"Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative"

MARK THROWER MANAGING EDITOR

MODULE ONE

AIR CONDITIONING & LOW ENERGY SYSTEMS

The latest air conditioning technologies and applications

George R Norrie, managing director, City Energy Solutions

CPD FUNDAMENTALS » SERIES 12 » MODULE 1 » PUBLISHED IN EIBI MAGAZINE MAY 2014

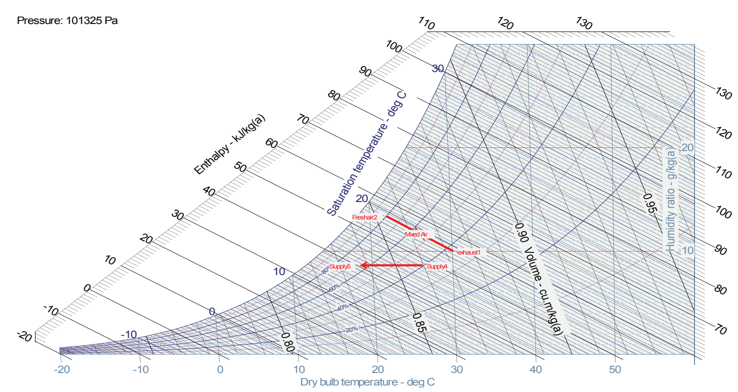
Air Conditioning is a general term used to describe the use of technology to control the environment for occupants in a building. It is generally wrongly thought of as controlling only the cooling in buildings. It is in fact the control of all the environmental factors; ventilation, heating, cooling, humidification, noise, odours and pollution (air quality). This article is designed to introduce readers to some of the various air conditioning technologies and their applications.

Various air conditioning systems exist and technologies are being implemented continually across the world as part of the search for more carbon friendly building design solutions. The implementation of the upgraded part L building regulations will require designers and operators to take a closer look at air conditioning standards in order to meet the necessary carbon targets.

Air is mainly a mixture of gases and water vapour and as such its properties vary depending on the atmospheric and internal conditions. To evaluate the specific air conditions at any point in an air conditioning system a psychrometric chart is used. In using this chart and by plotting at least two known conditions, all the actual properties of the air can be identified at that condition, including relative humidity, temperature, specific enthalpy (enthalpy = total of sensible heat + latent heat in the air) and density. By plotting the condition of the air as it passes through the air conditioning system and into and out of the building, the various humidification, heating and cooling loads can be established.

Psychrometric charts are now automated as computer programs and can be used directly to calculate the required variables by typing in two known conditions and reading off all other air data. By drawing lines along the chart between the points of the actual and required conditions, specific enthalpy, cooling and humidification loads can be calculated. The saturated water or dew point line shows where the water in the air will drop out and at what temperature. This can be useful for predicting condensation against cold walls or windows. See Fig.1.

Fig 1. Air Conditioning Theory - Properties of Air



Psychrometric Chart

System requirements

Fig.1 shows two lines. One shows the change of state when two separate air supplies are mixed equally. The first supply is the fresh air supply at 17°C and 90 per cent RH. This is mixed with re-circulated air at 30°C and 40 per cent RH. The resulting combined airstream is supplied back into the building and is at 24°C and 55 per cent RH. The second line shows constant cooling from 25°C and 40 per cent RH to 13C and 83 per cent RH. The change in enthalpy is 46-40 = 6kj/kg.

This information is used to evaluate system requirements and potential energy use. If the RH is allowed to be too high then moisture and mould growth can occur on cold walls and windows. This can be predicted and corrective action taken during the design.

The prime reason for air conditioning in buildings is to ensure that the buildings are suitable and comfortable for human occupation. This means that there is adequate clean air at a suitable temperature (ventilation), allowing for the occupants to breath normally. Air Conditioning also allows for the oxygen levels to be maintained within the building at appropriate levels (20.9 per cent) and the build up of potentially poisonous gases such as CO_2 and CO to be maintained at acceptable levels.

