GRADE 5 THESIS

Presented to the Commissioning Specialists Association

By

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Comfort Cooling

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Thesis Index

Section 1

Introduction

Comfort cooling in the UK is now becoming more widespread. The low cost of some of the DX (Direct Expansion) split units available are becoming more popular in the domestic housing market. The popularity increase in comfort cooling could be due to higher internal heat gains as properties house more electronic equipment than in previous years. Comfort cooling is now more affordable as manufacturers of such equipment can now mass produce systems at lowers costs. High CoP (Co-Efficient of Performance), energy efficient units in the commercial sector are reducing the energy running costs and making them more cost viable to install.

When considering designing a comfort cooling system for a building, various factors must be taken into consideration. These can include but are not limited to, the thermal comfort of the occupants in the building, the buildings location, the buildings use, costs and selection of system to be installed. When all the factors have been taken into consideration only then can the correct system be chosen.

The Thesis looks at why we use or need comfort cooling. I will look at the different types of comfort cooling systems available today. The basis of this thesis is to ascertain which system, within these categories provides the best choice for comfort cooling. For this I will use a typical two storey office block with open-able windows which has general open plan working areas and some cellular offices and meeting rooms.

Section 2

Thermal Comfort & Metabolism

Thermal Comfort

Thermal comfort of human beings is over a relatively small dry bulb temperature range approximately between 20°C - 27°C but has a wide humidity range of 25%RH to 80%RH.

In general air temperatures influence comfort more directly than humidity. Relative humidity ranges between 40%RH to 70%RH and is not considered to have any significant effect. Target comfort conditions for commercial and residential air conditioning applications in the UK can be taken as:

Dry Bulb Temperature : 20°C -22°C   Relative humidity: 50%RH - 60%RH

High humidities and high temperatures can feel oppresive and decrease the natural cooling process by persperation. High humidity and low temperatures cause the air to feel cold. Low humidity can cause static electricity to build up, give the feeling of dry skin and of a dry throat.

In comfort cooling the space temperature is generally controlled by a thermostat therefore the humidity levels can change depending on the temperture of the conditioned air entering the room space. In computer suites for example the humidity would be measured also and the air conditioned to keep the humidity within a tight range 50%RH to 60%RH to stop static electricity build up, this would be done with the aid of a humidifier in the Air Handling Unit.

Air Movement

Air movement also affects our feeling of comfort. The movement of air in a room helps to increase heat loss from the body by convection and can cause the feeling of draughts. The forehead, back of the neck and ankles are the most sensitive areas. Air movements greater than 0.1m/s require higher air temperatures to give the same degree of comfort

