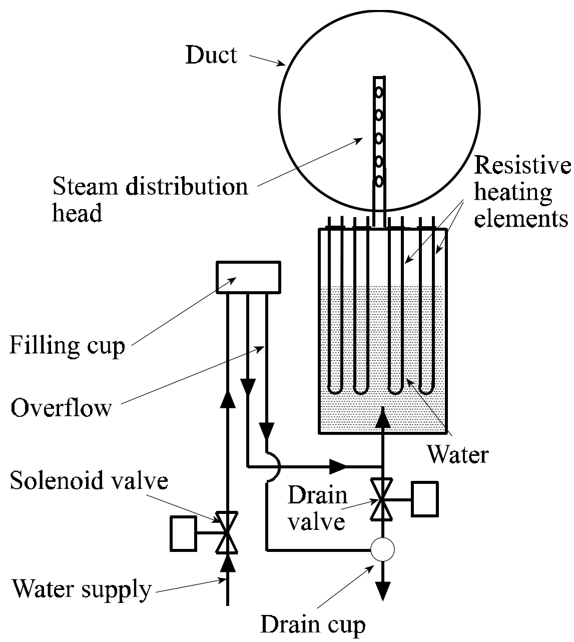

Figure 7.14 Resistive element humidifier

Gas-fired steam humidifiers use a gas heater to boil water and create steam. Gas is approximately four times


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cheaper per unit of energy than electricity. As a consequence the running costs of gas fired steam humidifiers are low, making them increasingly popular for humidification. Their structure is similar to the gas boilers described in section 1.2 except that the water is heated to boiling point by the burner.

7.5 Dehumidifiers

The relative humidity of a sample of air can be reduced using two principle techniques; cooling below the dew point temperature and chemical adsorption.

Dew point dehumidification. Humid air contains invisible water vapour. This only becomes visible when it changes back to liquid water. This phase change is achieved by cooling the humid air until condensation starts to occur. This is what happens when air in a room touches a cold window. It becomes chilled and condensation forms on the cold glass surface. However, this only happens if the glass is cold enough. The threshold temperature below which condensation occurs is called the dew point temperature (see IP22).

Dehumidification of air occurs in the same way. The air is made to pass over a cold coil in the air handling unit which is below the dew point temperature of the air. This causes some of the water vapour in the air to condense out onto the coil where it is drained away. In some dehumidification applications the condensate can be collected and re used. One example is in swimming pool dehumidification where the condensate is used to top up the pool to offset the use of some of the mains water which must be purchased.

Dehumidification by chilling is an energy intensive process since the air must be reheated to bring it back up to comfort temperatures. One way of achieving this efficiently is to use heat pump dehumidification. Both coils of the heat pump are placed in the ducting as shown in figure 7.15. The first coil the air meets is the evaporator coil. This is cold and removes water from the air by condensation. The air then passes over the condenser coil of the heat pump which re heats the air using energy which, in a simple cooling situation, would go to waste. Both sensible and latent heat are recovered in this process. This is discussed more fully in IP13 (page72). For manufacturer see page 104.

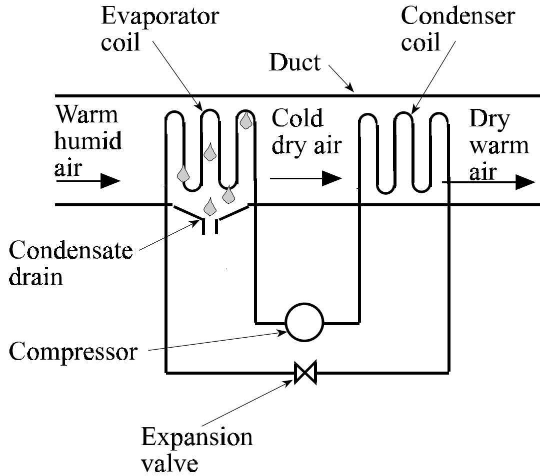

Figure 7.15 Heat pump dehumidification

Desiccant dehumidification involves the removal of water vapour from the air by chemical adsorption. The humid airstream (figure 7.16) is passed over a surface which is coated with a desiccant chemical such as silica gel. This removes water vapour from the airstream. The gel would quickly become saturated and unable to remove further water from the airstream. It must, therefore, be reactivated by heating. The desiccant chemical coats the tubes of a desiccant wheel. The lower part of this wheel absorbs moisture out of the airstream.

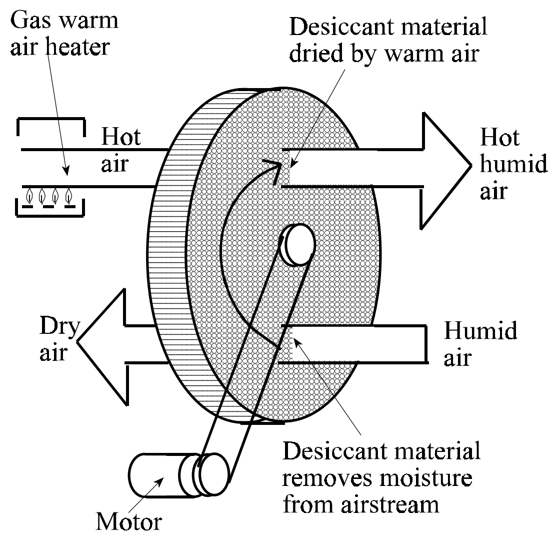

Figure 7.16 Desiccant dehumidifier


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This section then rotates into a new section of ducting where warm air drives off the moisture and re generates the wheel. The now dry section of wheel rotates back into the humid airstream to continue the drying process.

7.6 Diffusers

One of the most important aspects of air conditioning systems is the effective input of conditioned air into the room in which it is required. The following criteria must be satisfied;

- The air should enter quietly so that it does not create annoyance with respect to the ambient sound environment present in the room.

- The air should achieve effective distribution to all parts of the room and achieve adequate mixing so that no stagnant zones exist.

- The air should enter the room without directly impinging on the room occupants. This would cause uncomfortable physical and thermal sensations (draughts)

These three criteria can be achieved by the correct selection and positioning of room air diffusers. There are many forms of room air diffuser. Some of which are shown in figure 7.17. The differences provide a choice of air distribution pattern and flexibility for accommodating different applications. The following section describes some of the more common diffusers and uses a square ceiling diffuser to explain basic airflow concepts. Manufacturers (page 106) should be consulted for recommended arrangement and spacing of diffusers.

Square ceiling diffusers form part of a suspended ceiling system. To evenly distribute the air across the room they are positioned at the centres of a 3 to 4m square grid covering the space. Figure 7.18 shows how air enters the diffuser horizontally but is then deflected through 90^{o}, heading straight down towards the floor. This situation would be unacceptable since the airstream would hit any occupants standing beneath the diffuser. Draughts are avoided by using vanes within the unit to guide the airstream horizontally along the ceiling. This keeps the airstream out of the space in which the people work, known as the occupied zone. The occupied zone is considered to be any space in which occupants linger for a "significant" time. Physically it is a volume within the room with a height of 1.8m (comparable to a typical occupant) and bounded by a perimeter 0.15m from the walls.

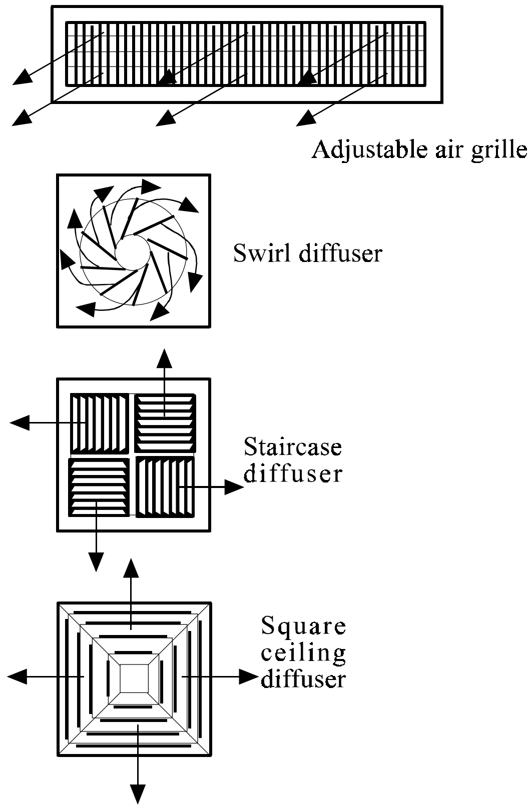

Figure 7.17 Four common types of diffuser

The airstream on leaving the diffuser moves along the underside of the suspended ceiling mixing with the room air as it does so by a process known as entrainment. The distance the airstream moves from the diffuser whilst maintaining a speed over 0.5m/s is known as its throw. The throw length is increased because the air leaving the diffuser experiences friction with the suspended ceiling. The result of this, known as the coanda effect, is to hold the airstream next to the ceiling. The distance covered before the airstream drops into the occupied zone is therefore increased. The texture of the underside of the ceiling and the presence of any projections can disrupt the throw of the diffuser.