The first requirement of good air conditioning is adequate ventilation.

Buildings are generally ventilated by either mechanical ventilation, using electrically driven fans, which has a high energy and carbon cost or by using natural ventilation, such as by opening windows, which has lower energy and carbon implications. The type of building and required ventilation rates normally dictate the method used. Multi Floor highly

Produced in Association with energy institute occupied buildings normally having mechanical ventilation whilst more traditional buildings with up to four storey construction have natural ventilation. This however is changing as free cooling and novel methods of natural and passive ventilation are being applied to larger highly occupied buildings in order to reduce energy use and carbon emissions. Passive ventilation will be applied to almost all new buildings in the future.

Depending on the type, location and use of the building, the air conditioning requirements will differ. In order to establish the air conditioning requirements an initial specification is required from which a decision has to be made. A typical decision making tree is shown in Fig.2.

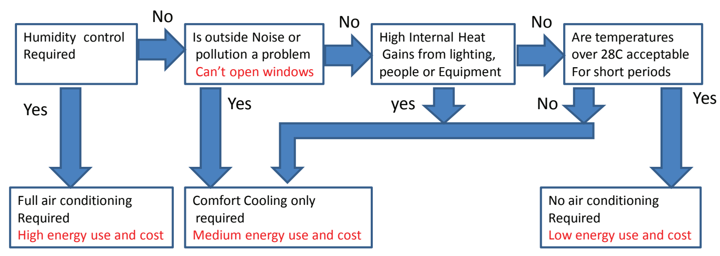
If humidity control is required then in high probably a full air conditioning system will be necessary. This would be a central system feeding the building.

If there is no noise pollution outside the building or some other reason why windows cannot be opened on warm days then comfort cooling alone may be appropriate.

If there is no humidity control required, no high internal heat gains and the space temperature can exceed 28oC for short periods, then it may be appropriate not to air condition the building.

The method used to evaluate the required ventilation rate in a room or building is by using either litres per second per person, or the number of air changes carried out per hour. The typical air flow rates range from 8 litres/sec/person for low clean areas, to 36 litres/sec/person for dirty areas such as where photocopiers are located within occupied spaces. As the room should be designed for the required maximum amount of people the air change rate is normally used in designing the ventilation systems. The recommended air change rate is dependant on the type of use and occupancy of the building. Some processes within the room or building may generate pollutants which may affect the air change rate. For example a hospital room will require greater ventilation due to the risk of air borne infection. Increasing the ventilation rate reduces the build up of contaminants and so reduces the risk. In the same way, increasing the ventilation in a room with a photocopier will reduce the build up

Fig 2. Air Conditioning Decision Tree



of the gases from the copier in the room and so the required air change rate will be higher. See Table 1 for typical ventilation air change rates.

Reduced air pollution

Since the UK introduced the law banning smoking in public buildings the potential for air pollution in public buildings due to smoking has greatly reduced. The effect has been a reduction in the recommended ventilation rates from 36 litres/sec/person to 8 litres/sec/person. See Table 2.

This has given large scope to reduce actual ventilation rates in public buildings and also to reduce energy use due to heating and air conditioning.

Air conditioning systems are required to supply and condition the incoming air into buildings. Conditioning the air at the most basic level involves only heating the building to the required occupancy temperature. In partially air conditioned buildings cooling of the incoming air may be required and in fully air conditioned buildings additional humidification of the air may be required. Filtration is normally required in mechanically ventilated buildings to ensure that the air supply is clean and free from pollutants.

The decision of whether the building will be naturally or mechanically ventilated will affect which type of heating, cooling, humidification and filtration systems are appropriate, if any, and the associated costs.