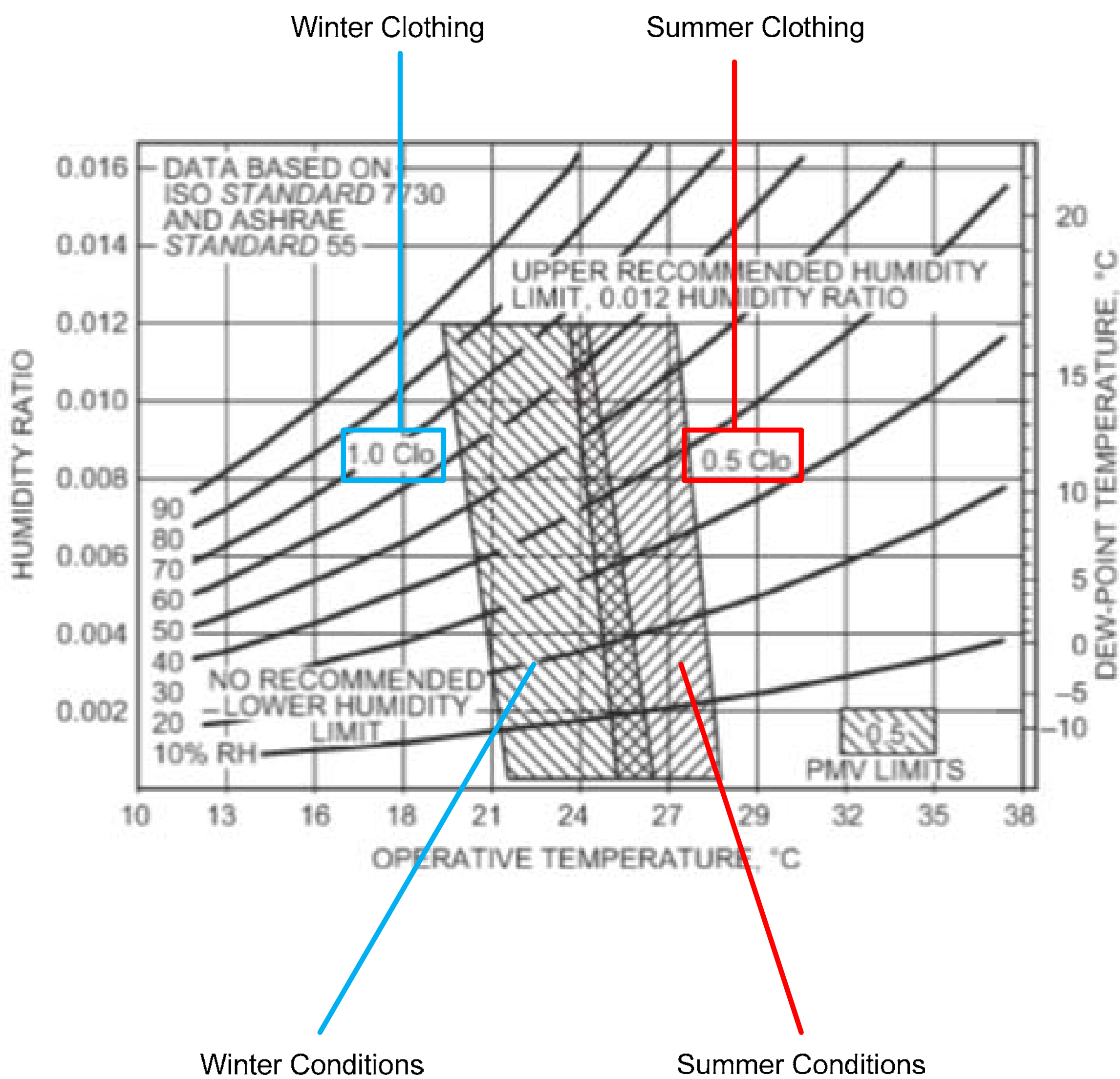


Figure 1. ASHRAE Summer and Winter Comfort Zones for Air movement less than 0.2m/s

Note: The figure shows that in winter people wear heavier clothing and the comfort temperature is lower and in summer people wear lighter clothing and the comfort temperature is higher

Human Comfort Conditions

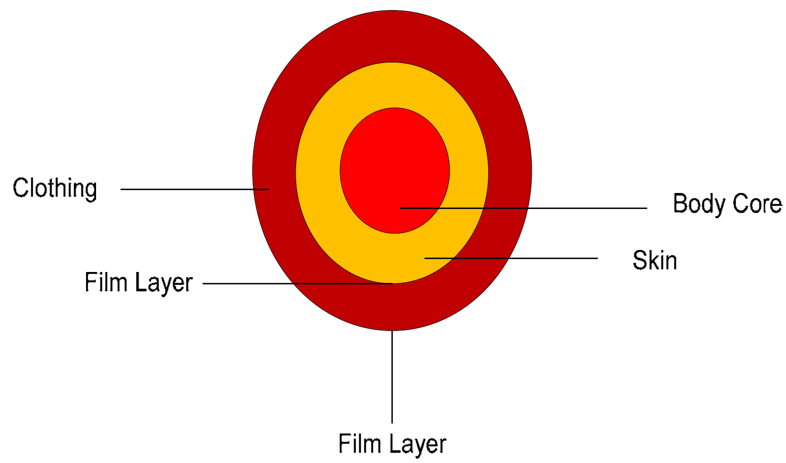
In order to appreciate the subject of human comfort it is first necessary to understand the principles of Sensible and Latent heat transfer.