I P 2 3 - P S Y C H R O M E T R I C . C H A R T - D I A G R A M

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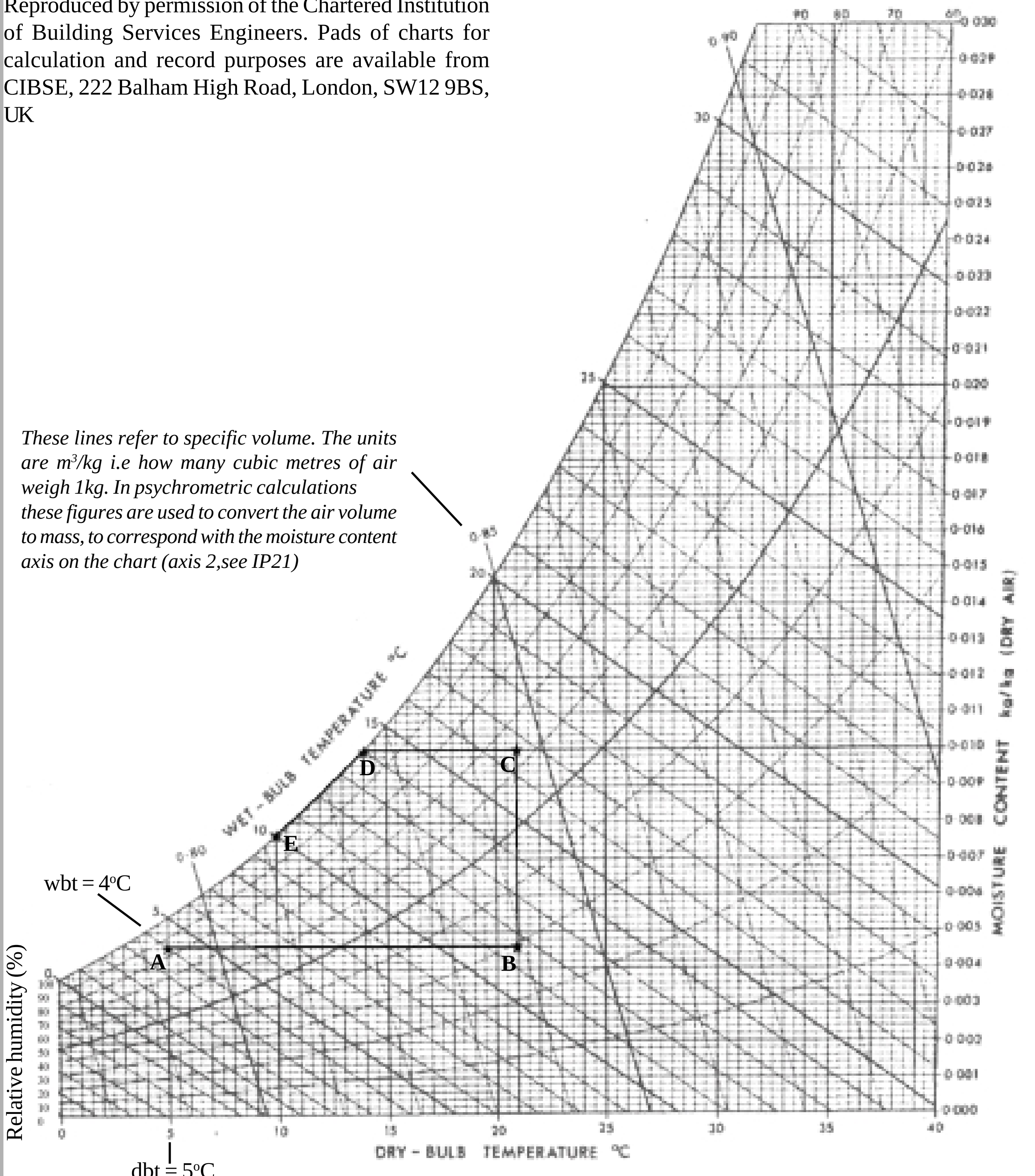


This is a shortened version of the psychrometric chart the actual CIBSE chart runs from -10 to 60°C dbt and gives information on enthalpy and specific volume.The structure of the chart is shown on page 96 and example of its use described on page 102

For example surface mounted luminaires projecting from the ceiling would cause the airstream to be deflected downward into the room.

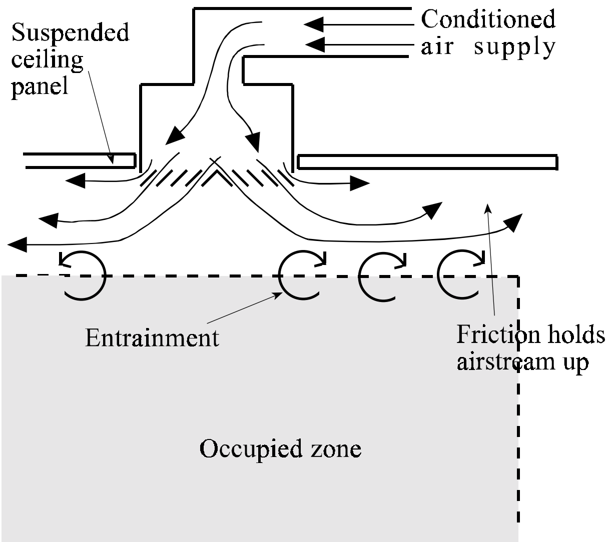


Figure 7.18 Suspended ceiling diffuser

When the airstream drops into the occupied zone its velocity should be no more than 0.25m/s in cooling/ summer mode or 0.15 m/s in winter. The former higher airspeed is considered acceptable in summer when its cooling effect is advantageous. However in winter this high airspeed would be felt as a draught so a lower speed is specified.

The airflow pattern from square suspended ceiling diffusers is in four directions perpendicular to each other. The airflow in any of the four output direction can be modified using additional adjustable vanes and dampers within the diffuser.

As well as being ceiling mounted, diffusers can also be mounted in walls or floors. A simple wall mounted diffuser located just below the ceiling would send a stream of air parallel to the ceiling into the room. The coanda effect would once again assist throw, air entrainment and avoidance of inappropriate air entering the occupied zone.

The operation of floor mounted diffusers requires careful consideration since they are within the occupied zone. The air velocity leaving the diffuser must be low, it is also beneficial if it is made to swirl. Both of these reduce the risk of discomfort as air enters the room. Adequacy of mixing with the existing room air is assisted by movement of the occupants and convection currents set up by temperature differences between the input supply air temperature and the temperature of the occupants and office equipment. The ultimate manifestation of this is displacement ventilation which is discussed in section 8.0.

It is not always possible to mount an array of diffusers across a space which is tall and has no suspended ceiling, although some installations do leave an array of ducting and diffusers exposed as a feature. The alternative is to use jet diffusers (figure 7.19). These devices produce a jet of air with a very long throw which is suitable for supplying air to large atria, halls, factories and leisure complexes such as swimming pools. They are constructed as a ball and socket and so are highly adjustable in terms of direction of throw.

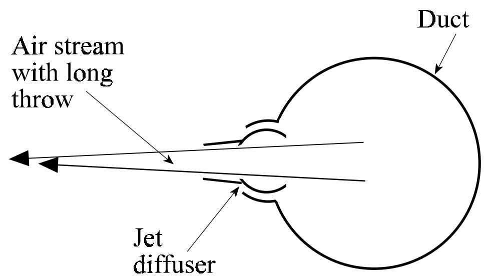


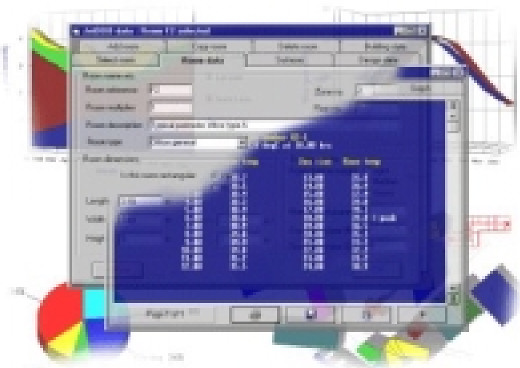
Figure 7.19 Jet diffuser

POSITIONING OF SUPPLY DIFFUSERS

Manufacturers will supply information on the best positioning of diffusers to obtain optimum performance. This information is available for individual diffusers based on experience obtained from actual installations and also laboratory testing using test rigs and room mock-ups. It has been found that the performance of diffusers depends on;

- dimensions of the room - any air stream entering a room horizontally say from within the ceiling will travel along it until it meets a projection or a vertical wall. When it does so it will be deflected downwards.