Overall heating and cooling loads are calculated based on: the ventilation heat losses and gains, the conduction heat losses and gains, and the building internal heat gains, such as lighting systems, people, machinery, office equipment etc. These are:

• fabric losses and gains;

• conduction through building envelope roof, walls floor, solar gains from windows. Simplified equation $Q_f = Ah((t_{ai} - t_{ao})$ where:

Q_f is the fabric heat loss or gain

A is the surface are of the external building

h is the average heat transfer coefficient of the surfaces in kW/m^2./C

• ventilation losses and gains

Simplified equation $Q_v = 1.2q_v (t_{ai} - t_{ao})$ where

Q_v is ventilation heat loss or gain – kW (negative is gain)

q_v is volume flow – m^3/sec

t_{ai} is inside air temp – 0C

t_{ao} is outside air temp – 0C

Q total = $Q_f + Q_v$ + Internal heat gains

Q total of the heating or cooling requirement will change continually

Table 1. Typical Recommended Air Change Rates

Assembly hall	5-10	Kitchen – small	20-40
Bathroom & w/c	6	Kitchen – large	10-20
Boiler room	4	Laundry	10-15
Changing room	10	Lavatory	5-10
Cinema	5-10	Office	3-8
Engine room	4	Restaurant	5-10
Garage	5-6	Swimming pool	5-15

and the air conditioning system will be required to deal with these changes and maintain appropriate building temperatures and conditions. The main changes will occur when changing from winter to summer conditions, when the operation of fully air-conditioned buildings will change from heating to cooling. Using the psychrometric chart and the above calculations, the size and type of the building air conditioning system and associated ducting etc, can be established.

Air conditioning can be carried out by a number of systems, these include a range from Centralised air conditioned forced ventilation systems, to localised simple heating and cooling systems with natural ventilation.

In smaller, naturally ventilated buildings independent local heating and/or cooling systems are usually most appropriate. These can be a simple wet radiator system fed from a boiler carrying out the heating, or an independent ceiling or wall mounted comfort cooling refrigeration systems. The latest low carbon designs normally use refrigeration/heat pump cassette units to provide both heating and cooling. These systems are generally lower in cost to install but require good control to ensure that they are operated efficiently. They also offer low carbon and low operating costs if well controlled. Naturally ventilated buildings do not require humidification.

Air handling units

In most large mechanically ventilated and fully air conditioned buildings the air is supplied by centrally located air handling units (AHU) which have a main fan supplying the air to the area. There is usually also an extract fan designed to extract the air from the building.

The AHU is usually fitted with an appropriate heating and cooling system to heat or cool the supplied air. The heating can be carried out by either a direct fired burner, injecting heat into the supply air stream, by a hot water or steam heated heat exchanger, mounted across the air stream, or even by electric heating elements located in the incoming air stream.

The cooling is provided by a cooling battery, which is supplied from a refrigeration system. The cooling battery is normally chilled water which is fed from a separate

For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 28**

refrigeration system although in some cases the refrigeration system can be used with the evaporator coil being directly located in the air stream. The required air temperature is maintained by controlling the air heating and cooling systems. Humidification is sometimes required and is supplied by either spraying a fine mist of water or steam into the air stream or by locating water trays in the air stream which allow the air to pick up humidity as they pass over. Humidification is normally very expensive and can be difficult to control and should be avoided if possible.

Variable speed control

Energy efficiency options are normally available for these large systems. The most common is now variable speed control over the supply and return fans.

The fans can be controlled on time and/or with carbon dioxide. The fans are run at slow speed until the levels of CO_2 start to increase, at which point the fans speed up to increase the ventilation rate.

Savings are due to reduced fan electrical power usage and reduced heating and cooling due to the reduction in air being conditioned.

Heat recovery systems are also available, some of which are described here:

• simple recirculation systems where a percentage of the exhaust air from the building is fed back into the AHU incoming air stream in order to preheat the incoming fresh air. This requires a summer/winter damper to mix the air in the winter when heating is required. It is more efficient if the damper is fully automated to maintain an optimum supply temperature especially if heating and cooling are carried out.

• recuperative heat exchangers can be fitted between the supply and extract ducts. The exhaust air and supply air are passed over the heat exchanger and the hot or cold air is recovered from the exhaust air and transmitted to the supply air to the AHU.

