8 Keeping tabs on energy efficiency

Passive cooling

Mechanical cooling systems use energy to modify the ambient air temperature. It is sound practice to minimise heat gains to buildings and to use the fabric and natural sources before resorting to mechanical means of cooling.

Avoiding unwanted heat gains

The main sources of heat are the sun, people, office equipment and lighting. These sources provide typical heat input rates to offices of 60, 10, 25 and 25 W/m^2 respectively.

The sun

The first consideration should be to reduce glazed areas on south and west façades. However, sufficient glazing should be retained to allow good daylighting. Special glazing and shading devices can be used to prevent heat from the sun entering the building.

Equipment

The use of energy-efficient equipment should be encouraged.

Lighting

Lamps convert electricity to light but they also produce heat. The more efficient the lamp the more light and less heat is produced. Lamps should therefore have as high an efficiency as possible. In addition, the lamps should only operate when required.

Passive cooling

The simplest form of passive cooling is to ventilate the building with fresh outside air. So long as the outside air temperature is lower than the internal temperature the introduction of outside air will have a cooling effect.

The most commonly used passive cooling system is to use exposed mass within the space. An example of this is to leave the concrete ceiling exposed. Heat contained in the room air is absorbed by the mass reducing the air temperature. The heat gained by the fabric must be purged during the night so that it can act as a passive cooling mechanism again the next day. This is achieved by ventilating at night-time with cool air.

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

5.0 Introduction

Air conditioning is the process by which the air in a space is modified to make it comfortable for the occupants. The primary function of air conditioning is cooling although all systems filter the air and some also provide heating and adjustments to the humidity levels.

Cooling is needed when the room air temperature rises above a comfort threshold of 27°C. Temperatures rise above this level due to a combination of high outside temperatures and internal heat gains. For example, in summer the outside air temperature may be 22°C or above. When this warm air enters the building its temperature will be further increased by heat gains from people, artificial lighting , appliances and the sun. Increases of 6°C due to these casual gains are not uncommon pushing the incoming air temperature above the comfort threshold. Even in winter when outside air temperatures are low, office buildings may experience sufficiently high casual heat gains that cooling is required.

Many of the situations previously described in section 4.2 as requiring mechanical ventilation also need a degree of air conditioning. To summarise, those situations most likely to require air conditioning are;

- Rooms subject to high solar gains, such as south facing rooms especially those with large areas of glazing

- Rooms with high equipment densities such as computer rooms and offices which make extensive use of IT

- Rooms in which environment (temperature, dust or humidity) sensitive work is being carried out such as operating theatres and microprocessor manufacturing units.

Air conditioning systems can be categorised into three main types;

Local comfort cooling systems - These systems cool the air in a room to bring its temperature down to acceptable levels. The cooling equipment is located in the room itself. The main forms of local comfort cooling system are;

- Window sill air conditioners
- Split systems
- Multi split systems
- Variable refrigerant flow split systems

Centralised air systems - All of the heating or cooling is carried out in a central air handling unit. Room by room control of temperatures is achieved using the following systems;

- Constant volume systems
- Variable air volume (VAV) systems
- Dual duct systems

Centralised air systems do not just provide heating or cooling but can filter, humidify or dehumidify the air as required. The central plant is usually in a ground floor plant room or may be a packaged unit situated on the rooftop.

Partially centralised air/water systems - A central air handling unit is used first to filter and then heat or cool an airstream. Final adjustment of temperatures is carried out using room based equipment. System types are;

- Terminal re heat or fan coil systems
- Induction systems
- Chilled ceilings and displacement ventilation

See IP16, page 80 for a basic system selection tree. All of the above systems and their components will be discussed more fully in later sections. The next section will

IP13-LATENT.HEAT.RECOVERY.USING.HEAT.PUMPS

Water based leisure complexes by their very nature have large areas of water exposed to the air. The pool water readily evaporates increasing the relative humidity of the atmosphere. This in turn leads to thermal discomfort (see IP5) and damage to the pool structure due to corrosion and condensation of liquid water on cold surfaces. Evaporation can be slightly suppressed by keeping pool hall temperatures two degrees higher than pool water temperatures i.e. 29 and 27°C respectively and by keeping pool side air relative humidity levels between 60 and 70% RH. Increased activity in the pool or the presence of features such as flumes will increase the evaporation rate.

> Evaporation of water from swimming pools creates a high relative humidity atmosphere which causes discomfort and damages the structure if left unchecked.

In the past problems were avoided by simply extracting the humid air out of the pool hall. This however, causes wastage of both energy and water. Energy wastage takes two forms firstly the sensible energy used to heat up the pool air and secondly the latent energy contained in the water vapour (see IP6). This latent energy is lost from the pool water itself during evaporation (approximately 0.7 kW per litre) and causes a reduction in temperature. If this energy cannot be recovered from moisture in the air, additional heat input from the boiler system will be required. It should therefore be a target of any design that latent energy should be recovered. Latent heat is released, and so can be recovered using a heat pump dehumidification system which condenses the water vapour back to a liquid.

An additional problem with pool hall air is that it contains chloramines. This is pollution, giving pools their characteristic odour, arising from the water treatment system and the bathers themselves. A fresh air supply is necessary to reduce the concentration of chloramines by dilution.

Water conservation is increasing in importance. Supplies are becoming more scarce resulting in shortages and rising prices. This has been brought about by increases in consumption and hotter summers created by global warming. It therefore follows that we can no longer be profligate in the use of water and that conservation is necessary. A heat pump dehumidification system can aid this by recovering up to 120 litres of water per hour from the extract air.

HEAT PUMP DEHUMIDIFICATION

Figure IP13 shows a schematic of a heat pump dehumidification system (also refer to section 7.5). The aim of this system is to extract warm humid air from the pool, remove sensible and latent heat from it and use this heat to re heat the pool water and the mix of fresh and dehumidified air supplied to the pool hall. Top up air heating is provided by a lphw heating coil supplied by gas boilers or a CHP unit (section 1.2.1).

Finally substantial savings in energy and reduced evaporation are achieved by using pool covers when the pool is not being used.

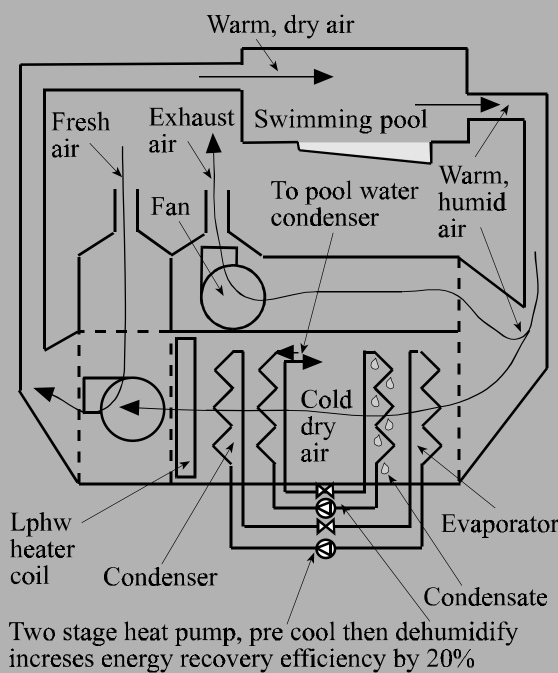

Figure IP13 Heat pump heat recovery ahu consider the cooling equipment on which all air conditioning systems are based.

5.1 Cooling

To warm air or water energy in the form of heat must be added to it. The converse is also true, to reduce the temperature of air or water energy must be removed from it. The system which is used by the majority of air conditioning systems is based on the vapour compression cycle. A less common system is absorption chilling (section 5.2)

It should be noted that the term "cooling" usually relates to the direct production of cold air whereas the term "chilling" relates to the production of cold water. This cold water is then circulated through the cooling coil of an air handling or fan coil unit to cool the airflow.

Vapour compression cycle. Most people have daily contact with cooling caused by the vapour compression cycle in the form of the domestic refrigerator. The refrigerator is a useful example to keep in mind whilst considering how the system works. Cooling systems used in buildings use the same principle but on a different scale. Figure 5.1 shows the components of a vapour compression chiller.

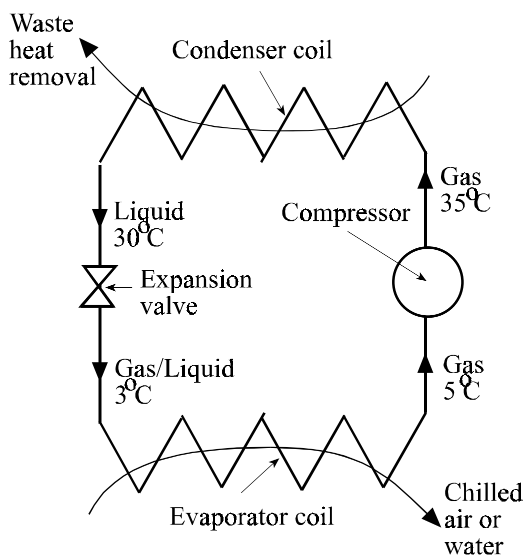

Figure 5.1 Vapour compression chiller

The main components are an evaporator coil, a compressor, a condenser coil, and an expansion device. These components are connected together using copper pipe through which refrigerant circulates in a closed loop. Cooling is achieved in the following way;

Liquid refrigerant is forced through the expansion valve. As the refrigerant leaves the expansion valve its pressure is reduced. This allows it to evaporate at a low temperature. For any liquid to evaporate it must absorb energy. The refrigerant evaporates by removing energy from the evaporator coil which in turn removes heat from the air which is flowing over it. Hence the air becomes cooled. The refrigerant, now in a vapour state, leaves the evaporator and passes through the compressor. The pressure is increased causing the refrigerant vapour to condense in the condenser coil. This occurs at a relatively high temperature. As the refrigerant condenses it releases the heat it absorbed during evaporation. This heats up the condenser coil. Air passing over the condenser coil takes away this waste heat.

In terms of a domestic refrigerator the evaporator would be situated in the ice compartment and the condenser is the grid of piping at the rear of the refrigerator which is warm to the touch. In building cooling systems significant amounts of waste heat are produced at the condenser and various techniques are used to safely remove it from the building. The method of heat rejection depends on the amount of waste heat produced and operational decisions such as the choice between using a dry system or a wet system. Air cooled condensers are discussed together with condensers utilising water in section 7.3.

The evaporator and condenser coils are simply arrays of copper pipe with aluminium fins mechanically bonded to their surface to increase the area for heat transfer. The following sections will consider refrigerants and compressors which are two of the more complex components of vapour compression chillers.