Mechanical & Electrical Software



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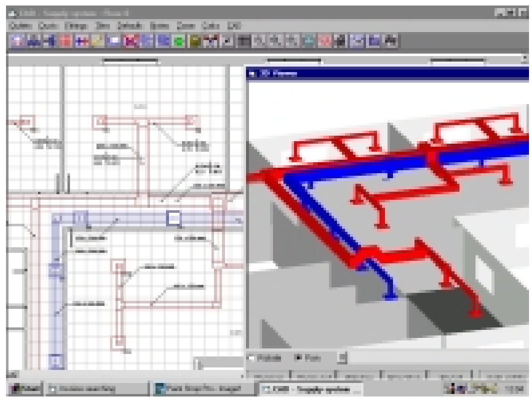
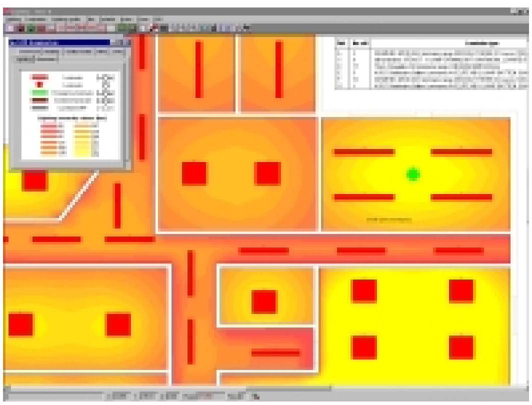


Load calculations such as heat loss, radiator sizing, heat gains (CIBSE, Carrier and ASHRAE), shadow analysis, heating and air conditioning energy, summer overheating, Room data can be set up automatically from an imported DXF CAD drawing or directly entered. Room selection for load calculations is either graphical from the drawing or by direct selection.



Systems can be sketched out schematically on screen, forming the data input to Hevacomp's pipe and duct sizing programs. This powerful graphical interface provides a simple and intuitive input method which enables systems to be defined faster and with less error. Systems can be sketched in plan or as an isometric.

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· texture of surfaces - The distance an airstream in contact with a surface travels depends on the friction experienced between it and the surface. Highly textured surfaces will increase friction and reduce throw.

· ambient temperatures - Strong sources of heat in a room such as office equipment will set up a strong upward convection current. These could disrupt design diffuser/room airflow patterns and should be considered if possible during the design.

· air velocities - the velocity of air entering a room through a diffuser has a major influence on the travel of the airstream. However the speed of air movement also effects the amount of noise produced at the diffuser. As a result in quiet office conditions air velocities must be limited to reduce noise levels. In noisy locations such as leisure complexes or atria velocities can be higher

· whether the system will be predominantly used for heating or cooling. - chilled air entered at high level into a room would descend downwards. Heated air would tend to remain at high level due to its buoyancy. The opposite effect would occur with low level entry of chilled or heated air. The diffusers should be positioned to take advantage of these natural air movements to assist room air diffusion.

· Spacing of diffusers - diffusers should be suitably spaced so that airstreams from adjacent diffusers do not interact. For example if two airstreams running along the underside of a ceiling were to hit head on the tendency would be to cause a downward current midway between the two diffusers.

Following careful design, fine tuning of the system can take place on site using the adjustment available within the system provided by integral dampers and guide vanes.

EXTRACT GRILLES

Systems incorporating a return air path require an extraction grille. The locations of these are less critical than supply diffusers since the air flowing into them is at room temperature and is at a lower velocity than the incoming air. It is therefore less likely to cause an uncomfortable thermal or physical sensation if this air passes by an occupant. However the extract grilles do work as part of the system and their positioning can be used to improve the effectiveness of the ventilation system. The following factors should be considered;

· Incoming air will be filtered and cleaned to avoid staining of surfaces near the supply diffuser. However, extract air will be carrying dust from the room this, over time, will cause some staining of finishes near the extract grille.

· If the location of sources of pollution such as photocopiers are known, then the exhaust grille should be positioned near to them. This will remove the pollutants from the room as they are produced. This also applies to heat pollution. A number of manufacturers produce extract luminaires which remove the heat given out by the lighting at source along with room extract air. Care must be taken if the ceiling void is used as an exhaust air plenum as the temperature of the suspended ceiling may increase. The effect of this is to increase thermal discomfort since the ceiling will act as a warm radiator. This is a particular problem in rooms with low ceiling heights.

· The exhaust terminal should not be close to a supply diffuser as this would short circuit the system causing supply air to leave the room without having had the opportunity to mix with the existing room air.

· For the ventilation system to work effectively it is important that all parts of the room benefit from the conditioned air entering it. If any stagnant zones exist such as in alcoves the extract grille could be positioned there to encourage air movement through these still areas.

7.7 Ducting

Ducting forms the distribution network for air based air conditioning systems. Their function is analogous to pipes in wet heating systems. However because of ventilation requirements and the low heat/cooling carrying capacity of air, ducting tends to have a relatively large cross sectional area. Because of this careful consideration must be made early in the building design stage to accommodate and integrate ducting runs into the structure and fabric of the building. This is espe-

cially so near the plant room where duct sizes are at their greatest.

Careful design of ducting systems is important as the way the ducting delivers air to the diffusers strongly influences the way air enters the room. The air should flow in a smooth manner as turbulence can change the air distribution characteristics of the diffusers.

The layout of the ducting dictates how much fan energy is needed to overcome resistance to airflow. Changes in the ducting such as 90 degree bends, size reductions and other components increase airflow resistance. Ducting runs should therefore be as simple and linear as possible (layout can be designed using software - see page 110). The fan must be sized to overcome air resistance in the ductwork and so duct design has important implications for fan size and energy use. Ducts carry heated or cooled air. Loss of this conditioned air from leaks in the distribution network results in wasted energy and lack of control. This also results from heat transfers through the walls of the ducts. To overcome this ducting joins should be well sealed and ducts insulated where temperature differentials between air in the ducting and ambient conditions dictate it.

Finally, ducting can be a source of noise in the rooms being served. The sources are transfer of noise and vibrations from the plant room and noise due to airflow in the ducts. A range of anti vibration mountings and acoustic isolation joints are available to prevent vibration transfer. Sound attenuators can be positioned in the ducting to absorb airborne noise. Air flowing through ducting and dampers creates noise in itself. To overcome this there are restrictions on maximum air velocities in ducting and dampers should be positioned as far away from the room air outlet as possible.

7.8 Dampers

Dampers are analogous to valves in a water distribution system. They vary the volume of air flowing through ducting by restricting or extending the open cross sectional area of the duct. They are constructed from an array of blades which rotate about their central axis like a louvred window system. The rotation is driven by motorised actuators (see section 1.6) in response to signals from the building energy management system. Accurate and reproducible positioning of the damper blades by the actuator is essential for close control of the air delivery system (page 112).

Dampers can be grouped under the following categories;

Butterfly dampers are the simplest form of damper, they are composed of a single blade which can be positioned either parallel or perpendicular to the airflow (figure 7.20). These two positions give maximum or minimum airflows respectively. Their small size means they are widely used in terminal units or small branch ducts. A disadvantage of butterfly dampers is that they create a very turbulent airflow which can result in noise within the ducting system.

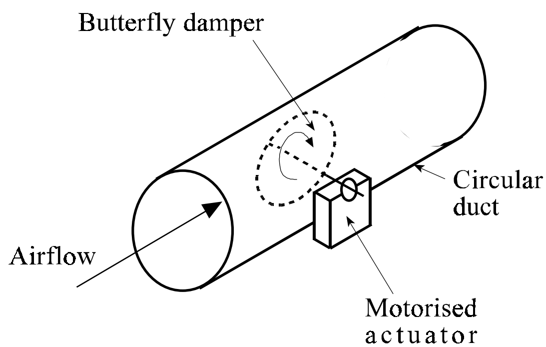

Figure 7.20 Butterfly damper

Multi blade dampers come in two patterns; opposed blade dampers (figure 7.21) and parallel blade dampers (figure 7.22).

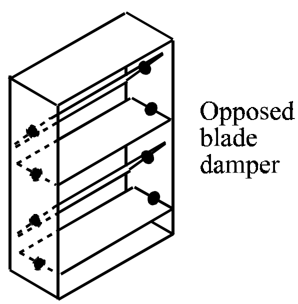

Figure 7.21 Opposed blade damper

NOTES

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These dampers regulate the air flow rate through themselves by rotating the blades. Ideally there will be a linear relationship between blade angle and airflow however, in practice linearity is seldom achieved. Operation of opposed blade dampers restricts the airflow but does not affect the airflow direction.

Parallel blade dampers do change the direction of the airflow since the blades are all rotated in the same direction. This effect is used to control the direction of airstreams leaving a diffuser. It can also be used to mix fresh and recirculated air within the air handling unit using two duct mounted dampers.