Sensible heat transfer is either convective, i.e. a body exchanging heat with a fluid (air) at a different temperature through a fluid/solid boundary, or radiative where a body exchanges heat with a solid surface.

Latent heat transfer occurs when moisture evaporates from a surface. Every kg of water absorbs about 2300 kJ of heat energy when it evaporates.

The human body can be simulated by assuming it is a cylinder consisting of a "core" which is surrounded by a skin layer which offers some resistance to heat transfer and which causes the skin surface temperature to be a few degrees lower than the temperature of the body's core. Refer to figure 2 below.

Figure 2



Metabolism

The body generates energy through a process called Metabolism which turns the chemical energy from food and body fat into heat and mechanical energy. This energy is necessary to maintain life. In a sedentary state (sitting, lying) a body needs some energy to keep bodily processes functioning (breathing, pumping blood etc). It needs larger amounts when engaged in physical activity.

Since the creation of mechanical energy from another source must always be accompanied by the creation of heat (second law of thermodynamics). It follows that the body is always generating heat. If this heat is not disippated its temperature would continue to rise.The body's core temperature must be kept very close to 37°C for a person to remain healthy. Deviations of only 2°C either side of 37°C core temperature can indicate quite serious illness.

Metabolic rates depend on the level of physical activity a person is engaged in. They vary from about 70 W (sedentary) to 700 W (playing squash). A person carring out light work at a room temperatureof 21°C emits 140 watts this would be broken down as 100w sensible and 40w latent. As the room temperature rises the person would still emit 140 watts but the break down would be different as the latent output would rise while the sensible decreased.

Section 3

Comfort Cooling Development

Modern Comfort Cooling really started out in the manufacturing industry where there was a need to keep temperature and humidity controlled i.e. Printing factories, Textile factories, food manufacturing plants etc.

One of the forefathers of modern air conditioning and comfort cooling was Willis Carrier. He realised that there was a connection between humidity, temperature and dew point. These are the main constituents of the psychrometric chart that we still use today. Willis Carrier and six other engineers established the Carrier Corporation in 1915.

In 1921 the Carrier Corporation patented the centrifugal chiller. This was the first practical method of cooling large spaces.

In the United Kingdom comfort cooling in office buildings started in earnest in the 1960's. These generally had induction units or dual duct systems. In the late 1960's the shortcomings of induction system and the expense of dual duct systems led to the introduction of Fan Coil Unit and VAV systems.

In the 1970's Fan Coil Units started being used in refurbished older buildings where VAV systems because of the size of plant and ducts was not an option

In the 1990's VAV became popular especially in new office buildings especially Shell and Core type projects like the Broadgate centre and Canary Wharf.

The most popular type of comfort cooling used in warmer climates around the world in small offices and in domestic situations is the small through the wall and window type air conditioning units. These units usually contain a small sealed hermetic compressor, an air cooled condenser outside the space, a thermostatic expansion valve, an evaporator inside the space and pipework containing a refrigerant (currently normally R410).

Figure 3 Condenser Units DX split system

Figure 4 Ceiling mounted cassette unit DX System

Today with the emphasis on saving energy and lowering carbon emissions we are starting to see the advent of naturally ventilated buildings using passive cooling and mixed mode systems.

Section 4

Types of Comfort Cooling

There are various types of comfort cooling systems available on the market.

All Air Comfort Cooling (Solution 1)

All Air comfort cooling systems have air handling and refrigeration plant remote from the conditioned space. The plant is usually situated in plant areas in the basement or on the roof. The conditioned air will then be supplied into the space through a ducting system then distributed through an appropriate outlet.

The mechanical plant associated with an all air solution will be larger than other systems as it has to deliver the cooling using the air as the cooling medium to be able to cope with the demands of external and internal heat gains. The distribution systems require a building design that allows sufficient riser and ceiling or floor void space to facilitate the ductwork that enables the air to be delivered to the conditioned spaces.