Refrigerants. Refrigerants are liquids that evaporate very easily at relatively low temperatures. Refrigerants are so volatile that if a liquid refrigerant was spilled in a room at normal temperatures it would very quickly dissapear by evaporation. Refrigerants must posses good thermodynamic properties but also have low toxicity and low flammability. Refrigerants are also the

IP14 - CAREFUL.USE.OF.REFRIGERANTS

It is estimated that 20% of refrigerant based systems will develop a leak resulting in a complete loss of refrigerant charge during their operational lifetime. Depending on the type of refrigerant the risks from this vary from fire and toxicity to global warming and ozone depletion. There are a number of methods of minimising or avoiding these problems. These include reducing the volume of refrigerant in the equipment, developing benign refrigerants, good practice including servicing, designing systems to avoid leaks and detection and rectification of leaks.

Some refrigerant gasses are known to damage the ozone layer. However, they can only do this if they are allowed to escape from the system.

REDUCTIONS IN REFRIGERANT CHARGE

If a leak occurs the amount of damage caused depends on the volume of refrigerant that has escaped. It follows therefore that if the volume of refrigerant used to charge the system can be reduced the effects of a total leak will be minimised. This can be achieved in a number of ways. The first method is to reduce dependance on refrigeration equipment. This can be achieved using passive cooling techniques. This may eliminate the need for refrigerants completely or reduce the size of the system required. The second involves chosing equipment that has a high efficiency. This means more cooling can be carried out with less refrigerant. Hydronic systems can be used where the chilled water is created in a local plantroom. This is then used in the building rather than use refrigerant pipework through the building which would increase the the number of refrigerant components through which a leak could occur.

LEAK DETECTION

Refrigerant leak detection takes two forms, visual and gas analysis. Visual systems require a fluorescent dye to be added to the refrigerant. If the refrigerant begins to leak out of the system say through a loose joint then this will be revealed under an ultra violet light as a glowing patch of dye. In this way the exact location of the leak can be pin pointed. Unfortunately the leak can only be detected if the system is inspected regularly. The second type of leak detection involves drawing a sample of air surrounding the refrigeration equipment into a gas analyser. The analyser will detect and warn of the presence of refrigerant in the air sample indicating that a leak was occuring. This system can be set up to continuously monitor a plant room for the signs of a leak. Pin pointing the leak would require a further inspection of the system using either a hand held detector or searching for the presence of escaped dyes as described above.

RECYCLING OF REFRIGERANTS

The production of a number of refrigerants has been banned under the Montreal Protocol and EU regulations. However existing stocks can still be used to service older equipment. It follows therefore that the refrigerant contained in systems about to be replaced has considerable value to existing users. It is illegal under the environmental protection act to release substances into the environment which are known to cause damage. Because of this all refrigerant should be removed from the system and stored before repair or decommissioning.

If the recovered refrigerant is of good quality it can be re used without further treatment. If the refrigerant is contaminated with oils, acids, moisture or particles then the refrigerant must be cleaned by filtration and distillation before being re-used. Heavily contaminated refrigerants must be reclaimed this requires that they are taken off site and purified to their original state.

A good network of refrigerant reclaimers and recyclers is important to manage refrigerants and deter the growing trade of smuggling illegal refrigerants into the country. See also IP15 - Refrigerants and the Environment.

subject of environmental concerns as described in IP14 and IP15.The evaporation and condensation of refrigerants in a chiller is controlled by lowering and increasing the pressure using the expansion valve and compressor respectively.

Compressors are electrically driven pumps of which there are three main types. These are; reciprocating, rotary and centrifugal compressors. Reciprocating compressors work by allowing refrigerant to flow into a chamber on the down stroke of a piston. The refrigerant is then forced out of this chamber towards the condenser as the piston moves upwards once more. Rotary compressors have two interlocked helical screws which when rotated move refrigerant which is trapped between the two screws along the line of the thread. Centrifugal compressors have a rotating impeller which forces the refrigerant outwards against the casing. This force is sufficiently strong to drive the refrigerant towards the condenser.

Compressors are further classified as either hermetic, semi hermetic or open depending on the seals between the motor and the compressor it drives. Hermetically sealed compressors have the motor and compressor together inside a shell whose seams are sealed by welded joints. Refrigerant is in contact with the motor and compressor. Semi hermetic compressors are similar but the joints are bolted rather than welded allowing servicing to take place. Open compressors have an external motor connected via a shaft to the pumping mechanism. A seal around the shaft stops refrigerant escaping.

The different forms of compressor are suitable for different cooling load ranges. Reciprocating up to 180kW, Rotary up to 2MW and centrifugal in the range 180kW to 3.5MW. Comfort cooling tends to be of a lower cooling capacity and so uses reciprocating compressors. Rotary and centrifugal compressors are used for large capacity centralised cooling systems.

5.1.1 Heat Pumps

Heat pumps are vapour compression systems, as described previously, but they are used for space heating rather than cooling.

It can be seen that what the vapour compression chiller is doing is extracting heat from a low temperature space and transferring it into an environment at a higher temperature. This is the basis of the heat pump (figure 5.2) which uses the vapour compression cycle to absorb heat from outside air and convert it to higher grade heat for indoor space heating.

The theoretical efficiency with which the heat pump carries out this function is very high at approximately 300%. This means for every 1kWh of electricity put into the compressor 3kWh of heat is obtained by the building. In practice however the operating efficiency tends to be lower. This is for two main reasons. The first is that the highest efficiencies are obtained when the inside and outside temperatures are similar. This is not the case in winter when heat pumps are required for space heating. The second cause of the fall off in efficiency occurs on cold winter days when the evaporator may become iced up due to low temperatures. This restricts heat transfer across the evaporator. This can be avoided by using an electrical heater on the outside coil to defrost it or to reverse the refrigerant flow direction. Both of which reduce the overall efficiency of the device.

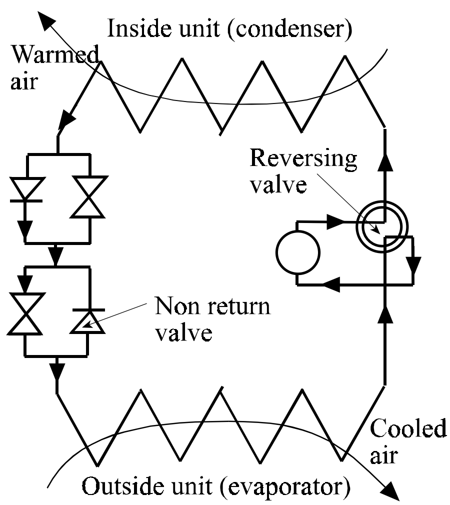

Figure 5.2 Reverse cycle heat pump in heating mode

Even with this reduction in efficiency the efficiency with which the unit uses electricity to provide heating is higher than simple resistive heating. The operating effi-

*GAS*Cool from GasForce

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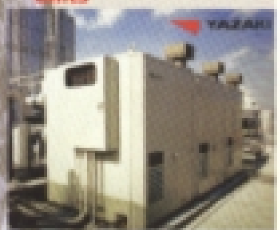
Gas & Hot Water-Fired Absorption Chilling

_GAS_Cool offers a wide range of high efficiency gas-fired absorption chiller and chiller/heaters providing comfort cooling to full air-conditioning. All _GAS_Cool chillers are CE approved and designed to be installed externally.

The Robur High Efficiency air-cooled chiller/heater range:

- Robur ACF 60.00 single air cooled chiller rated at 18kW.
- Robur AYF 60-108 single air cooled chiller/heater rated at 18kW cooling and 28kW heating.
- The Robur chiller or chiller/heater can be supplied in modular combinations, skid mounted on a steel base frame with all interconnecting gas/electrical and mechanical services, with options for control systems and chilled water pump.
- Robur ACF-60R single air-cooled low temperature chiller capable of suppling 11kW of chilled water at -10 degrees C, suitable for process applications and display cabinets in supermarket and mini-marts.

3 x Robur ACF.60.00 units



Yazaki CHV units

The Yazaki Gas-fired double-effect absorption chiller/heater range:

- Yazaki Aroace CHV range, comprising six individual models providing heating or cooling from the same unit. From 105kW - 352kW cooling and 126kW - 292kW heating.

The Yazaki Hot Water-powered absorption chiller units:

- The Yazaki Aroace WFC is available in two chilled water outputs 34.9kW and 115kW and is energised by hot water at 80-95 degrees C supplied by waste heat, solar collectors, district heating or cogeneration (CHP) systems.

Yazaki WFC 30 unit

THE _GAS_Cool SYSTEM IS AVAILABLE EXCLUSIVELY FROM GASFORCE THROUGH A NATIONWIDE NETWORK OF APPROVED SUPPLIERS AND CONTRACTORS.

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ciency of the device can be increased if a body of water is used as the heat source rather than the outside air. This is because the water will have a more stable and higher temperature than the surrounding air. Examples are canals, lakes, ground water or warm effluent.

Reverse cycle heat pumps are very useful pieces of equipment which can either heat or cool a space. This feature is obtained by equipping the heat pump with a valve which can reverse the direction of refrigerant flow (figure 5.3). The direction of the refrigerant flow determines if the coil inside the building is a cooling evaporator or heating condenser. Two expansion valves fitted with non return valves are also required. Each expansion valve works in one direction only.

Reverse cycle heat pumps are particularly useful where spaces may have a requirement for both heating and cooling but at different times. One application is in shops where at the start of the day heating may be required. Later in the day as the shop fills with customers and heat is given out by display lighting, cooling may be needed to maintain comfort.

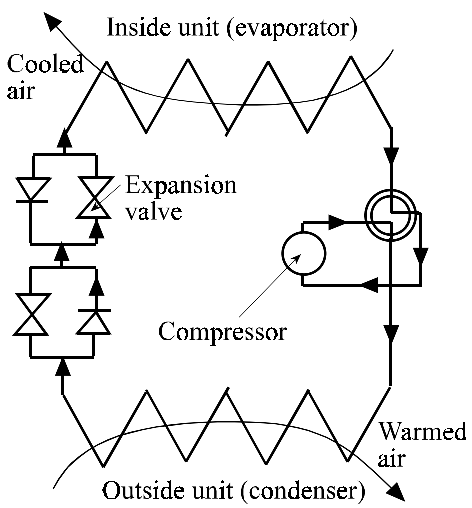


Figure 5.3 Reverse cycle heat pump in cooling mode

5.2 Absorption Chilling

There is growing interest in a method of cooling buildings which uses gas as a fuel instead of electricity. The technology is known as absorption cooling. The biggest differences between this and vapour compression cooling is that the compressor is replaced by a gas fired generator and the refrigerant is replaced by a refrigerant/absorber mixture. A diagram of an absorption chiller is shown in figure 5.4. The generator is filled with a mixture of refrigerant and absorber (solvent) which can be either water/lithium bromide (>35kW capacity) or ammonia/water. (>11kW). Note because water freezes the lithium bromide/water units can only cool down to 5^{o}C, ammonia/water units on the other hand can cool down to -10^{o}C. The way the system works can be illustrated using the ammonia/water pairing as an example. In this case water is the absorber and ammonia is the refrigerant. The water is called the absorber, giving the process its name, as it is so chemically attracted to ammonia vapour that it absorbs it out of the atmosphere.