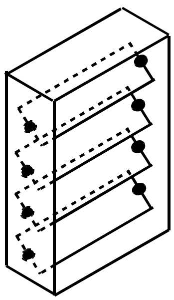


Figure 7.22 Parallel blade damper

FIRE DAMPERS

Fire and smoke can be spread through ducting from the source of a fire to other rooms unless it is prevented by the closure of fire dampers. Dampers can be made to close automatically in the event of a fire. The signal for the closure arises from the fire detection system. This may be linked into the building energy management system which can also shut down ventilation fans and/or operate smoke clearance fans.

Fire dampers can also be constructed from a single blade which falls into position across the duct, it does this when a fusible link burns out due to the high temperatures experienced in a fire. Finally, air transfer grilles painted with intumescent paint can be positioned across ducting. During a fire the intumescent paint expands to many times its normal volume and so closes the free area of the grille through which fire or smoke could spread.

7.9 Delivery Systems

Many modern office buildings with large glazed areas and heavy use of computers require year round cooling. However, the cooling load is unlikely to be the same in all parts of the building. Depending on equipment densities and orientation the cooling requirement will vary from area to area. Solar gains into south and west facing zones are a particular problem since they add considerably to the cooling loads caused by occupants, lighting and office equipment. There are three methods used by centralised air conditioning systems to heat or cool a space. The particular method used depends on the variation in heating/cooling load.

- If a large zone such as an open plan office requires cooling throughout the space then a single zone system can be used.

- Where the demand for cooling differs between spaces, control of individual temperatures is achieved by varying the amount of cooled air allowed to enter the room. This is achieved using a variable air volume (VAV) system.

- Where there is a need to control temperatures and at the same time maintain supply air volumes at a constant level then a dual duct system must be used.

Single zone system. A single air handling unit will, at a given time, supply air at one temperature only. If the building has an even demand for heating or cooling it can be treated as a single zone. Because of this the conditioned air will be delivered evenly throughout the space. If the cooling load should change, for example due to computer equipment being turned on, then the need for additional cooling will be dealt with by reducing the temperature of the air leaving the air handling unit.

If other large zones within the same building have different demands for heating and cooling then they must be treated individually. This is achieved by using additional air handling units and ducting. Each one supplying air at the temperature necessary to satisfy the zone it supplies.

Variations in demand on a smaller scale requiring room

by room control must be dealt with by changing the way the conditioned air enters the space. The methods are described below.

Variable air volume. This system is used in buildings which require cooling throughout but where individual spaces need different amounts of cooling. The system, shown in figure 7.24 and using symbols shown in figure 7.23, achieves room by room control of temperatures by varying the amount of chilled air allowed to enter the room. If the room is too warm more chilled air will be allowed to enter, if the room becomes too cool the amount of chilled air entering the room will be reduced.

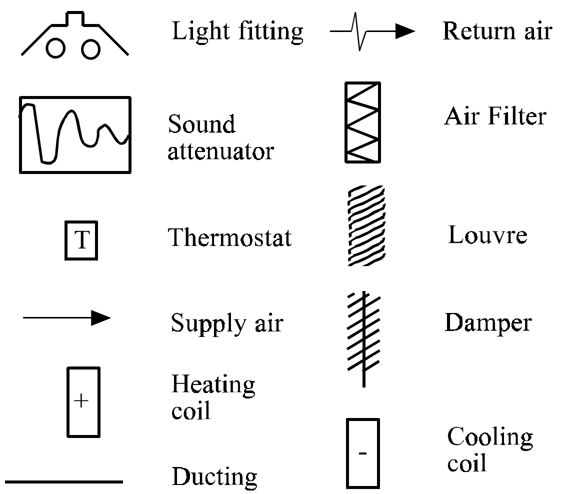


Figure 7.23 Symbols used in schematics

The central air handling unit supplies air sufficiently chilled to satisfy the maximum cooling load of the building. This is delivered to the rooms through units called variable air volume (VAV) terminals. VAV terminals (figure 7.25) control the amount of chilled air entering the room using a motorised damper. The position of this damper is determined in response to temperatures measured by a room thermostat. Depending on the room temperature the VAV terminal can vary airflow rates between zero and full flow.

An example of the control strategy begins with chilled air entering the room. This will mix with the existing room air and cause the room temperature to drop. The fall in room temperature will be detected by the room thermostat. This information is noted by the BEMS or a dedicated VAV controller which in turn will send a signal to the actuators controlling the damper position in the VAV terminal. The damper will close reducing the volume of chilled air being allowed into the room.

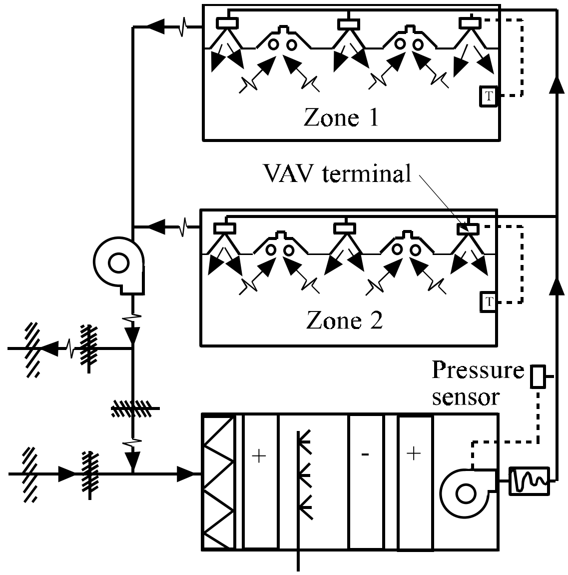


Figure 7.24 VAV air conditioning system

As the VAV dampers close the airflow from the air handling unit will be restricted and so the pressure in the ducting will rise. This is sensed using a supply duct pressure sensor which reduces the speed of the supply fan to maintain a constant pressure. In this way the fan matches the supply of air to demand.

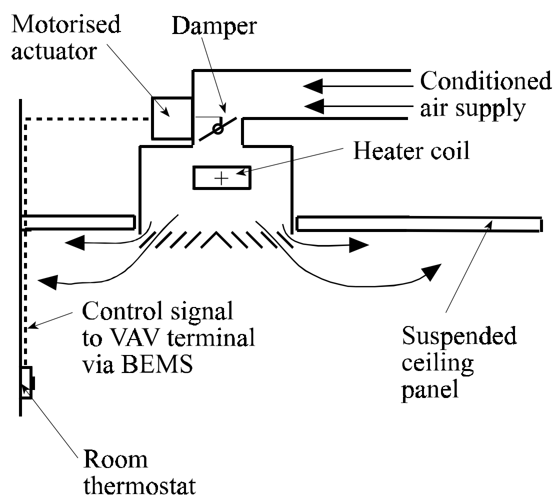
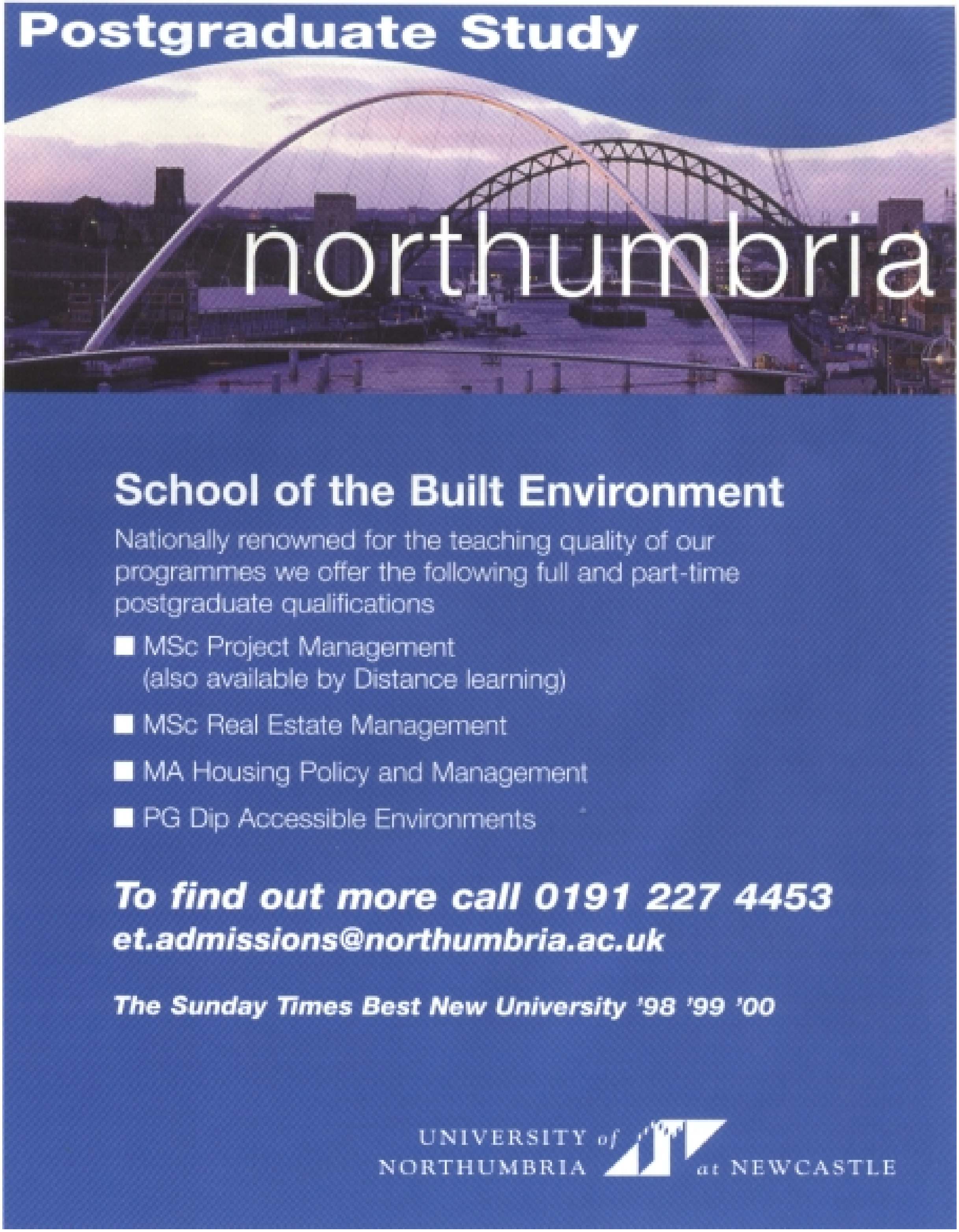