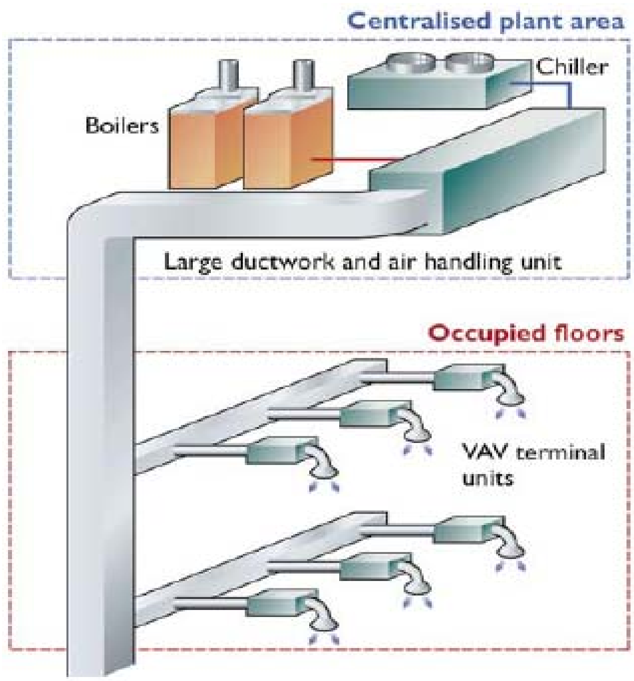


Figure 5 Air Based Comfort Cooling

List of Mechanical Plant items associated with Solution 1.

- Air Handling Unit
- Ductwork
- Chiller Plant
- Circulating Pumps
- Automatic Controls System.

Air and Water Based Comfort Cooling (Solution 2)

As with Solution 1 an air and water system will have the main air handling and refrigeration plant remote from the conditioned space. Only a small proportion of the cooling capacity to the conditioned area is provided by the air from the central plant. The majority of the cooling capacity comes from the chilled water circulated through a coil in a Fan Coil or similar unit.

The air handler associated with this solution would be smaller than in Solution 1 however the distribution systems still require a building design that allows sufficient riser and ceiling or floor void space to facilitate the ductwork and pipework that the fluids would be conveyed in from the plant to the spaces.

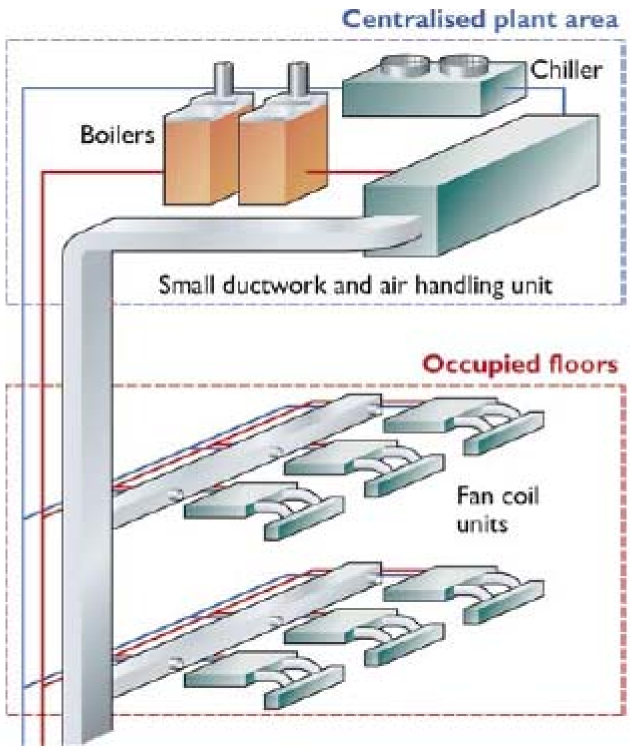


Figure 6 Air and Water based comfort cooling

List of Mechanical Plant items associated with Solution 2.

- Air Handling Unit
- Chiller Plant
- Circulating Pumps
- Pipework
- Fan Coil Units
- Automatic Controls System.

Packaged Comfort Cooling (Solution 3)

There are various types of Packaged Comfort Cooling systems (PCC) available, which can either cool, heat or cool, or heat and cool at the same time. These can include simple through the window/wall units to intelligent VRV systems containing a reversible heat pump and fan coils to produce heating or cooling, allowing different fan coil units to heat or cool. The VRV system can be quite flexible, easy and quick to install. This system also requires a small AHU to provide fresh air requirements to the building.