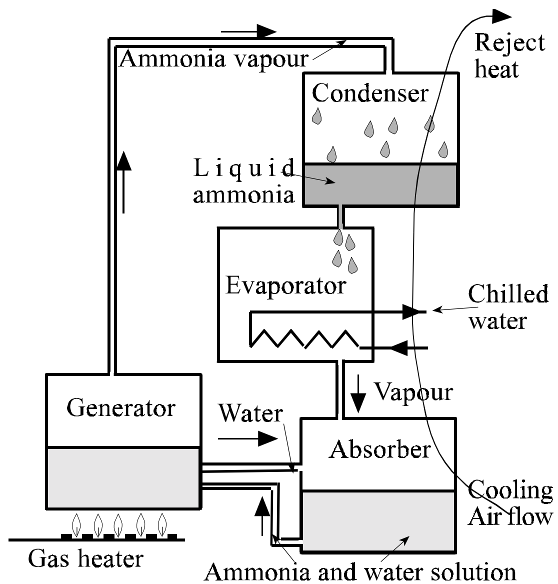


Figure 5.4 Absorption Chiller

A concentrated solution of ammonia in water is heated in the generator (figure 5.4) using a gas burner. The ammonia component vaporises first, as it has a lower

IP15 - REFRIGERANTS.AND.THE.ENVIRONMENT

During the last decade some refrigerants have been identified as ozone depleting gases and/or greenhouse gases. As a consequence the chemical companies producing refrigerants have been working to find alternative refrigerants which have a good blend of physical and thermodynamic characteristics but do not damage the environment if they escape. At the same time governments have brought in legislation which bans the production and use of the more damaging refrigerants. The most well known of these pieces of legislation is the *Montreal Protocol on substances which deplete the ozone layer*. This legislation has banned the production of the most ozone depleting refrigerants and has set a time limit on the manufacture of less damaging refrigerants. Many governments and the EU have brought in more strict legislation shortening timescales meaning that bans are now in place.

> Some refrigerants have been identified as contributing to ozone depletion and global warming

Refrigerants are identified in the building services industry by a refrigerant number. For example, R11 and R12 are chlorofluorocarbons (CFC's) which are highly destructive to the ozone layer and their production is now banned. R22 is an hydrochlorofluorocarbon (HCFC) which is less damaging to the ozone layer than CFC's and so its production is allowed until 2005. Existing stockpiles of both refrigerants can still be used. R134a is a Hydrofluorocarbon (HFC) it contains no chlorine and so does not damage the ozone layer. However like other refrigerants it is a global warming gas.

There are three indicese that are used for comparing the environmental effects of refrigerants;

Ozone Destruction Potential (ODP) - A measure of how destructive the chemical is to the ozone layer in comparison to R11 which is said to have an ODP = 1

Atmospheric Lifetime - The length of time, measured in years, that the refrigerant remains in the atmosphere causing ozone destruction.

Global Warming Potential (GWP) - A measure of the contribution the chemical makes to global warming in comparison to CO_2 whose GWP = 1.0.

Table IP15 below compares these indecese for various refrigerants. It can be seen that R134a has a zero ODP but still has a global warming potential. Environmental groups are now campaigning against HFCs because of their GWP. However, the dominant factor in global warming is CO_2 emitted (from power stations) as a result of electrical consumption by the chiller rather than the global warming effect of escaped refrigerants. A method of quantifying the contributions from each is given by the Total Equivalent Warming Impact (TEWI). This is a lifecycle analysis which considers both the direct global warming impact of the escaped refrigerant and the efficiency of the refrigeration system as a whole.

Environmental concerns have also led to renewed interest in traditional refrigerants such as ammonia and propane. Both of these do not affect the ozone layer or add to global warming. There are concerns over toxicity and flammability of these refrigerants and so they should be used externally and according to appropriate guidelines. Absorption chillers which use a mix of ammonia/water (section 5.2) and waste heat which would otherwise be wasted have a low contribution on global warming and ozone depletion when compared to other systems.[1]

Refrigerant	Type	ODP	Lifetime	GWP
R11	CFC	1.0	60 years	1500
R22	HCFC	0.05	15 years	510
R134a	HFC	0.0	16 years	420
R290	Propane	0.0	<1year	3
R717	Ammonia	0.0	<1year	0
Lithium Bromide		0.0	<1year	0

Table IP15 Environmental Indecese

1. Phone the ETSU enquiries bureau 01235 436747 to obtain a free copy of Good Practice Guide 256: An introduction to Absorption Chilling

boiling point than water, and passes into the condenser. The water which is left behind passes back to the absorber. The ammonia vapour condenses back to liquid ammonia in the condenser giving out waste heat. This heat is removed from the system by air which is blown over the condenser by a fan (section 7.3). The ammonia now passes from the condenser into the evaporator via an expansion valve. In doing so its pressure drops and so it can evaporate once more. It does this by absorbing heat from the chilled water circuit. Chilling has therefore, been achieved. The ammonia vapour now passes into the absorber where it is absorbed by the water from the generator to create a concentrated ammonia solution. Heat is given out when the two chemicals combine. This waste heat is also removed by the condenser cooling air flow. The ammonia solution is pumped back to the generator where the cycle continues once more.

The above device is known as a single effect absorption chiller. Double effect units are also available which use water and lithium bromide. This solution is pre heated on its way back to the generator by passing it through a heat exchanger. This improves the efficiency of the unit. Double effect units require a higher temperature heat source (>140^{o}C) derived from a direct gas fired burner or pressurised hot water.

Absorption chillers are less efficient than vapour compression chillers with a COP of approximately 0.7-1.2. It follows that more gas energy will be required than an equivalent electric chiller (COP = 3.0). However the cost and pollution differentials will be reduced because electricity costs and pollutes approximately four times more per unit of energy than gas because of wastage in the power stations. Contract gas prices are lower still in summer when gas is needed for cooling as less is needed for space heating.

As well as direct gas firing some absorption chillers can be operated using waste heat. One form of surplus heat is that generated by combined heat and power units. In winter their heat output is used for space heating. In summer this heat is surplus to requirements and so can be used to drive the absorption chiller. This is known as trigeneration or combined cooling and power. When heat, which would normally be wasted, is used absorption chillers emit much less CO_2 into the atmosphere than a vapour compression chiller for a given cooling effect (see IP15). Research is currently underway which is investigating the linking of absorption chillers with solar panels as a source of generator heat. It is an advantage that the appearance of large amounts of cost and pollution free solar energy coincides with the need for cooling.

OTHER BENEFITS

The only electrical elements in an absorption chiller are the pumps used to move the ammonia/water solution from the absorber back to the generator. These pumps consume much less power and produce less noise and vibration than a compressor. This latter point is useful if the chiller is to be sited near to a noise sensitive area.

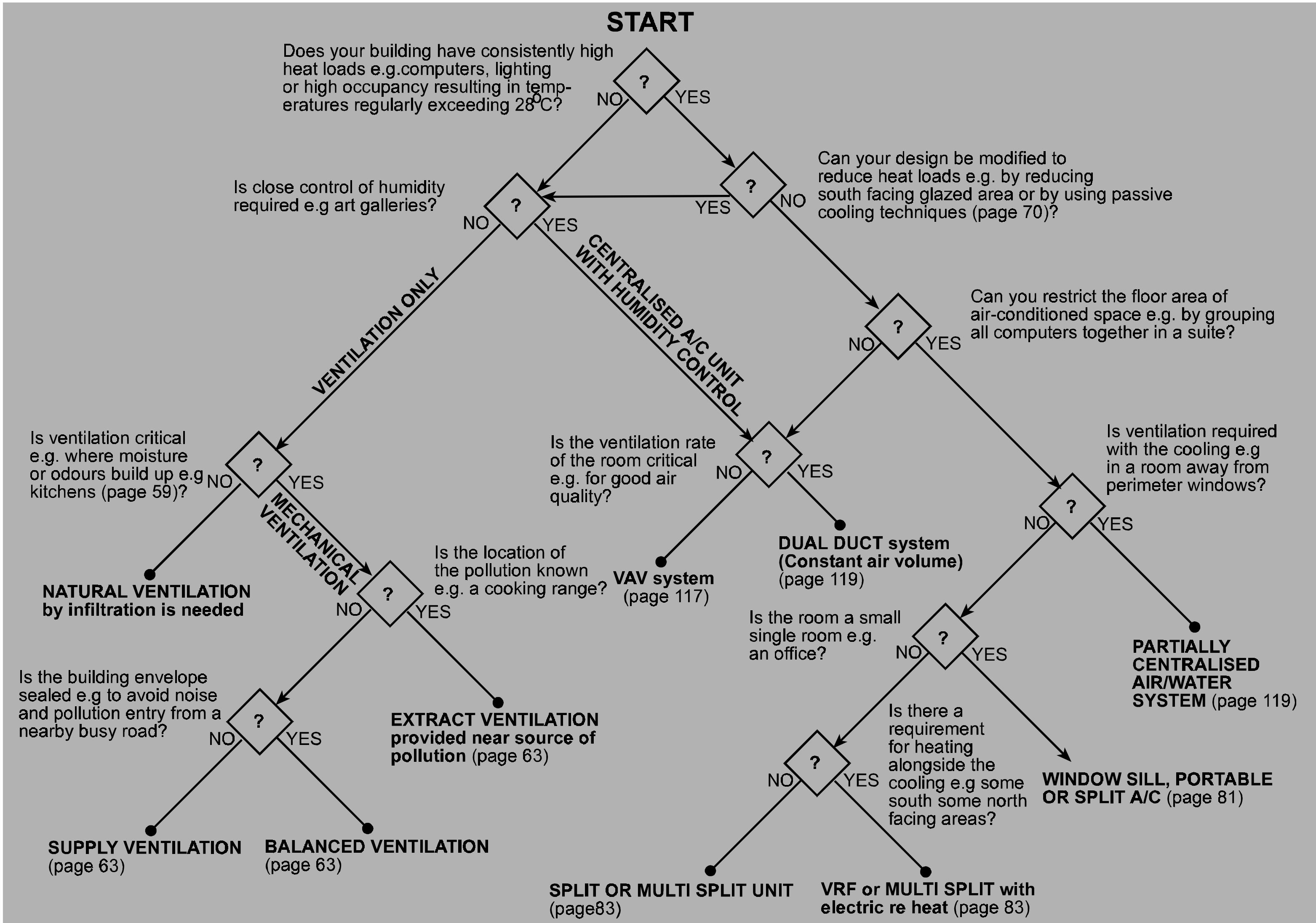
The pump along with the air cooled condenser fan and the gas burner fan are the only moving parts. The rest of the device consists of sealed metal chambers. This configuration means that maintenance costs are low.