Figure 7.25 Variable air volume (VAV) terminal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If there is a need for some heating of rooms or spaces alongside the cooling system then VAV units fitted with electric heaters are used to heat up the chilled air as it leaves the unit. One application of these devices might be at the perimeter of large open plan offices where heat losses from perimeter glazing could create a local demand for heating.

Dual duct system. From the description of the VAV system above it can be seen that the volume of air entering the room varies with the demand for cooling. In some cases it is necessary to maintain a constant ventilation rate but retain close control of temperatures. This can be achieved using a constant volume system also known as a dual duct system.

The dual duct system requires two air handling units or a single air handling unit which is able to produce both chilled air and heated air at the same time (figure 7.26). Two sets of ducting are required to deliver both of these airstreams to mixing units in the rooms (figure 7.27).

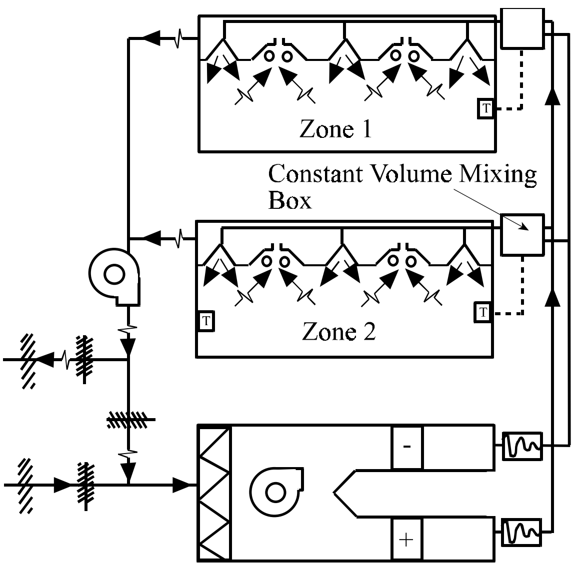


Figure 7.26 Dual duct air conditioning system

Room temperatures are controlled by varying the temperature of air entering the space by mixing the hot and cold airstreams. If cooling is required the motorised damper will allow more chilled air into the room. If heating is required the mixing box will respond to the room temperature sensor and control signals by allowing more heated air into the space. It can be seen that the system ensures that a constant volume of air always enters the space although the proportions of hot and cold air that make up this constant volume may vary. Controlling temperatures by mixing hot and cold airstreams is not a very energy efficient technique. The system does however give good delivery of ventilation and close control of temperatures.

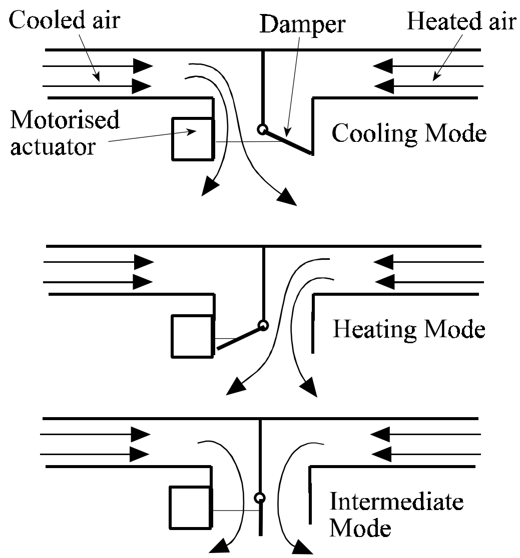


Figure 7.27 Dual duct mixing box

8.0 Partially Centralised Air/Water Systems

One of the disadvantages of centralised air conditioning systems is that the ducts needed to deliver heating or cooling to the spaces are much larger than if ventilation only were supplied to the space. This makes them difficult to accommodate within the structure especially if it is upgrading or retrofit work in an existing building. Partially centralised systems (figure 8.1) use reduced duct sizes because they only deliver enough filtered and tempered air to the rooms to satisfy the ventilation requirements. The heating or cooling demand is satisfied using room based devices. There are two types of room units, fan coil units and induction units both of which are supplied with heated water and/or

chilled water from boilers and chillers situated in the plant room.

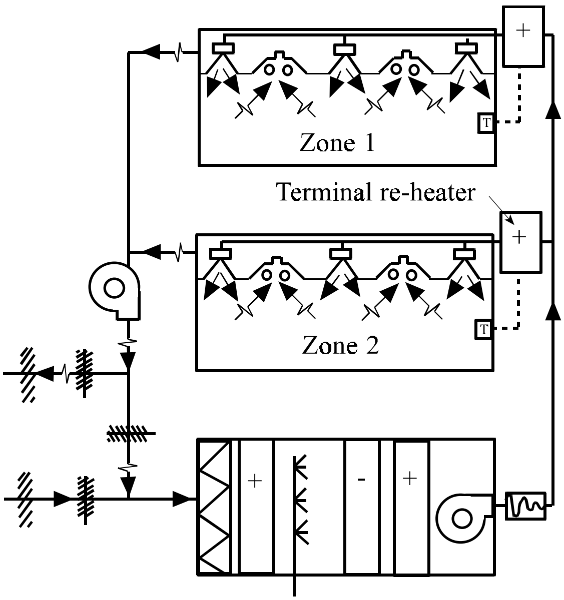


Figure 8.1 Partially centralised air/water system

Terminal units. Figure 8.2 shows a room based four pipe induction unit. Tempered ventilation air enters the unit at a relatively high speed. This incoming air drags or induces room air to also enter the unit. The mixed supply and room air then passes over a hot coil or a cold coil depending on whether there is a demand for heating or cooling. The conditioned air enters the room through an upper grille. Some units are two pipe units having a single coil. Heated or chilled water is sent through this coil as required.

Fan coil units are fitted with heating and cooling coils like the induction units but the air movement through them and mixing of supply and room air is generated using a fan and not the momentum of the air.

Displacement ventilation is a partially centralised air conditioning system which is increasingly being used in the UK (figure 8.3). In this system air is input to the room at very low velocity using raised floor terminals or low level wall terminals. The incoming air is at 18°C which is a relatively high temperature when compared to all air systems. The low airspeed and high temperature are necessary to avoid discomfort since the air is input directly into the occupied zone.