• run around coils can be used to recover the heat from the exhaust air; a heat exchanger is fitted into the supply and extract ducts and water is pumped between the two heat exchangers collecting heat from the exhaust air and feeding it into the supply air. This method is used normally where the supply

Table 2. Ventilation Rates - Prior to non smoking regulations

Level of smoking	Proportion of occupants who smoke %	Fresh air supply rate litre/sec/person
No smoking	0%	8
Some smoking	25%	16
Heavy smoking	45%	24
Very heavy smoking	75%	36

Large scope for ventilation and air conditioning savings due to reduced ventilation requirement since building designs prior to no smoking regulations

Recommended ventilation rates for public buildings

and extract ducts are some distance apart. Again a summer/winter control is required.

• other systems such as thermal wheels and heat pumps can be used to recover heat and reduce the energy consumption. Thermal wheels should not be used in potentially contaminated air streams.

As energy costs increase, the likelihood is that heat recovery systems will become more common and more sophisticated, recovering more energy from the air existing the building.

Most large buildings have a high level of internal heat gains through computers, lighting, office equipment and people. The building insulation levels have also increased dramatically with the improved building standards. This has made buildings easier to heat. Cooling is now the largest energy use in most commercial buildings. The average annual air temperature in all regions of the UK is below 10oC. In summer the average is around 16oC. Under normal conditions there is enough heat and cooling available from the ambient air to maintain normal building space temperatures at 23^{O}C for most of the time with little additional energy. The heat in the existing exhaust air is available for upgrading in winter and free cooling available in summer. The water temperature and ground temperatures are almost continually below 10oC and as such the scope for Heat pumps and low carbon or free cooling using water or ground source energy is high in all situations.

Buildings supplied with 100 per cent fresh air normally have heat recovery systems fitted.

Low energy air conditioning technologies are generally based on using heat pumps and refrigeration systems either to recover heat or upgrade heat. A heat pump is a refrigerator but the heat output from the condenser is used for heating and the refrigeration evaporator coil is used to absorb heat from the surrounding ambient conditions.

Heat pump types

These systems are available in these types:

• using ambient air to provide heat or cooling via an air to air or air to water heat pump/chiller;

• using river or lake water to provide heat or cooling to the air via a water to water heat pump/ chiller;

• using the under ground temperature as a heat or cooling source to supply an air to air or air to water heat pump/chiller. These ground source heat pumps operate better in the winter for heating as the ground temperature is relatively constant at 10C even when the air temperature is below freezing.

The heat pump/chiller condenser and evaporator coils in these systems can be changed over automatically to give either cooling or heating when required. As the refrigeration/heat pump system has a Coefficient of Performance (COP) of around 4 at best, then one kW of electricity used to drive the compressor will move 4kW of heat around the system providing either heating or cooling. This gives a carbon dioxide (CO_2e) value of around 1.34kg/kWh for the heat pump, against 5.37kg/kWh for electrical heating, 2.6kg/kWh for oil heating and 1.85kg/kWh for natural gas.

Ambient temperature

Buildings are generally unoccupied at night and the ambient temperature normally drops during this time. If the building is designed with passive cooling then there is scope to increase the free cooling at night when the building is empty, as the available free cooling is greater.

The most important advance in technology regarding building air conditioning and low energy design is the introduction of truly intelligent building simulation and control systems. These are now able to predict the effect of occupancy and ambient conditions on the building and optimise the buildings response by switching off lighting, cooling and heating to unoccupied areas and optimise temperature control across the building using local sensors and actuators. These systems can predict high temperatures due to solar gains and take appropriate action before the building is over heated. They offer the opportunity to optimise the use and interaction of the building H&V systems to minimise energy use and carbon emissions.

Intelligent energy monitoring and targeting systems are now sophisticated enough to allow detailed knowledge to be gained of how individual buildings behave under different circumstances. These can be outside weather conditions i.e. hot and cold days, windy days or building occupancy levels and how well the controls respond to these conditions. Using this information appropriate control strategies can be enabled and operational plans improved.