External, air cooled, modular packaged units mean that cooling capacity can be easily expanded as the building is developed or as heat loads increase. Flexibility is further enhanced as units are also available that provide heating in winter and switch to cooling in summer. Features and photographs of commercially available absorption chillers are shown on page 76.

SELECTION CRITERIA

From the above it can be seen that absorption chilling is particularly appropriate where;

- You have excess heat production from your CHP plant in summer or a production process which can be used to drive the absorption chiller
- The electrical supply to the site is not robust enough to supply the necessary electricity required for vapour compression chilling and an expensive upgrade would be necessary.
- You wish to optimise the use of clean gas as a fuel throughout the year, not just in winter
- You have a source of low cost or free heat energy available such as solar energy or heat released from the combustion of landfill gas.



This ventilation and air-conditioning selector chart is for guidance only, It is intended to illustrate some of the issues involved in the selection process. There are other issues involved which are not considered here and which may take priority, these include; Capital and maintenance costs, Cooling capacity and Energy consumption. To be able to make comparisons, these later factors are stated in pounds or watts per square metre of treated floor space. It is likely that in the future the decision to air-condition a building will be subject to building regulation approval. For further details on selection criteria consult the CIBSE Guides or phone BRECSU on 0800 585794 and ask for a free copy of *Good Practice Guide 71: Selecting Air Conditioning Systems*.

6.0 Local Comfort Cooling Systems

Comfort cooling systems operate by circulating room air over the evaporator coil of a vapour compression chiller so that it becomes cooled. The system also includes a method of rejecting the waste heat from the cooling process outside of the building.

The vapour compression cycle is used in a number of commercial room cooling products. The main variants are; Window sill, split, multi split, variable refrigerant flow air conditioners, water to air reverse cycle heat pumps and chilled water fan coil units.

Window sill air conditioners are the most basic form of cooling system. They are typically used as a retrofit solution to an overheating problem which may have arisen due to the introduction of computers into an office space. The refrigerating equipment is contained within a cabinet which sits on the window sill (figure 6.0).

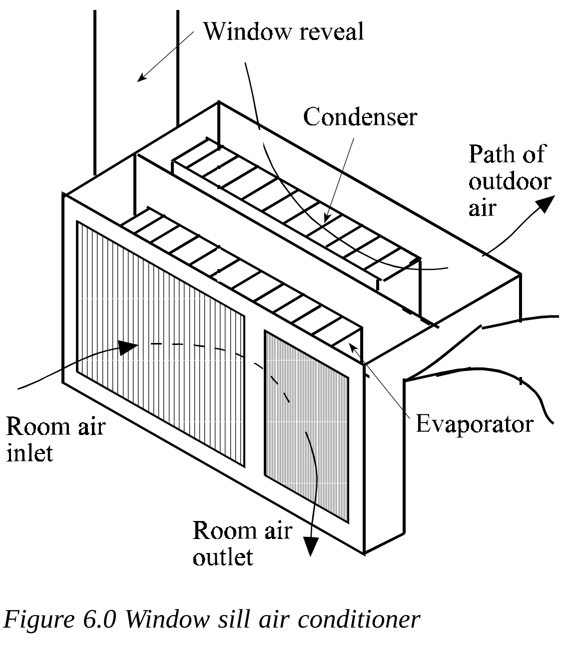


Figure 6.0 Window sill air conditioner

The window must be modified to seal the remaining gap above and to the sides of the unit. The room side of the air conditioner is sealed from the outdoor side. Air is drawn by a fan from the room, through a filter, over the evaporator coil and then is returned, chilled, back to the room. At the same time outside air is circulated over the condenser coil to carry away the waste heat. All the controls and the compressor are fitted into the casing to create a self contained unit.

Portable air conditioners are based on the same principle except that the cabinet is designed to be moved into different rooms as required. A length of flexible ducting which runs from the cabinet to the outside through an available opening such as a window is used to discharge waste heat out of the building.

Split air conditioning systems. Split air conditioning systems are so described because the evaporator is housed in a room unit and the condenser is housed in a separate outdoor unit. Refrigerant flow and return pipes connect the two units together. The indoor unit can be wall or floor mounted or accommodated within a suspended ceiling. The finish of the indoor unit is of high quality to integrated with the appearance of the room decor or suspended ceiling panels.

A diagram of a ceiling unit is shown in figure 6.1. A fan is used to draw room air across the evaporator to provide the necessary cooling. Chilled air is then output via directional slots. These slots are adjusted to keep the cold airstream away from the room occupants so that cold draughts are avoided. The chilled air mixes with the room air outside the occupied zone. The mixed air eventually diffuses throughout the room to create the cooling effect.

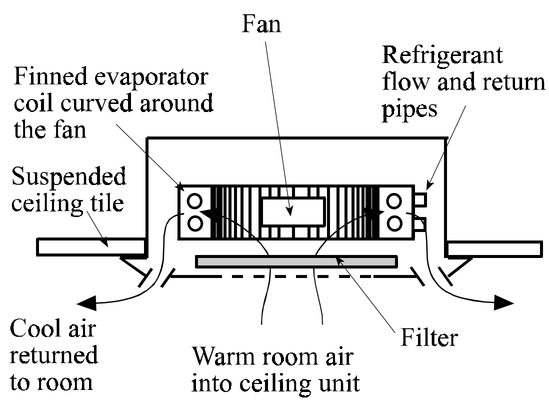


Figure 6.1 Indoor unit (cassette) of a split air conditioning system

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

The outdoor unit (figure 6.2) contains the condenser which is air cooled. The condenser like the evaporator has its surface area increased using fins. A fan is used to draw outside air across the condenser to discharge the waste heat to atmosphere. The outdoor unit can be placed a considerable distance (up to 50m pipe length including 30m vertical rise) from the indoor unit. This allows flexibility of design and sympathetic positioning of the outdoor units on the external surfaces of the building.

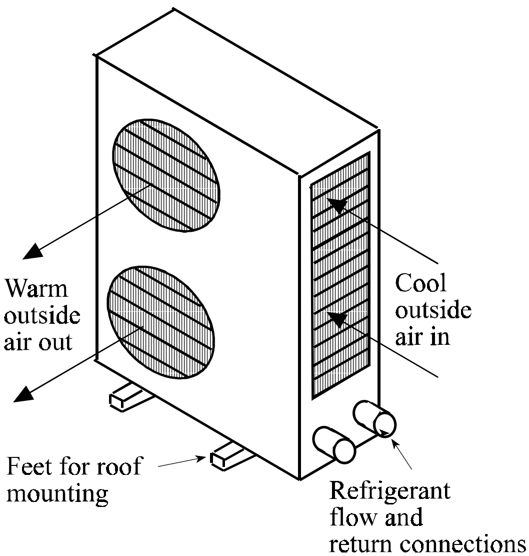

Figure 6.2 Outdoor unit of a split air conditioning system

Multi split air conditioning. Is based on the same principle as single split air conditioning except that up to four indoor units can be served by a single outdoor unit. Each indoor unit has its own set of refrigerant pipe work connecting it to the outdoor unit. All of the indoor units operate in the same mode i.e. all heating or all cooling, although individual control of the degree of heating or cooling from off to full output can be exercised over each unit. Some indoor units are fitted with electric heaters so that whilst the multi split group is operating in cooling mode odd single units can provide a degree of heating.

Variable refrigerant flow (VRF) air conditioning. In this system up to eight indoor units can be operated from a single outdoor unit. The main advantage of this system over multi splits is that each indoor unit can operate either in cooling or heating mode independently of the other units. This is achieved by having collection vessels for both vapour and liquid refrigerant (figure 6.3). A sophisticated control system redirects these two refrigerant phases to the indoor units as required. As a consequence VRF air conditioning systems incorporate heat recovery in their mode of operation. Waste heat say from rooms on the south side of the building can be re distributed by the refrigerant to indoor units on the north side of the building. The distance between indoor and outdoor units can be up to 100m including a vertical rise of 50m.

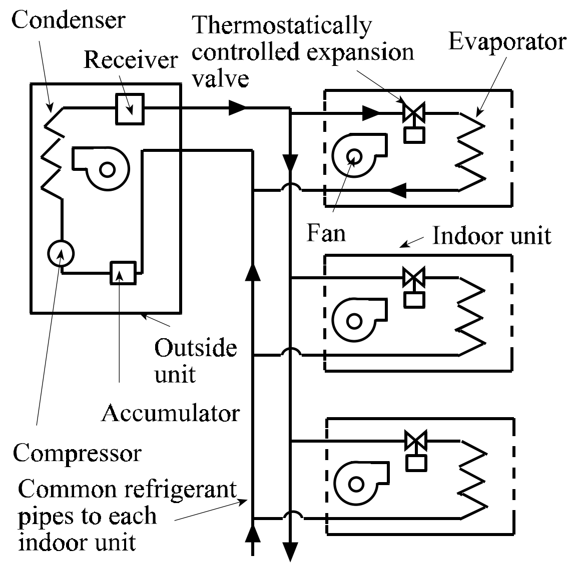

Figure 6.3 Variable refrigerant flow system

Filtered and tempered air can be supplied to each unit from a centralised air handling unit to provide ventilation as well as heating/cooling.

Water to air reverse cycle heat pumps are a heat pump system which gives the opportunity for efficient operation through heat recovery. The water to air reverse cycle heat pump system is also known as the versatemp system after the first commercial system produced by Clivet Ltd. The system (figure 6.4) is comprised of room based reverse cycle heat pumps. These heat pumps have an air coil which supplies heat or cooling to the room depending on the direction of refrigerant flow. The other coil is part of a refrigerant to water

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heat exchanger. The water flow and return pipes to this heat exchanger connect into common flow and return pipes which also serve other reverse cycle heat pumps throughout the building.

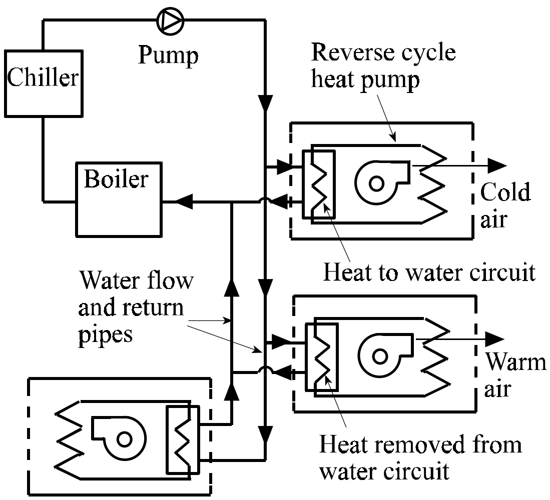


Figure 6.4 Water to air reverse cycle heat pump system

Heat pumps operating in cooling mode will extract heat from the room and deposit it into the water circuit. Other heat pumps which are in heating mode will take heat from the circuit. In this way the reject heat say from computer rooms can be recovered and deposited into rooms requiring heating. If it is required additional heating or cooling can be input to the water loop using boilers or chillers respectively.