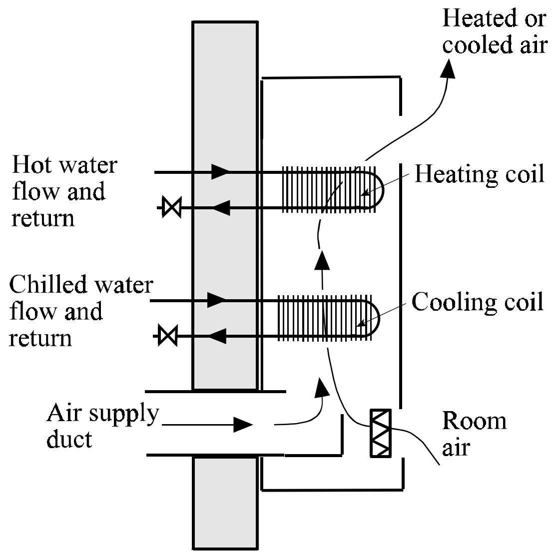


Figure 8.2 Four pipe terminal unit (induction)

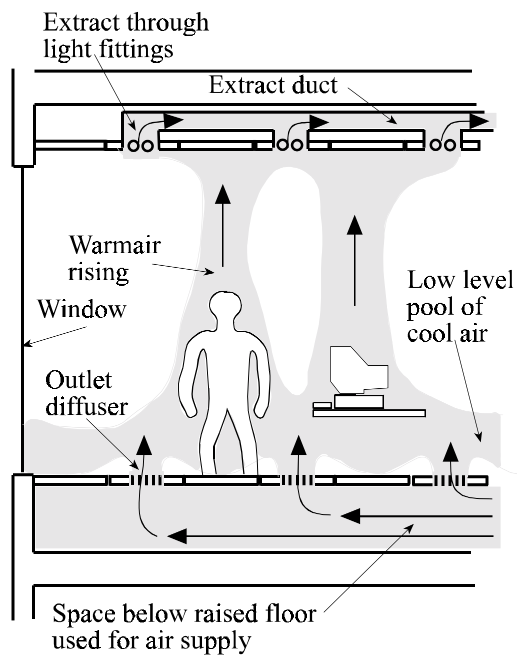


Figure 8.3 Displacement ventilation and chilled ceiling system

The supply air being cooler than the existing room air, pools in a layer along the floor. The presence of any sources of heat such as occupants bodies, office electronic equipment or pools of sunlight on the office floor will heat this pool of air causing an upward convection current to develop at the site of the source of heat. As a result fresh cool air is automatically brought to the heat source. Heat sources usually coincide with a source of pollution also. Occupants for example give out heat, metabolic CO_2 and odours. The rising warm, stale air from these sources is extracted at high level.

Because of the relatively high input air temperature displacement ventilation cannot satisfy very high cooling loads and so it is often used in conjunction with a chilled ceiling or chilled beam cooling system.

Chilled ceilings (figure 8.4) are composed of an array of purpose built suspended ceiling panels. The panels are of a standard size and made out of perforated aluminium sheet. A coil of copper pipe is fixed, in close contact, to the back of this panel. When chilled water is circulated through this pipe the ceiling panel becomes chilled. As a result any air in contact with the ceiling will become cooled and descend into the room. The room occupants will also feel cooler because their bodies will radiate heat to the chilled ceiling making them feel cool. This is the opposite effect to being stood next to a hot radiator.

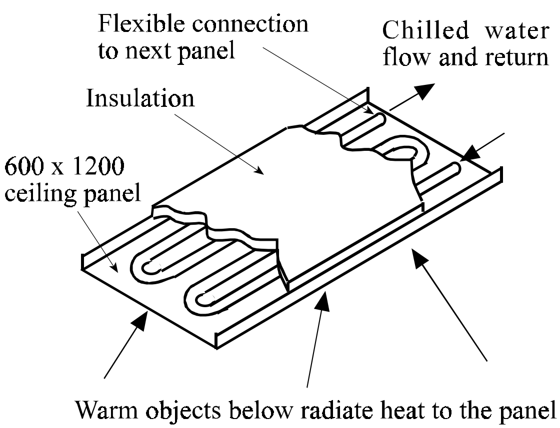


Figure 8.4 Chilled ceiling panel

There is a risk that condensation will form on the chilled ceiling. To avoid this the chilled ceiling control system must monitor humidity levels within the space. If the humidity levels indicate a risk of condensation occurring then either the incoming air must be dehumidified or the chilled ceiling surface temperature must be raised.

Chilled beams can also be used in conjunction with displacement ventilation. A passive chilled beam is shown in figure 8.5 and page 122. It can be seen that the chilled surface is formed into a linear finned coil, this coil is then surrounded by a pressed steel casing and is suspended from the ceiling. Warm room air rises to the ceiling and enters the top of the beam . It is then cooled by contact with the cold coil. The cool air descends into the room through outlet slots on the underside of the beam. It can be seen that chilled beams cool a room entirely by convection.

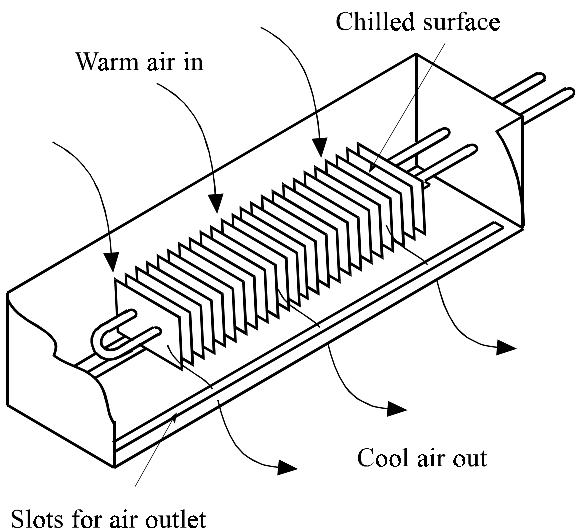
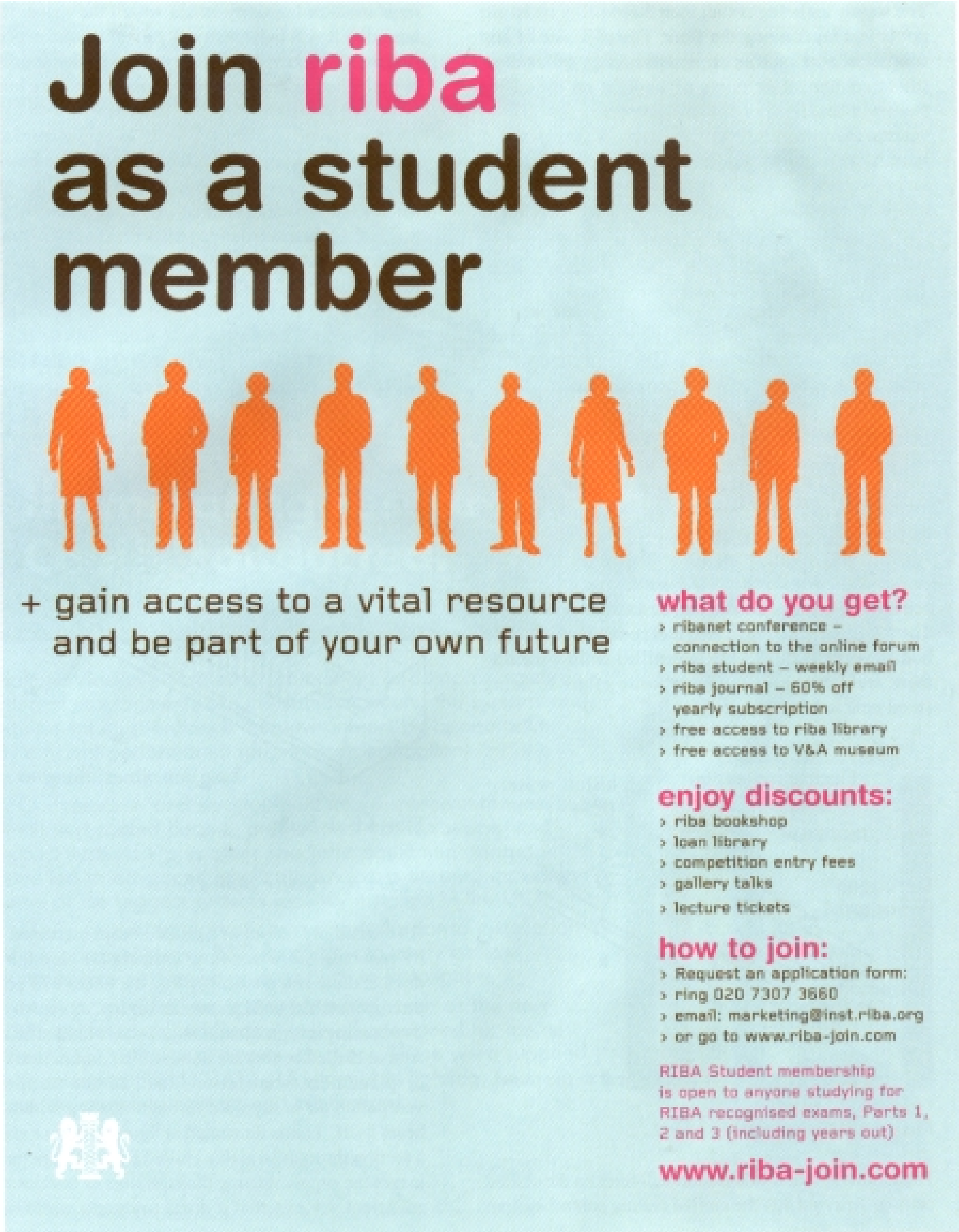


Figure 8.5 Passive chilled beam

As the cooling output of a chilled beam increases, say by reducing the water flow temperature through the device, there is a possibility that the beam will create uncomfortable cold down draughts. One way of overcoming this problem is to use active chilled beams. Active chilled beams are not used in conjunction with displacement ventilation, instead the tempered ventilation air is supplied through ducting within the beam itself. This is illustrated in figure 8.6 which shows a section through an active chilled beam. Tempered air leaves the supply ducting through slots or nozzles with sufficient velocity that it drags (induces) warm room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air into the beam and through the cooling coil reducing its temperature. The supply and chilled room air mix and enter the room via outlet slots on the underside of the beam. The velocity with which the air leaves the inclined slots is sufficiently high to project it horizontally into the room above the occupied space. In this way cooler airstreams can be used without creating a cold draught in the occupied zone.