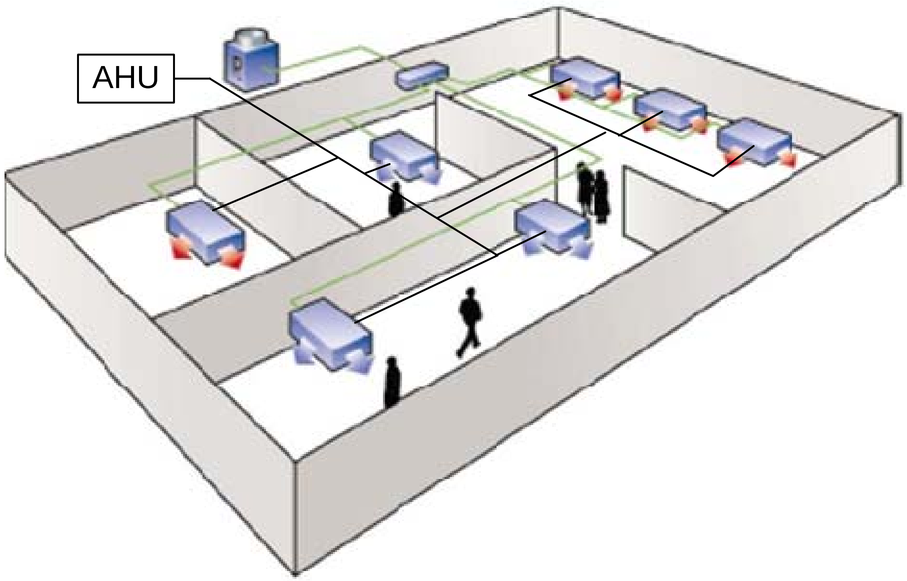


Figure 7 VRV system simultaneously providing heating and cooling

List of Mechanical Plant items associated with Solution 3.

- External Condenser
- Internal Evaporator (Fan Coils)
- Packaged Controls
- Refrigeration Pipework
- Fresh Air AHU

Passive Comfort Cooling (Solution 4)

Given the focus on reducing carbon emissions associated with Solutions 1 to 3 Passive Comfort Cooling systems are now becoming a viable option for some buildings. One type of a passive comfort cooling system makes use of thermal chimneys, in the form of tall towers or atria. The sun heats air in the thermal chimney creating convection currents that drive warm air up and out of the building, to be replaced by cooler outside air normally from the shaded area of the building.This use of the stack effect, which has been used for centuries in middle eastern countries, is now becoming common in the UK with low rise buildings having thermal chimneys on their roofs in new buildings, especially in new school and supermarket buildings.

Passive cooling makes use of the differences in wind forces, differential pressure between the windward and leeward side of a building and differences in temperature to create a ventilation path to cool the building. There are several ways that this could be achieved, these are cross ventilation, stack ventilation and single sided ventilation.

Stack Ventilation uses the simple solution of that hot air is less dense than colder air. This allows the hot air to rise and be replaced by cooler air from outside to create a comfort cooling solution. Figure 7 shows how this would work in practice.