Chilled water fan coil units. This system of comfort cooling uses a centralised chiller to produce cold water. This water is then distributed to room based fan coil units (figure 6.5). The fan coil units provide cooling in a similar manner to split system indoor units. The difference is that the heat transfer coil is filled with cold water instead of refrigerant. The units can be floor or wall mounted or recessed into a suspended ceiling.

There are a number of advantages to this system;

- Fewer constraints on the number of room based units

- The distribution system uses chilled water instead of refrigerant. As a result part of the system can be installed by tradesmen used to water systems as opposed to specialist refrigeration engineers.

- Chilling and heat rejection occurs in the centralised chiller. This may be in a plant room or on the roof top. The charge of refrigerant is therefore reduced and since the lengths of refrigerant pipe work are shorter the risk of leakage is diminished.

- Use of hydronic circuits and low fan speeds results in quiet operation making the units useful for noise sensitive locations.

Supplying the chilled water fan coils with fresh air using ducting brings the system closer to a partially centralised air/water system as described in section 8.0

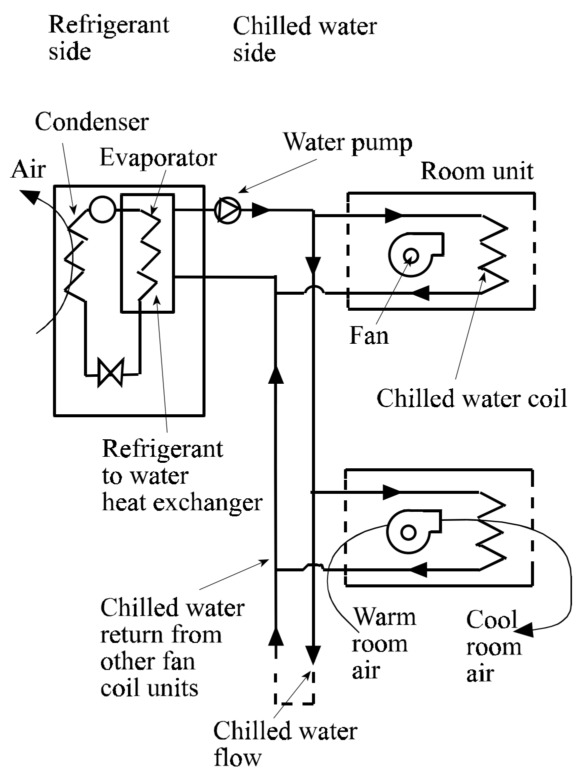
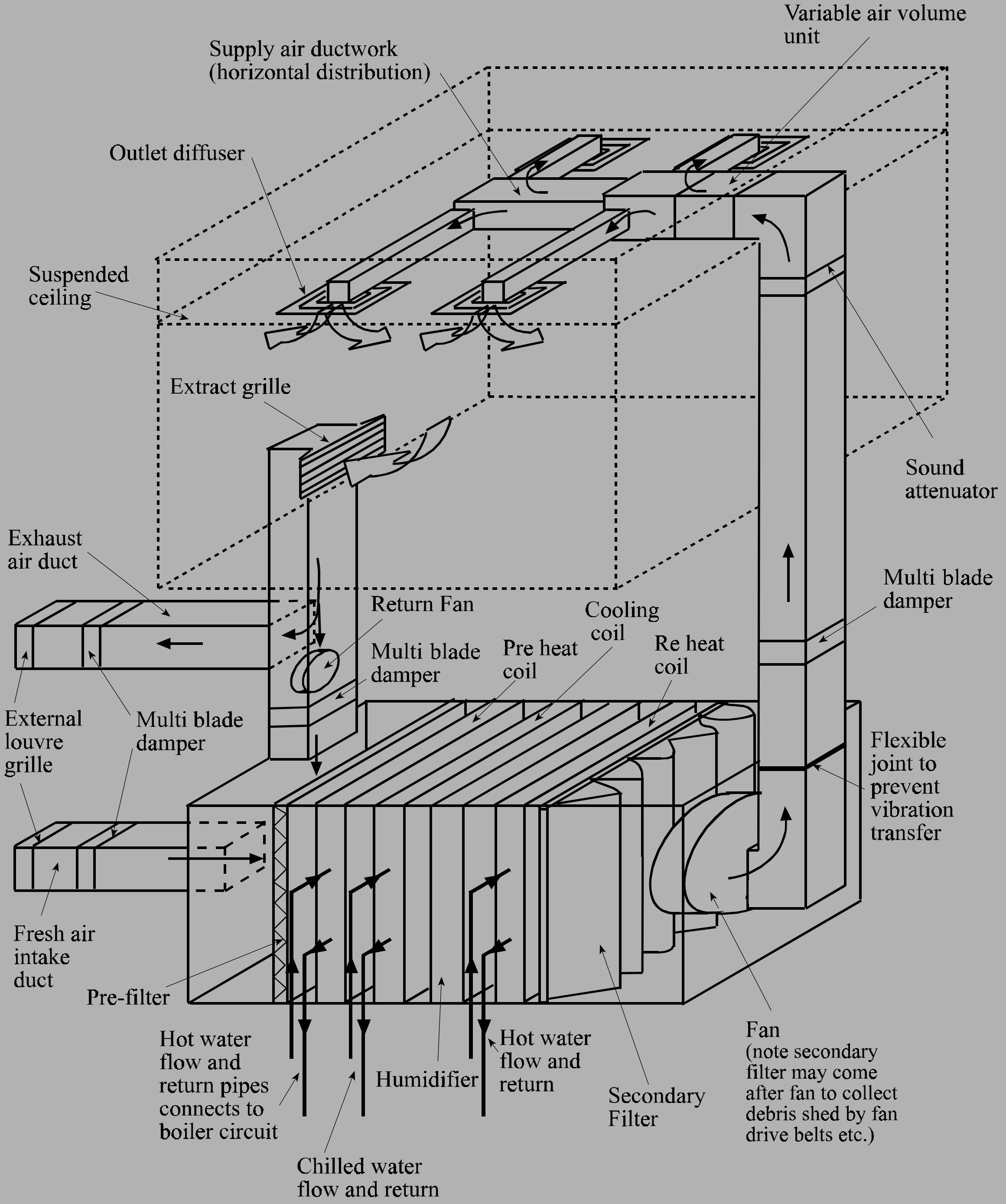


Figure 6.5 Chilled water fan coil units

IP17-CENTRALISED.A/C.SYSTEM-MAIN.COMPONENTS



7.0 Centralised Air Conditioning Systems

Centralised air conditioning systems differ from comfort cooling systems described previously in that they are able to humidify or dehumidify the airstream in addition to providing cooling, heating and filtration. These changes are applied to the air using an air handling unit situated in the plant room or enclosure on the roof. The conditioned air is then delivered to the rooms using ducting.

At the heart of a centralised air conditioning system is an air handling unit (AHU) (figure 7.1and IP17). This is a pressed steel cabinet containing the various components needed to condition the air which passes through it. Air is brought into the air handling unit via an inlet grille built into an external wall. This should be located to avoid sources of dust and pollution such as near by roads. If cooling the building is a priority then a north facing inlet grille will provide cooler inlet air temperatures. Rooftop inlets are often used in cities to avoid ground level pollution. Air enters the AHU where it is suitably conditioned by passing through filtration, heat recovery, humidity control and chilling or heating stages. A centrifugal fan drives the air movement through the AHU.

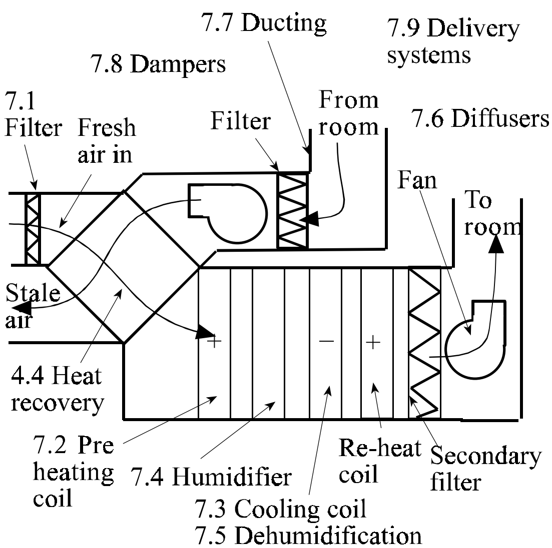


Figure 7.1 Air handling unit including heat recovery

Centralised air conditioning systems must have some way of responding to changes in demand for heating or cooling within the occupied spaces. This is achieved in the way that conditioned air is delivered to the rooms. The methods used are; constant volume systems, variable air volume (vav) systems and dual duct systems. Each of these will be discussed in section 7.9 following a description of the main components in a centralised air conditioning system.

Here we will be discussing components in relation to a centralised air conditioning system but it should be remembered that many of the components are also used in other systems. For example filters and heating/cooling coils are used in fan coil units (section 8.0) and ducting is used whenever air movement needs guidance such as in extract ventilation systems (section 4.2).

7.1 Filtration

Air carries with it a large quantity of suspended particles including dust, fibres, bacteria, mould and fungal spores, viruses and smoke. It also carries gaseous pollutants such as benzene, NO_2, SO_2 and other odours emitted from vehicle exhausts. This is especially so where buildings are sited in urban areas where there is typically twenty times as much dust per cubic metre of air than is found in rural areas. The particles in the airstream vary in size from the visible such as hair and ash to the microscopic such as bacteria and viruses (IP18). It is essential that air passing through an air handling unit is filtered to remove these impurities. Inadequate removal of these particles leads to problems of poor air quality and ill health. Dust particles accumulate on heating/cooling coils reducing their effectiveness. Ductwork surfaces become coated in dust providing a breeding ground for bacteria. Finally, the presence of dust in the airstream leaving an air outlet causes unsightly dirty streaks on adjacent surfaces. In 1996 health and safety regulations concerning ventilation system maintenance and cleaning came in to force requiring that ductwork be cleaned on a regular basis.

There are two methods by which air can be filtered these are mechanical filtration and electrostatic filtration. Gases and vapours are removed from the airstream

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using the process of adsorption.