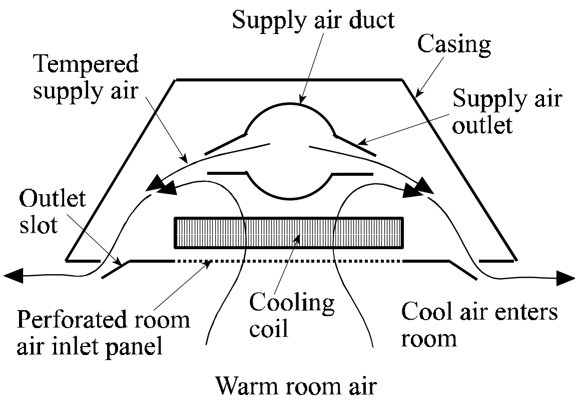

Figure 8.6 Active chilled beam

Chilled ceilings and beams are a low maintenance method of cooling a room. There are no internal fans or filters that could break down or need cleaning. The fin spacing on chilled beams means that dust build up can be largely ignored.

Energy issues. One of the benefits of systems incorporating chilled ceilings or chilled beams with displacement ventilation or active chilled beams alone is that they are an energy efficient method of cooling. This arises due to the operating parameters of the system. The first is the low fan speed used to deliver air to the outlet diffusers. Information panel IP11 explains how reducing the fan speed gives considerable reductions in fan motor energy consumption. Secondly, the chilled ceiling and beams operate at a relatively high chilled water flow temperature. This means that the chiller has to do less work and therefore will consume less electricity. The coefficient of performance of the chiller is also improved by approximately 20% due to the higher evaporator temperature(see information panel IP20, page 94).

In addition, the high operating temperatures allow the use of free and natural cooling. On the air side, if the outside air is sufficiently cool, it can be brought into the building as the supply. Since it does not have to be tempered by chillers it is known as free cooling. On the water side, it is possible to achieve the flow temperatures required using evaporative cooling. This is when water is chilled by natural evaporation in a cooling tower (page 97) and is used to supply the chilled beam or ceiling.

Q U E S T I O N S

INDIRECT.HEATING

1. **Which of the following is not a function of pipe insulation?**
- ☐ Preventing heat loss from hot pipes
- ☐ Protecting the pipe from impacts
- ☐ Preventing heat gain by cold pipes
- ☐ Preventing condensation on cold pipes

2. **Which of the following is not related to indirect heating**
- ☐ Single flue
- ☐ Heats one room only
- ☐ Single fuel supply
- ☐ Centralised control

3. **Which of the following is not related to direct heating?**
- ☐ Stand alone heaters.
- ☐ Complex control of many rooms.
- ☐ Individual fuel supply to each heat emitter.
- ☐ Heat distribution using water as a medium

4. **Which of the following categories of heating system considerations involves avoiding the release of asphyxiant gasses?**
- ☐ Economics
- ☐ Comfort
- ☐ Environment
- ☐ Safety

5. **What would be the boiler power needed for a typical detached house?**
- ☐ 5 kW
- ☐ 10 kW
- ☐ 15 kW
- ☐ 20 kW

6. **Which of the following devices prevents unburnt gas building up in a boiler?**
- ☐ Flame failure device
- ☐ Pilot light
- ☐ Boiler thermostat
- ☐ Heat exchanger

7. **Which of the following is not an effect of acid rain?**
- ☐ Atmospheric warming
- ☐ Leaf damage
- ☐ Damage of freshwater life
- ☐ Erosion of statues

8. **Which of the following prevents a reversal of flue gasses through the boiler on windy days?**
- ☐ Fan dilution
- ☐ Flue terminal
- ☐ Ventilation openings
- ☐ Draught diverter

9. **When the load on a gas boiler decreases the efficiency**
- ☐ Increases
- ☐ Stays the same
- ☐ Decreases
- ☐ Becomes unstable

10. **Which of the following does not help maximise CHP running hours?**
- ☐ Sizing of heat output to match base loads
- ☐ Export electricity meters
- ☐ Installing the CHP as lead heat source
- ☐ Routine maintenance

11. **What is the efficiency of a typical 3kW pump motor?**
- ☐ 61%
- ☐ 71%
- ☐ 81%
- ☐ 91%

12. **Which of the following radiators would give the highest heat ouput for a given area?**
- ☐ Double panel
- ☐ Double convector
- ☐ Single panel
- ☐ Single convector

13. When a person is near, but not touching, a cold window they experience

- ☐ Radiant heat losses
- ☐ Convective heat gains
- ☐ Conductive heat losses
- ☐ Evaporative heat losses

14. Which of the following is usually only encountered in commercial buildings?

- ☐ Combi boilers
- ☐ Water to water plate heat exchangers
- ☐ Indirect cylinders
- ☐ Gas fired water heaters

15. When a substance absorbs sensible heat it

- ☐ Changes from a solid to a liquid
- ☐ Increases in temperature
- ☐ Changes from a liquid to a gas
- ☐ Decreases in temperature

16. What percentage of total floor area is taken up by services in a speculative air-conditioned office?

- ☐ 4 - 5%
- ☐ 6 - 9%
- ☐ 10 - 15%
- ☐ 15 - 30%

17. Which of the following gives room by room control of temperatures?

- ☐ Boiler thermostat
- ☐ Thermostatic radiator valves
- ☐ Zone thermostat
- ☐ dhw cylinder thermostat

18. Decreasing boiler flow temperatures as outside air temperatures increase is known as

- ☐ Compensation
- ☐ Boiler step control
- ☐ Optimisation
- ☐ Boiler cycling

19. Which of the following may not require its heating system to be zoned?

- ☐ A large cellular office building with south facing glazing
- ☐ A small open plan office
- ☐ A school holding night classes
- ☐ An office building with a computer suite

20. Which of the following devices opens and closes valves?

- ☐ Outstations
- ☐ Actuators
- ☐ Sensors
- ☐ Supervisor

21. Which of the following is not a function of a BEMS

- ☐ Optimum start/stop timing
- ☐ Adjustment of set points
- ☐ Fault reporting
- ☐ Making the tea

22. Which of the following valves is used to isolate faulty components?

- ☐ Globe valve
- ☐ Three port valve
- ☐ Two port valve
- ☐ Butterfly valve

23. What is the typical temperature range of MTHW?

- ☐ 35 - 70°C
- ☐ 70 - 100°C
- ☐ 100 - 120°C
- ☐ 120 - 150°C

24. For the same amount of heat transfer air ducts are

- ☐ Smaller than steam pipes
- ☐ Smaller than hot water pipes
- ☐ The same size as steam and hot water pipes
- ☐ Bigger than steam and hot water pipes

D I R E C T . H E A T I N G

1. **Which of the following heat transfer methods does not require a transfer medium?**
- ☐ Conduction
- ☐ Mass transfer
- ☐ Convection
- ☐ Radiation

2. **How is the heat output of a fan assisted electric storage heater regulated?**
- ☐ By switching the fan on and off as required
- ☐ By having no insulation in the casing
- ☐ By turning the heating current on and off
- ☐ By closing the damper whilst the fan is running

3. **Commercial warm air cabinet heaters should not be used when**
- ☐ The space to be heated is draughty
- ☐ The space to be heated is not draughty
- ☐ People are working in the space
- ☐ Destratification fans are installed

4. **Which of the following does not apply to a roof mounted heating and ventilation direct heater**
- ☐ Can recirculate air in the space
- ☐ Can provide free cooling in summer
- ☐ Can assist in destratification
- ☐ Cannot supply fresh air

5. **Which of the following would be an inappropriate use for a high temperature radiant heater?**
- ☐ In rooms with low ceilings (<3m)
- ☐ In rooms with high ceilings (>3.5m)
- ☐ In draughty rooms
- ☐ Where spot heating is required

6. **What is the approximate operating efficiency of a direct fired water heater?**
- ☐ 70%
- ☐ 80%
- ☐ 90%
- ☐ 100%

V E N T I L A T I O N

1. **Which of the following is not a function of ventilation?**
- ☐ To raise the relative humidity
- ☐ To supply oxygen for breathing
- ☐ To dilute pollutants
- ☐ To remove unwanted heat

2. **The dilution of body odours from sedentiary occupants requires a ventilation rate of**
- ☐ 40 l/s
- ☐ 32 l/s
- ☐ 16 l/s
- ☐ 8 l/s