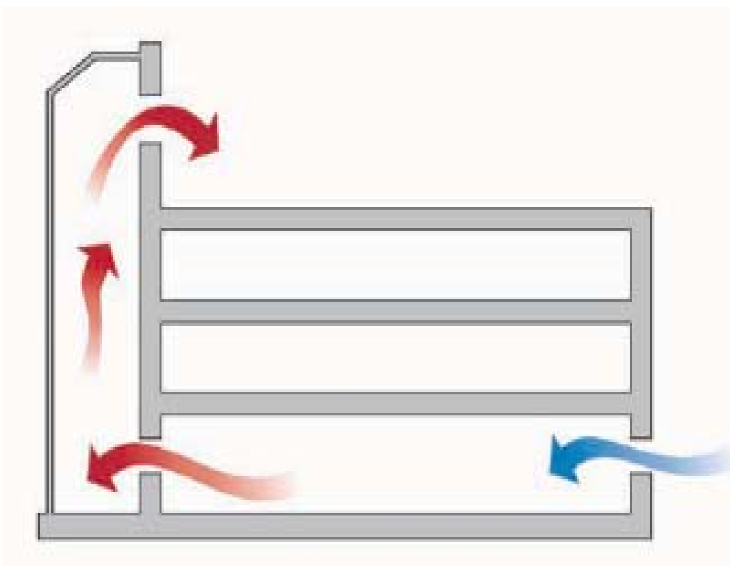


Figure 8 Stack Ventilation

Cross Ventilation

Cross ventilation uses differences in pressure between the windward and leeward of the building. This differential pressure across the building would allow the air to flow from the high pressure side (windward) to the low pressure side (leeward) creating a ventilation path and giving a cooling effect. Figure 9 shows how this would work in practice

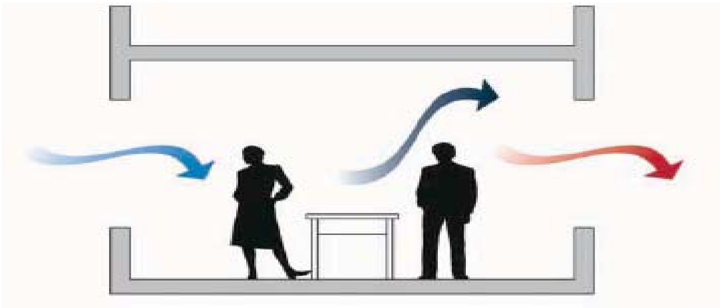


Figure 9 Cross Ventilation

Single Sided Ventilation

Once again single sided ventilation uses convection current to cause air movement. A tall window is utilised that can be opened at the top and bottom the hot air rises and moves out of the top of the window. The hot air is then replaced by denser colder air providing a cooling solution. Figure 10 shows how this works in practice

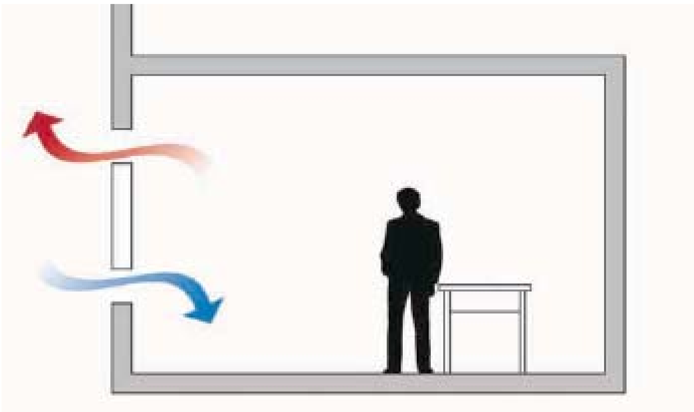


Figure 10 Single Sided Ventilation

List of Mechanical Plant items associated with Solution 4

- Control Dampers
- Automatic Control System

Section 5

Pro's and Cons of Comfort Cooling Systems

Air Based Comfort Cooling (Solution 1)

An air based comfort cooling system using large central plant can provide the user with comfortable conditions once the system has been set up correctly and fine tuned to the user's specific needs. This solution could incorporate constant volume boxes or VAV units. The VAV units could also include an internal reheat battery if required. This Solution requires large ductwork to carry the conditioned air to the space as it is using air as the medium.

This type of system when operating correctly offers the user a fixed space condition which should provide many years of use. This type of solution will require an Automatic controls system, which requires all areas to be controlled to a set point; these systems require specialist installation and maintenance.

List of Specialists Required.

- Chiller Specialist.
- Boiler Specialist
- Water Treatment Specialist.
- Automatic Controls Specialist.
- Testing and Balancing Specialist

If there are any alterations to this type of system in the future, great thought has to be given to what affect the alterations have to the system as a whole, as the system may have to be dynamically re balanced to ensure the correct conditions are maintained.