MECHANICAL FILTERS

Mechanical filtration involves passing the airstream through a porous material known as the filter media. The materials are usually fabrics, glass fibre, non-woven synthetic materials or paper. Each is held across the airstream by a supportive framework. The capture process involves three mechanisms; Direct interception, inertial impaction and diffusion. These involve either directly stopping large particles as a result of a single collision or by gradually slowing down smaller particles by multiple collisions with successive fibres. Eventually the small particle loses energy and comes to rest. A fourth capture mechanism for some filters is to give the fibres an electrical charge during manufacture. This will attract dust out of the airstream but the effectiveness will reduce with time as the charge is lost.

Since filters are required to be changed regularly it makes sense to construct them in a robust and effective way but cheap enough to be disposed of at the end of their life. It also makes sense to utilise the grades of filters in such a way as to extend the life of the most expensive filters for as long as possible. The effectiveness of lower grade (G2-G4) (see IP18) pad and panel filters can be enhanced by using a filter media of graduated density. This means that the back of the filter will have smaller pores than the front, and therefore will be able to capture a broader range of particulate sizes.

Pad Filters are used as the first bank of filters to prevent large particles from entering the system. A single flat sheet of material, they are held in a card or re-usable steel or lightweight aluminium frame. They protect the higher grade, and hence more expensive filters, next in line. They are normally referred to as Primary Grade Filters ranging from G2 to G4 in classification.

Panel filters. As shown in figure 7.2, the filter media is folded into pleats. This extends the media surface area when compared to the flat pad of material in a pad filter. The filter media is backed by an open strengthening grid and is then sandwiched into a card, wire-mesh or plastic frame. This panel can be easily slid into position in a metal holding frame in the air handling unit (AHU). They are particularly suited to AHU's which have insufficient depth to accommodate a bag filter (see later). When the filter requires changing it is removed, disposed of according to regulations, and a replacement inserted in the same manner. Some filters of this type are available as primary filters (usually G4) but more commonly are used for grades F5-F8 and as a secondary filter.

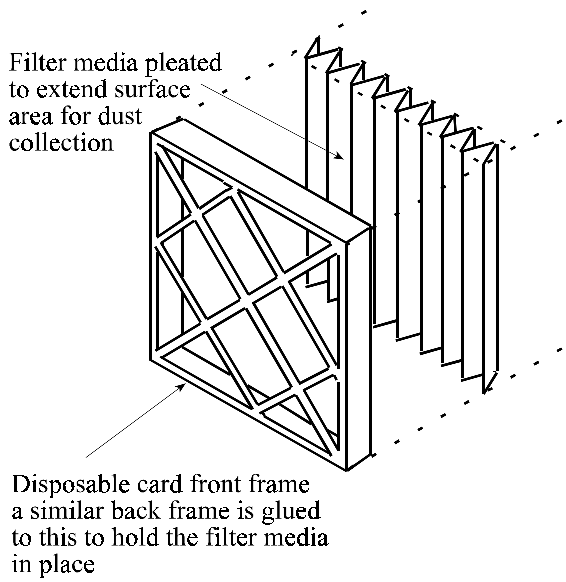


Figure 7.2 Panel filter

Anti-microbial filters. This is a panel filter surface sprayed or impregnated with biocides. The biocides used fall into one of two categories: inhibitor or eradicator. Inhibitors simply prevent the micro-organism from reproducing an eradicator kills it completely. The range of micro-organisms against which the biocide will be effective includes various types of bacteria, algae and yeasts. Anti-microbial filters are most commonly used in hygiene sensitive areas such as hospitals or food processing outlets. They are however being increasingly used in office environments to improve general indoor air quality and health. All grades of filter are available from G2 to F9.

Bag Filters have a filter medium which is formed into a bag and held in place by a metal or plastic frame (figure 7.3). The seams are well sealed and it is mounted so that the open end of the bag faces the oncoming air-

IP18 - AIR.FILTER.CHARACTERISTICS

The standard method of testing to evaluate performance of air filters in general ventilation and air conditioning is BS6540 (EN779:1993, European Standard). The test consists of two parts:

A: The synthetic dust weight arrestance test - providing an arrestance value when the filter is fed with a blended synthetic dust.

B: The atmospheric dust spot efficiency test - giving an efficiency value produced using an atmospheric staining technique.

The following values are obtained

Initial efficiency -
The efficiency of the filter against carbonaceous staining contamination in its clean state.

Initial arrestance - the effectiveness of the filter against large particulate matter in its clean state.

Both efficiency and arrestance have average values which represent performance at the average condition of the filter through its life.

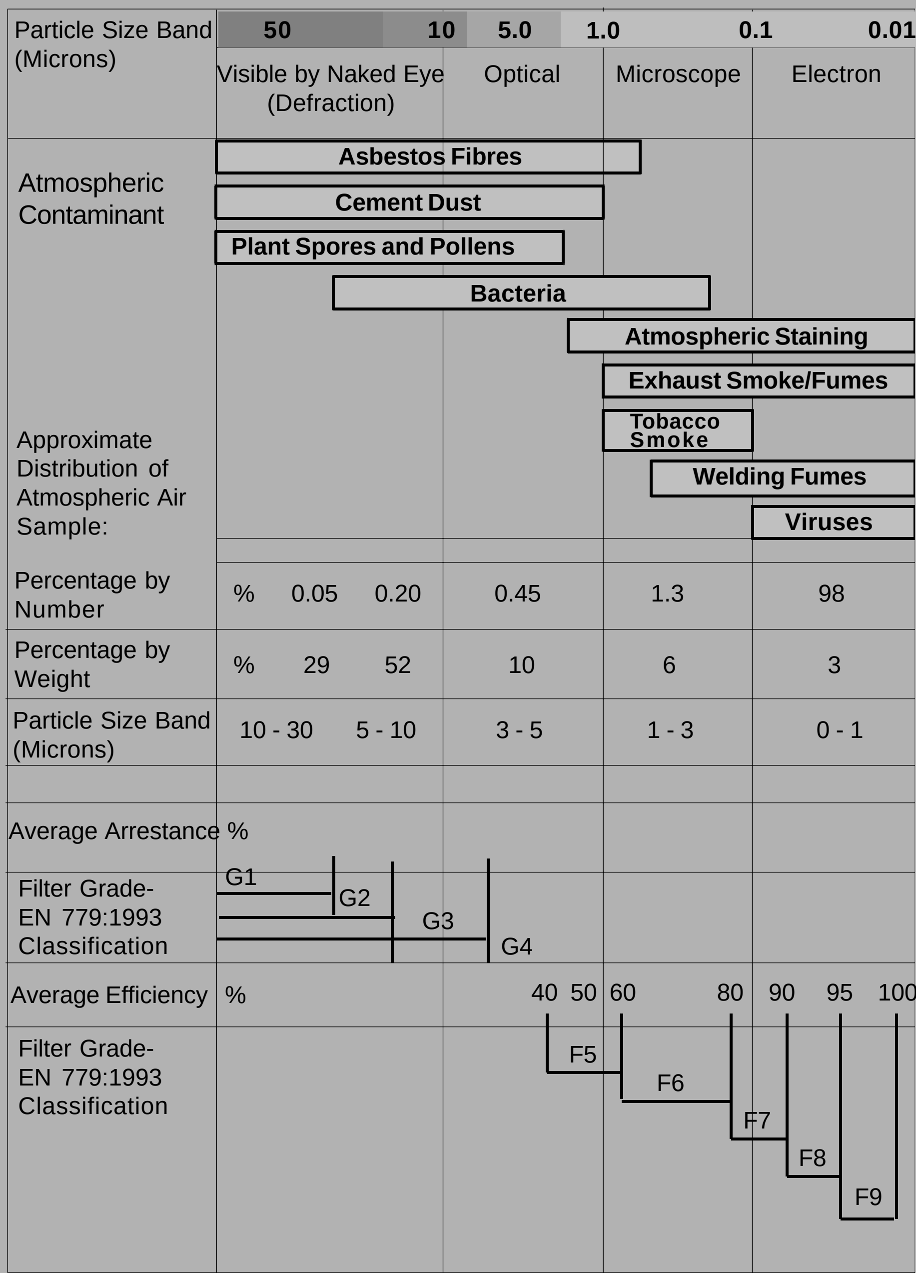


Figure IP18 Dust particles, their sizes and appropriate filter grades

This chart has been reproduced with permission from publication NFC4 produced by the Nationwide Filter Company Ltd. 5 Rufus Business Centre, Ravensbury Terrace, London, SW18 4RL. Tel +44(0) 20 8944 8877.

flow. Providing that the bag has sufficient depth this form greatly extends the surface area over which filtration can take place and as a result bag filters have a long life, a high dust carrying capacity and offer a low resistance to airflow. To minimise the risk of sagging or collapse, some bag filters are manufactured with spacers to help the individual pockets remain open even at reduced airflows. Bag filters are usually available in grades from G4 to F9.

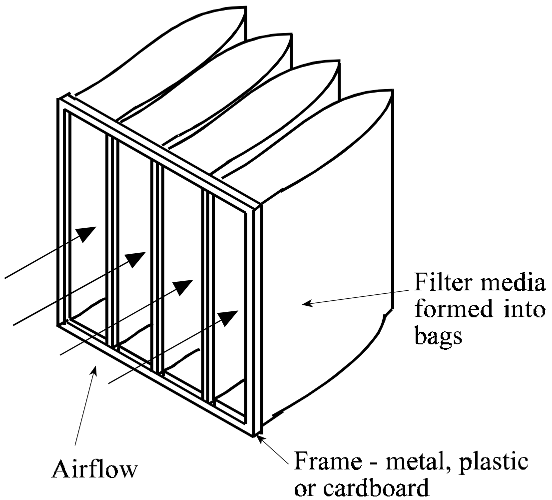


Figure 7.3 Bag filter

High Efficiency Particulate Air (HEPA) Filters are panel filters with extremely fine filter media with collection efficiencies ranging from 99.95 to 99.999%. To extend the life of a HEPA filter it must be used in conjunction with at least one pre-filter. HEPA filters may be included in the main area of the ahu or only at the air inlet grilles serving those rooms which require the cleanest air. HEPA filters are used where a very clean environment is required such as in micro electronics and pharmaceutical manufacturing and storage areas for documants and artefacts. An even higher grade of filter, the Ultra Low Penetrating Air (ULPA) filter is used in environments where ultra clean air is required such as the nuclear or space industries.

ELECTROSTATIC FILTERS

Electrostatic filters remove dust from the air by electrostatic attraction. Dust laden air entering the unit passes over an ioniser (figure 7.4). This induces a positive electrical charge on the dust particles. The airstream then passes between positively and negatively charged plates. The positive plates repel the charged dust particles towards the negative plates which are at the same time attracting the dust particles. The dust collects on the negatively charged plates.