3. **Infiltration is**
- ☐ Ventilation using ducts
- ☐ Uncontrolled natural ventilation
- ☐ Fan driven ventilation
- ☐ Ventilation through a vertical tube

4. **A humidistat turns off the bathroom extract fan when**
- ☐ The light is switched off
- ☐ The room air moisture content is satisfactory
- ☐ The room goes cold
- ☐ Condensation forms on the windows

5. **Which of the following is least likely to need mechanical ventilation?**
- ☐ A room where the volume per person is <3.5m^3
- ☐ Deep plan rooms away from outside walls
- ☐ Shallow rooms with outside wall and windows
- ☐ Shallow room with sealed winows

6. **Which of the following involves the fanned supply and extract of air to rooms?**
- ☐ Balanced Ventilation
- ☐ Supply ventilation
- ☐ Extract ventilation
- ☐ Passive stack ventilation

7. **Which of the following fan types changes the direction of airflow by 90^o?**
- ☐ Axial flow fan
- ☐ Propeller fan
- ☐ Centrifugal fan
- ☐ Extract fan

8. Which of the following air to air heat recovery methods has no moving parts?

- ☐ Run around coils
- ☐ Thermal wheel
- ☐ Plate heat exchanger
- ☐ Heat pump

AIR-CONDITIONING

1. Which of the following rooms is least likely to need air conditioning?

- ☐ Office with large south facing windows
- ☐ Computer suite
- ☐ An operating theatre
- ☐ Domestic living room

2. Which of the components of a vapour compression chiller is used to reject heat extracted during cooling?

- ☐ Evaporator coil
- ☐ Compressor
- ☐ Expansion valve
- ☐ Condenser coil

3. Which of the following refrigerants is most destructive to the ozone layer if it escapes?

- ☐ R11 - CFC
- ☐ R22 - HCFC
- ☐ R134a - HFC
- ☐ Ammonia

4. What is the coefficient of performance (COP) of a typical heat pump?

- ☐ 2.0
- ☐ 1.0
- ☐ 4.0
- ☐ 3.0

5. A split air conditioning unit is so called because

- ☐ The refrigerant is divided by the expansion valve
- ☐ Chilled air output is bi-directional
- ☐ It has a seperate indoor and an outdoor unit
- ☐ It sits on the window sill, part inside and part outside

6. The indoor and outdoor units in a variable refrigerant flow system can be seperated by

- ☐ 100m including a vertical rise of 50m
- ☐ 100m including a vertical rise of 10m
- ☐ 50m including a vertical rise of 10m
- ☐ 50m with no vertical rise

7. At the heart of a centralised air-conditioning system is the

- ☐ Diffuser
- ☐ Filter
- ☐ Air handling unit
- ☐ Damper

8. Which of the following filters has the largest dust carrying capacity?

- ☐ Panel filters
- ☐ HEPA filters
- ☐ Bag filters
- ☐ Biological filter

9. The only type of filter which can remove gasses and odours is a

- ☐ Roll filter
- ☐ Electrostatic filter
- ☐ Pre-filter
- ☐ Activated carbon filter

10. An absorption chiller

- ☐ Has a COP higher than a vapour compression chiller
- ☐ Uses a gas burner or waste heat to drive it
- ☐ Uses HCFC's as a refrigerant
- ☐ Use electricity to drive a compressor

11. Which of the following does not apply to air cooled condensers

- ☐ Must have a stream of air flowing across it
- ☐ Requires a constant spray of water
- ☐ Is less efficient than an evaporative condenser
- ☐ Has the advantage of not requiring water

12. Legionnaires disease is associated with poorly maintained

- ☐ Window sill air conditioners
- ☐ Air cooled condensers
- ☐ Split air conditioning units
- ☐ Wet heat rejection equipment

13. For human comfort the relative humidity in a room should be in the range

- ☐ 10 - 20% RH
- ☐ 40 - 70% RH
- ☐ 20 - 40 % RH
- ☐ 70 - 90% RH

14. The most energy efficient wet humidification system is a

- ☐ Capillary washer
- ☐ Atomizing nozzle humidifier
- ☐ Air washers
- ☐ Ultrasonic humidifier

15. Steam humidifiers operate adiabatically. This means

- ☐ The air temperature decreases
- ☐ The air temperature stays the same
- ☐ The air pressure increases
- ☐ The air pressure decreases

16. Dehumidification by chilling is energy intensive. This is because

- ☐ The air must be cooled to 0°C
- ☐ The air must be heated to 100°C
- ☐ The air must be heated to dry it then re-cooled
- ☐ The air is cooled below dew point then re-heated

17. Which of the following statements regarding the entry of conditioned air into a room using diffusers is incorrect?

- ☐ The air should enter quietly
- ☐ The air should mix outside of the occupied zone
- ☐ The air should enter the occupied zone immediately
- ☐ The air should ventilate all parts of the room

18. The mechanism which increases the distance travelled by air leaving a suspended ceiling diffuser is called?

- ☐ The entrainment effect
- ☐ The throw effect
- ☐ The swirl effect
- ☐ The coanda effect

19. Which of the following locations is unsuitable for a room air extract grille

- ☐ Within a stagnant air zone
- ☐ Next to the supply diffuser
- ☐ Near a known source of pollution
- ☐ Where light dust staining of surfaces is acceptable

20. Which of the following does not increase duct airflow resistance

- ☐ Keeping ducting linear
- ☐ Bends
- ☐ Dampers
- ☐ Reducing the cross sectional area

21. Which type of damper is used to change the direction of airflow

- ☐ Butterfly damper
- ☐ Opposed blade damper
- ☐ Fire damper
- ☐ Parallel blade damper

22. Which centralised air conditioning delivery system offers room by room control of temperatures whilst maintaining ventilation

- ☐ Variable air volume (VAV) system
- ☐ Dual duct system
- ☐ Variable air volume incorporating electric heating
- ☐ Single zone system

23. In a displacement ventilation system

- ☐ Cool air is input from ceiling diffusers
- ☐ Cool air is input at low level
- ☐ Warm air is input at low level
- ☐ Warm air is input from ceiling diffusers

24. A chilled ceiling cools by

- ☐ Convection and thermal radiation
- ☐ Convection only
- ☐ Thermal radiation only
- ☐ Conduction

25. Active chilled beams differ from passive chilled beams in that

- ☐ They have inbuilt fans
- ☐ They supply ventilation alongside comfort cooling
- ☐ They cool by convection and thermal radiation
- ☐ They have a lower cooling capacity

E N E R G Y . E F F I C I E N C Y

The following questions relate to the information given on the keeping tabs on energy efficiency advice pages

1. Which of the following is not a recommendation for reducing lighting energy consumption?

- ☐ Lighting to appropriate levels but not more
- ☐ Use efficient electric lighting and provide good controls
- ☐ Leave lights on in classrooms at all times
- ☐ Make good use of daylight

2. Which of the following is not a method for reducing space heating energy consumption?

- ☐ Use night time ventilation
- ☐ Provide adequate building insulation
- ☐ Specify efficient space heating equipment
- ☐ Provide effective controls

3. Which of the following forms of energy produces the most carbon dioxide per kWh

- ☐ Solar energy
- ☐ Oil
- ☐ Gas
- ☐ Electricity

4. Energy use in buildings accounts for which of the following percentages of UK carbon dioxide output?

- ☐ 4%
- ☐ 40%
- ☐ 45%
- ☐ 54%

5. Which of the following building types is most likely to benefit from a CHP system?

- ☐ Factories
- ☐ Leisure centres with pools
- ☐ Houses
- ☐ Cinemas

6. Which of the following is not a consideration in holistic low energy design?

- ☐ Low cost forms of energy
- ☐ The building form
- ☐ The building services
- ☐ Post occupancy monitoring and targetting

7. The SAP rating of an energy efficient home is likely to be?

- ☐ Less than 10
- ☐ 40
- ☐ Under 80
- ☐ Over 80

8. When pressure tested for air leakage the target range for leakage in homes is

- ☐ less than 7.5 m^3/h
- ☐ 7.5 to 15 m^3/h
- ☐ 15 to 20.5 m^3/h
- ☐ 20.5 to 25 m^3/h

9. Which of the following is not a benefit of increased airtightness of buildings?

- ☐ Less discomfort due to draughts
- ☐ Reduced energy costs
- ☐ Reduced pump size
- ☐ Reduced heating plant size

10. Using larger ducts with slower air speeds reduces the energy consumption of mechanical ventilation systems by?

- ☐ 70%
- ☐ 50%
- ☐ 30%
- ☐ 10%

11. Which of the following is not an element in a passive cooling strategy?

- ☐ Reduce solar heat gains
- ☐ Use a vapour compression chiller
- ☐ Reduce equipment and lighting heat gains
- ☐ Leave structural mass exposed to the room air

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