Air and Water Based Comfort Cooling (Solution 2)

An air and water based comfort cooling system using central plant can provide the user with comfortable conditions once the system has been set up correctly and fine tuned to the user's specific needs. This solution is air and water based and would incorporate primary air serving Fan Coil Units for example. The Fan Coil Units normally include Heating and Cooling batteries served by Chilled & LTHW pipework. The ductwork on this system would be smaller than Solution 1 as it is only providing fresh air. This Solution is using a mixture of air and water as the medium.

This type of system when operating correctly offers the user a fixed (user adjustable) space condition which should provide many years of use. List of Specialists Required.

- Chiller Specialist.
- Boiler Specialist
- Fan Coil Unit Specialist
- Water Treatment Specialist.
- Automatic Controls Specialist.

- Testing and Balancing Specialist

If there are any alterations to this type of system in the future, great thought has to be given to what affect the alterations have to the system as a whole as the system may have to be dynamically re balanced to ensure the correct conditions are maintained. The controls systems

Packaged Comfort Cooling (Solution 3)

This type of solution requires a smaller footprint for the external units, even for the larger installations. The space required for the routing of the fresh air ductwork and refrigerant pipework is less than that required for the ductwork of Solution 1 and the ductwork and pipework used in Solutions 2. This Solution is using refrigerant and air as the medium. The controls for this type of system are basic and user friendly and the systems can be maintained by two specialists without any input from other sources. This type of system if altered in the future requires less re commissioning than Solutions 1 & 2 and any re commissioning would be less intrusive.

List of Specialists Required.

- Refrigeration specialist
- Control specialist
- Testing and Balancing Specialist

Passive Comfort Cooling (Solution 4)

This solution is the most basic, requiring only simple control logic. This solution offers the user a low cost alternative, albeit with restrictions. This system can operate satisfactory as long as the ambient temperature is below the room temperature otherwise the user will not feel any benefit. The system will require an Automatic Controls system to operate the control dampers. The installation and any ongoing maintenance would be greatly reduced compared to Solutions 1, 2 & 3 above. Alterations to this solution are very limited due to the nature of the system.

List of Specialists Required.

- Control Specialist

Costs

Capital and Maintenace Costs associated with all the solutions above, based on a scale of 1 to 5 with 5 being the most expensive are indicted below.

<table>
<tr><td></td><td colspan="5">Cost</td></tr>
<tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Solution 1</td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td><td bgcolor="red"></td></tr>
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Section 6

Conclusion

The property used as an example is a two story office block and the conclusion reached is:-

Any of the solutions described earlier in the document could be used and each has their pros and cons.

Solutions 1 & 2 have been ruled out. The large amount of plant items and space required to facilitate them may reduce the developers' sellable footprint. These solutions could also attract planning consent restrictions which can add adverse timescales when planning a project and large capital, running and maintenance costs

Solution 4 system has its limitations to the amount of cooling it can deliver, as it is totally reliant on external temperatures, wind speeds, wind direction and orientation of the building, however should outdoor conditions be favourable it could be integrated into a mixed mode strategy to supplement energy efficiency of the other systems. This would entail modification of the controls strategy to ensure that the natural and mechanical systems run independently

Solution 3 has been selected in this instance as it uses less space, is more cost efficient to install, has lower maintenance costs and provides a more flexible system. This solution also provides the same comfort cooling benefits as Solutions 1 & 2.This solution can offer the user a flexible solution which if altered in the future will have less of an impact. This is a system that comes complete with simple packaged controls that the end user will be able to use. The ongoing maintenance of Solution 3 is less than that of Solutions 1 & 2 and the initial capital cost of the comfort cooling system makes it the most attractive solution for the sample property.

References

BSRIA Illustrated Guide to Ventilation – Pages 7 to 11

BSRIA Illustrated Guide to Mechanical Cooling – Pages 8 to 12

ASHRAE Fundamentals 2009 - Chapter 9.12

ASHRAE Handbook – Chapter 1

CIBSE Knowledge Series KS6 Comfort – Pages 4 – 21

CIBSE Guide A – Table 6.3, Chapter 1.3.1.3

Air Conditioning Applications and Design – Chapter 1, 2, 3 & 6