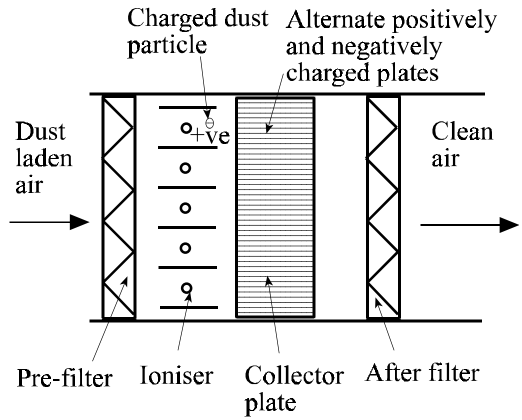


Figure 7.4 Electrostatic filter

Electrostatic filters have a mechanical pre filter to remove the larger particles and a post filter to collect any large clumps of aggregated dust which may become dislodged from the unit. Some units have automatic cleaning systems which periodically wash down the collector plates which become coated in accumulated dust. In other systems the collector array is removed via a side hatch for cleaning before re assembly.

Electrostatic filters once seen as a low maintenance low pressure drop option have recently fallen out of favour. This is due to the increased cost of mechanical parts and the high cost of replacement plates that become less effective after 'pitting' and accumulation of inground atmospheric particulate staining.

ACTIVATED CARBON FILTERS

Activated carbon filters are used to remove gaseous pollutants and odours from the airstream which cannot be removed by mechanical or electrostatic filters. The carbonaceous material is first processed to produce a char and then heated to 800-1000^{o}C to give it its micropore structure which enables the adsorption of gaseous

IP 19 - MANAGEMENT.OF.FILTERS

There are two criteria used to compare the performance of filters. The first is the pressure drop which occurs from one side of the filter to the other. This pressure drop arises due to the resistance that the air encounters passing through the small pores in the media. The smaller the pores the greater the resistance. The second criterion is the filters ability to remove dust from the airstream, measured in terms of the filter efficiency. Various standard test methods exist (BS6540) (see IP 18) which involve measuring how much dust there is in the air upstream and downstream from the filter. The removal efficiency of the filter, expressed as a percentage can be calculated from these two values.

The efficiency will depend on the size of the dust particles and the pore size of the filter media. So for example a coarse filter with a relatively large pore size will have a high efficiency at collecting large particles but a low efficiency at collecting smaller particles. Materials with small pore sizes are good at removing both the large and small suspended matter. They do however, cause a greater pressure drop within the system. A large pressure drop will necessitate the use of a higher capacity fan which will increase the electrical consumption of the system. A common compromise is to select a medium grade filter even though this may not necessarily provide the quality of air required. One way of avoiding this compromise and reducing the pressure loss in higher grade filters, is to increase the surface area through which the contaminated air can flow. The list below shows how we increase the working area of filters as the grade increases to maintain an acceptable working resistance. Face area 600x600mm in all cases

> Systems that concentrate movement of air also concentrate the dust and grime contained in it. Filtration is the only way to remove it.

Type	Area m^2
low grade pad filter 50mm deep	0.36
medium grade 4 bag filter 400mm deep	1.92
high grade 6 bag filter 600mm deep	5-5.76

Modern developments include the 'rigid pack' paper filled filter a 600x600x300mm unit can provide a working area up to $18m^2$

FILTER REPLACEMENT

If filters are to carry out their role of dust extraction from the airstream whilst not affecting the air movement considerably they must be replaced by clean filters at regular intervals. This can be carried out using routine maintenance or condition based maintenance.

Routine maintenance involves making a decision based on previous experience, knowledge of dust conditions in the building and filter performance to determine a period after which the filter should be changed. So for example the filters in an air conditioning system may be routinely changed every six months. This is a simple method but may mean that the system operates with dirty filters for a time if the filters have clogged up quicker than expected. It could also mean that if the dust load is low relatively clean filters are being removed and replaced.

Condition based maintenance avoids the problems encountered with routine maintenance. Filter changing is based on the actual state of the filters rather than an assumption of their condition. The system works as shown in figure IP19. Transducers either side of the filter monitor air pressures. The pressure at point P_1 will always be higher than P_2 due to the resistance of the filter. However when the filter begins to clog up this pressure differential will increase. The pressure transducers can be observed manually or the signals fed into a BEMS system which will inform the building operators that the filters need changing.

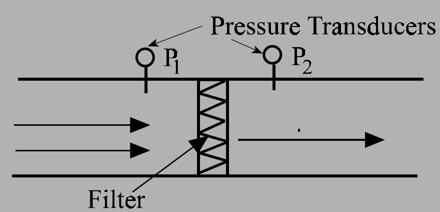


Figure IP19. Monitoring filter condition contaminants and odours. While most activated carbon filters are made of base carbon, the carbon can be impregnated to improve its ability to adsorb certain types of contaminant such as nitrogen dioxide(NO_2) and sulphur dioxide(SO_2) which are particularly damaging to documents and works of art. Carbon filters can be constructed of loose carbon, bonded carbon biscuits, carbon impregnated paper or fibre and pleated granular mat depending on the application. The filter is commonly housed in a metal frame and should always be preceeded by a pre-filter. In certain instances the carbon can be reactivated and reused at the end of its life.

The degree of effectiveness of a carbon filter is generally related to the amount of time that the air spends within the carbon. This is known as the dwell time. The greater the dwell time (lower the air speed or greater the carbon area) the more effective the carbon filter will be at odour or gas removal. Pressure losses through carbon filters can be high and manufacturers should be consulted to select a filter to optimise gas removal and minimise pressure drop.

7.2 Heater Coil

One of the functions of an air handling unit is to heat the incoming airstream. This can be achieved using direct heaters such as electrical heating elements. However it is more commonly achieved using heater coils. Heater coils are composed of a staggered grid of copper pipes conveying heated water between flow and return headers as shown in figure 7.5. The pipes can be connected by return bends which allows the flow and return headers to be at the same side of the heating coil. Coil heat output is improved by increasing the number of pipe rows. Low, medium or high temperature hot water or steam flows through these pipes in parallel assuring equal distribution of heat across the heater coil face. Attached to the surface of each tube are aluminium or copper fins. These fins increase the surface area for heat transfer between the hot coil and the airflow. Further increases in heat output are possible by corrugating the fins, but this does also increases the resistance the air experiences when passing through the coil.

Temperature control is achieved by fitting a temperature sensor into the rooms being heated or the extract duct work. This signal is fed into a control unit and is used to set the position of a valve supplying hot water from the boilers to the flow header. If the temperature of air in the extract duct work is higher than the room set point then the hot water flow to the coil will be modulated down or shut off. Thereby preventing further unnecessary heating of the room.

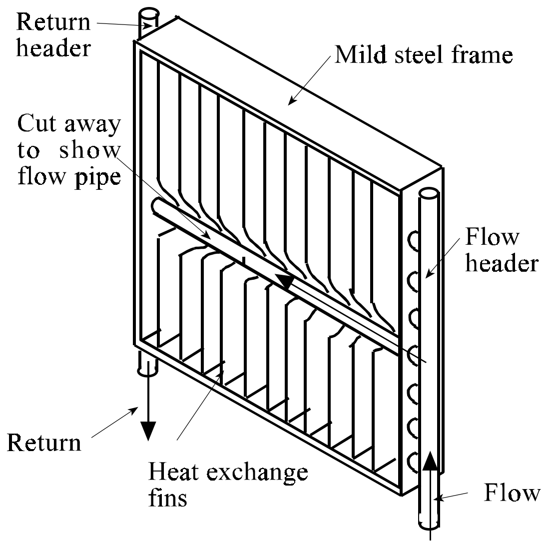


Figure 7.5 Heater coil

7.3 Cooling Coil

Cooling of the airstream is achieved by bringing it into contact with a cold surface. The cold surface is a cooling coil. The cooling coil can be either a direct expansion (DX) cooling coil which is the evaporator of a vapour compression chiller or it may be a water coil similar to the heating coil described above. It differs from the heating coil in that a mixture of water and antifreeze (glycol) circulates through it rather than hot water. This mixture is cooled using a chiller.

WASTE HEAT REJECTION

Vapour compression chillers have been described previously in section 5.1. An alternative method of cooling called absorption cooling is described in section 5.2.

IP20 - REFRIGERATION.PLANT.EFFICIENCY

Refrigeration plant is equipment which converts electricity into coolth. Coolth is the same stuff as heat i.e. thermal energy except that it has a negative value. In other words it is heat being removed from something causing a reduction in temperature. Most refrigeration systems are based on the vapour compression cycle and this information panel will concentrate on this system.

The energy consumption of a cooling system is by two principle components. Firstly by the compressor, and secondly by any fans or pumps used to remove waste heat from the condensor and remove coolth from the evaporator. The compressor consumes the majority, approximately 95%, of the energy input to the refrigeration equipment.

It is unfortunate that cooling is required in summer as this results in reduced system efficiency!

COEFFICIENT OF PERFORMANCE (COP)

The efficiency of a cooling system is normally called the coefficient of performance or COP. The COP of a real system is given by;

$$COP = \frac{\text{Cooling Capacity (kW)}}{\text{Total Power Input (kW)}}$$

Typical COP's for cooling are 1.5 to 2.0 which indicates that you can achieve 2kW of cooling for the consumption of 1kW of electricity. This compares with a COP of 2.5 to 3.0 if the refrigeration equipment is being used as a heat pump. To study factors affecting performance more clearly it is useful to look at the formula for the theoretical COP. This is given by;

$$COP = \frac{T_1}{T_1 - T_2}$$

where T_1 = Evaporator ambient air temperature (K)
T_2 = Condenser ambient air temperature (K)

From this it can be seen that for the COP to be high the difference between T_1 and T_2 should be small. Since T_1 is set by system requirements the variable is T_2 , the ambient temperature surrounding the condenser. taking a split cooling system as an example, what this means in practice is that when the outside air temperature increases the efficiency of the system will fall. This is unfortunate since most cooling is required in summer when high ambient condenser temperatures prevail. However, there are a number of things that can be done to improve this. The first is to increase the size of the air cooled condenser and ensure that there is good airflow through the device to keep the ambient temperature low. The next is to consider evaporative condensers (page 95) these use latent heat removal to reduce ambient temperatures. Finally, stable low temperature heat sinks should be considered such as surface and groundwaters.

ICE STORAGE

The efficiency of a chiller varies with the amount of work it is required to do. At low loads the efficiency will be reduced. One way of overcoming this problem is to use an ice storage system. Ice storage involves using an undersized chiller to produce an ice slurry during the night. The ice is stored in an insulated tank. During the day the chiller would not have enough capacity to satisfy the cooling demands of the building. However by operating the chiller at full load and drawing additional coolth from the ice store the building cooling demand can be satisfied.

The advantages of the system is that the chiller operates most of the time at full load and hence peak efficiency, it also provides a good proportion of the cooling requirement of the building using cheaper night time electricity tariffs. Both of these contribute to reducing operating costs.