Air conditioning and low energy systems are now available to allow every air conditioned building to be operated efficiently and with minimum energy use and carbon emissions. There is now a will to implement these technologies which will incur significant capital cost but will produce worthwhile economic and environmental benefits.

Acknowledgements

CIBSE Guide B2: 2001 for Technical information in Tables

For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 28**

CPD ENTRY FORM

SERIES 12 » MODULE 01 » MAY 2014

Air Conditioning & Low Energy Systems

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

Q1. What is an air conditioning system?

☐ A system which cools a building
☐ A system which controls the condition of the Air in a building including ventilation rate, temperature, humidity, noise, odours and pollutants (Air Quality).
☐ Cooling which is supplied by refrigeration systems
☐ A ventilation system

Q2. What is now the minimum recommended ventilation air requirement in litres/sec/person in public buildings in the UK?

☐ 8
☐ 12
☐ 36
☐ 20

3. What is the average annual air temperature in all regions of the UK?

☐ 20°C
☐ 18°C
☐ Under 10°C
☐ 16°C

Q4. What is enthalpy?

☐ Enthalpy = sensible heat + latent heat
☐ Enthalpy = sensible heat - latent heat
☐ Enthalpy = sensible heat x latent heat
☐ Enthalpy = sensible heat / latent heat

Q5. What does night cooling mean?

☐ Constant temperature cooling
☐ Constant cooling during the day
☐ Constant volume cooling
☐ Cooling carried out during the night when the building is unoccupied

Q6. 100 per cent fresh air systems are normally fitted with what

☐ Heat recovery systems
☐ Spray humidifiers
☐ Reheat batteries
☐ Chillers

Q7. AHU is an abbreviation of

☐ Air Heating Unit
☐ Air House Use
☐ Air Handling Unit
☐ Air Heater Use

Q8. Thermal wheels should not be used in what type of environment?

☐ Dry
☐ Cold
☐ Wet
☐ Contaminated

Q9. Passive ventilation systems will become standard in what?

☐ Public buildings
☐ Future buildings
☐ Small buildings
☐ Large buildings

Q10. The total heat or cooling load on a building Q total is what?

☐ Q total = QFabric +Q Ventilation + Internal heat gains
☐ Q total =heat loss+ heat gain
☐ Q total = heat input + heat output
☐ Q total =heat input - heat output

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

Business ....

Business Address ....

....

....

....

Post Code ....

email address ....

Tel No. ....

Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry, P.O. Box 825, GUILDFORD, GU4 8WQ

Produced in Association with

energy institute

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

How to obtain a CPD accreditation from the Energy Institute

NEW SERIES

EiBI

Energy in Buildings and Industry and the **Energy Institute** are delighted to have teamed up to bring you this **Continuing Professional Development** initiative.

This is the first module in the eleventh series and focuses on understanding air conditioning technologies. It is accompanied by a set of multiple-choice questions.

To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to EiBI for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, for a fee of £15 (for members) or £25 (for non-members).

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject.

Modules from the past 11 series can be obtained free of charge. Send your request to mark.thrower@btinternet.com. Alternatively, they can be downloaded from the EiBI website: www.energyzine.co.uk

SERIES 11
MAY 2013 - APR 2014

1 Renewable Heat Incentive
2 The Green Deal
3 Underfloor Heating
4 Voltage Optimisation
5 Heat Pumps
6 Thermal Imaging
7 Boilers & Burners
8 Data Centre Management
9 Building Regulations Update
10 Monitoring & Targeting

SERIES 12
MAY 2014 - APR 2015

1 AirConditioning
2 First Steps in Energy Management
3 Photovoltaics
4 Utility Purchasing
5 Drives & Motors
6 Behaviour Change
7 Small Scale Wind Turbines
8 Water Management
9 BEMS
10 Lighting