This section will look at methods of condenser heat rejection.

Chillers generate a large amount of waste heat. In a domestic refrigerator, which we have used as an example of an every day chiller previously, the waste heat is simply allowed to enter the kitchen via the condenser coil at the rear of the refrigerator. However, in air conditioning systems the amounts of waste heat involved are too great and would cause serious overheating in the plant room. Because of this the waste heat must be safely rejected outside the building. There are three main ways in which waste heat is removed from the condenser. These are by using; air cooled condensers, evaporative condensers or water cooled condensers.

Air cooled condensers (figure 7.6) have been described previously in their application to split air conditioning systems. They are predominantly used for smaller cooling loads (less than 100kW) although they are used for rejecting up to three times this value mainly due to the fact that water is not used in their operation. This means maintenance costs are low.

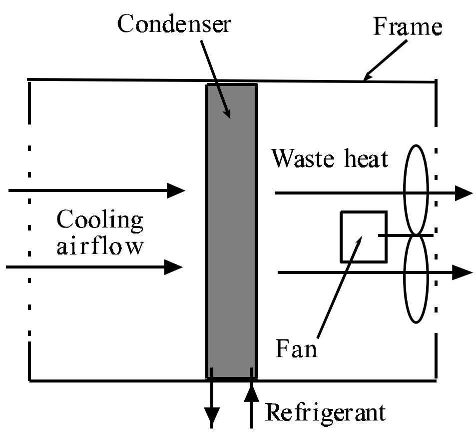


Figure 7.6 Air cooled condenser

Evaporative condensers. Are similar to air cooled condensers except that their heat rejection capacity is increased by spraying water over the condenser coil (figure 7.7). As this water evaporates it absorbs heat. Cooling of the condenser coil is therefore achieved by both sensible and latent means. The practical implication of this is that the unit has a smaller physical size for a given heat rejection capacity than an air cooled condenser.

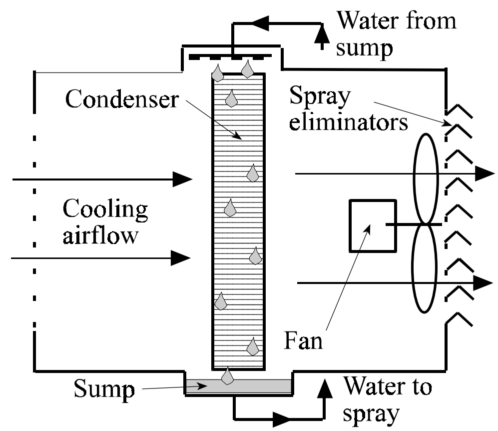


Figure 7.7 Evaporative condenser

The water circulating over the condenser is treated to prevent bacterial growth. In addition spray eliminators must be used to avoid water droplets, which may be contaminated, leaving the unit. Evaporative condensers can be used up to 500kW cooling capacity.

Water cooled condensers. Variations in ambient air temperature cause changes in the efficiency of air cooled condensers (see IP20). A more temperature stable heat sink is water. Water cooled condensers make use of this by jacketing the condenser in a shell which is filled with water (figure 7.8).

The condenser passes its waste heat to the water increasing its temperature by about 5^{o}C. The water is then pumped to a water to water plate heat exchanger. Water from a large nearby source, such as a canal, river, lake or sea is also circulated through this heat exchanger having first been strained and filtered. In this way the condenser cooling water only makes thermal contact with the heat sink water. The heat sink water having picked up heat from the condenser circuit is returned to the main body of water where the heat it carries is dispersed. The condenser cooling water leaves the plate heat exchanger and returns once more to the condenser to pick up more waste heat. The use of bodies of water such as rivers and canals as a heat sink is subject to water authority approval.

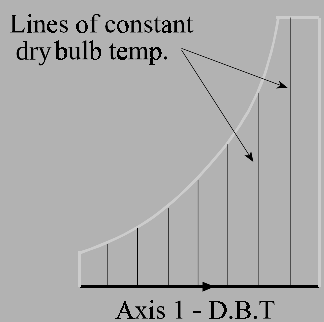
IP21 - PSYCHROMETRIC.CHART-STRUCTURE

The psychrometric chart shown in information panel 23 (page 108) looks daunting because of its complexity. However it is a very useful tool for studying the relationships between the temperature and moisture content of air. This information panel explains the structure of the psychrometric chart by breaking it down into simple components.

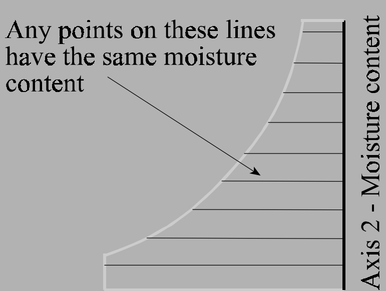
STRUCTURE

The psychrometric chart is like a sheet of graph paper. Instead of the normal x and y axese creating a square grid it has a number of axese and some of the grid lines are curves rather than straight lines.

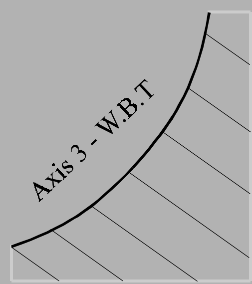
Axis 1 is dry bulb temperature (DBT). This is like the x axis on a standard x-y graph. Any points drawn on the vertical lines on the graph will all have the same DBT. Dry bulb temperature is the temperature taken by a normal mercury in glass thermometer - units ^{o}C.



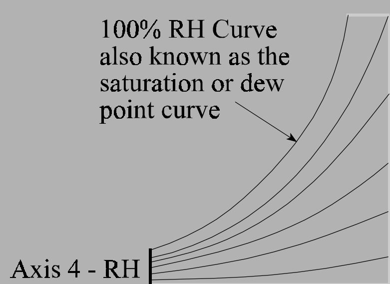
Axis 2 is moisture content. This is like the y axis of an x-y graph but is on the right hand side of the x axis. Any points drawn on the horizontal lines have the same moisture content - units kg/kg i.e the weight of moisture (kg) in 1 kg of dry air.



Axis 3 is wet bulb temperature (wbt). As you can see this axis is curved and the lines of equal wbt are diagonal, sloping down from the axis. Wet bulb temperature is the temperature taken using a mercury in glass thermometer but with the bulb covered in damp cloth - units ^{o}C. Evaporation of water from this cloth cools it down so the wbt is usually lower than dbt. The amount of evaporation and hence temperature depression depends on the moisture content of the air. The dryer the air the greater the evaporation and the greater the depresion of wbt below dbt.



Axis 4 is relative humidity (RH). This is a short y type axis on the left hand side of the dbt axis. As you can see the lines of equal RH curve upwards from this axis. One point to note is that the 100% RH curve forms the wbt axis. This curve is also known as the saturation curve.



By overlaying each of the axese and related constant lines the psychrometric chart is formed. (see page 102 for its use and page 108 for the chart)

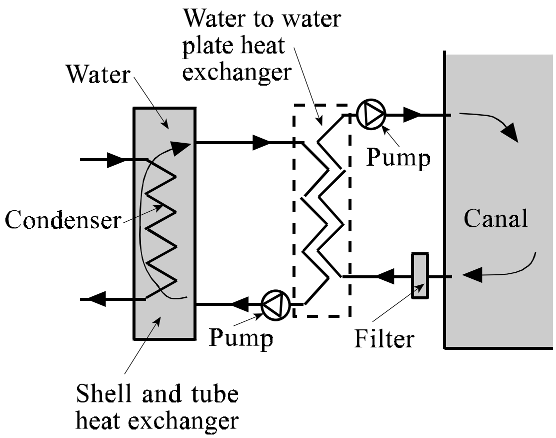


Figure 7.8 Water cooled condenser

Cooling Towers. In locations where there are no large bodies of water that can be used as a heat sink, the water cooled condenser is used in conjunction with a cooling tower. A cooling tower is a device which cools the condenser cooling water by evaporation before returning it to the condenser to collect more heat. Figure 7.9 shows a forced draught cooling tower. It can be seen that the condenser cooling water is allowed to tumble down through the device whilst air is forced upwards through the cascading water by a fan.

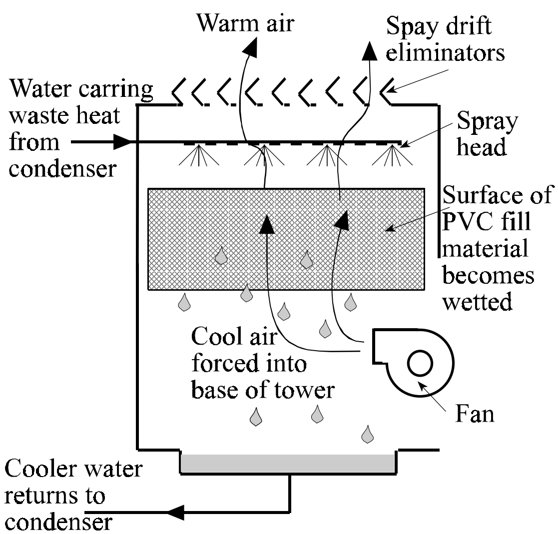


Figure 7.9 Forced draught cooling tower

The purpose of the tower is to enhance evaporative cooling of the condenser water. It does this by increasing the surface area of the water exposed to air. Evaporation is a surface effect so increasing the surface area of water in contact with the air increases evaporation. Water surface area increases are achieved in a number of ways such as by allowing the water to tumble down splash bars, by spraying or by running it over a PVC matrix. When the condenser water evaporates it absorbs latent heat from the water which is left behind. The effect of this is to cool the water which collects in the sump at the base of the tower. This is pumped back to the water cooled condenser to remove more waste heat.

Cooling tower hygiene is an important area of concern since the water temperatures in the tower are conducive to bacterial and algal growth. In particular legionnaires disease, which is a form of pneumonia, has been associated with wet heat rejection equipment. The legionella bacteria grow in the warm water of the cooling tower. They escape from the tower as part of the mist created by the flow of air and water through the tower. If ambient conditions are suitable and the bacteria carrying droplets are breathed in by a susceptible passer by a potentially fatal infection can occur. The problem is avoided by using air cooled condensers. However, dry heat rejection uses approximately 30% more energy for the same capacity as a wet method. Cooling towers can be used safely with the following precautions;

- Use of spray eliminators to prevent the release of infected droplets

- The tower should be built of easily cleanable materials such as plastics or epoxy coatings with smooth surfaces. Access doors should be incorporated into the tower to facilitate cleaning.

- The tower should be positioned away from air intakes which could draw infected droplets into the building through the air conditioning system.

- A programme of maintenance and cleaning should be carried out throughout the life of the tower. This should include dosing the cooling water with bactericides. Chemicals to prevent algal growth should also be used since algae tend to coat surfaces and give the legionella a medium on which to grow.