Keeping your cool

Keith Horsley gives an overview of the most common types of air-conditioning system and the issues that affect their installation

In these days of rising energy costs and increasingly challenging carbon emissions targets, the first thought in the minds of a design team considering the options for air conditioning for a new build or refurbishment project should be: can we do without it? Or how can the heating and cooling loads be minimised and active systems designed out as much as possible? There are many factors to consider here, ranging from the orientation of the building, window design and fabric U-values, to exposed thermal mass and solar shading.

According to its strict CIBSE definition (Guide B[1]), air conditioning implies a system which provides ventilation, heating, cooling, humidification and dehumidification. However, it is commonly used to describe systems which provide only some of these functions. Such systems should more accurately be described as 'indoor climate control' systems, a term which includes both passive and active solutions.

Fan coil systems have had to evolve over recent years to meet the increasingly challenging carbon emissions targets of successive updates of the Building Regulations

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An installed fan coil

Indoor climate control systems can be thought of in an incremental fashion. The simplest type is a heating system which operates in conjunction with natural ventilation. If properly designed, and if internal heat gains are not unusually high, this option can be perfectly capable of providing effective ventilation and good temperature control for most of the year in the UK climate.

However, if the few hours in the summer when internal temperatures peak around 28°C are considered unacceptable or if cold draughts in winter are a problem, a 'mixed mode' system may be the answer. A typical mixed mode building would be naturally ventilated (and heated when required) for the majority of the year, but would be provided with a mechanical ventilation system and, often, cooling which would kick in at times of very high or very low outside temperature.

A mixed mode solution may be effective for many buildings. However, an active indoor climate control system will be required if there are high internal heat gains, a high occupation density, a requirement for tighter temperature control or for control of relative humidity.

The CIBSE Guide B lists 20 types of active indoor climate control systems and when variations of each type are considered there are many more. This article will consider three of the most common systems.

The four-pipe fan coil

This is still the system of choice for most high-quality office developments as it is well understood in the commercial property market and provides a good compromise between performance, cost and space requirements. It is also suitable for many other building types such as laboratories, education buildings, large retail units and some healthcare buildings.

A fan coil is a terminal unit containing a filter, fan, heating coil and cooling coil which conditions the occupied space by delivering recirculated air at the appropriate temperature. Ventilation is usually provided by a separate fresh air supply and extract systems fed from central air-handling plant. Each fan coil is connected to a low temperature hot water (LTHW) system for heating and a chilled water (CHW) system for cooling, which are both also fed from central plant.

In offices, fan coil units are usually mounted in a ceiling void and are ducted to supply and extract grilles in the ceiling. However, various other configurations are used including floor-standing, wall-mounted and floor void-mounted.

Fan coil systems have had to evolve over recent years to meet the increasingly challenging carbon emissions targets of successive updates of the Building Regulations. Variable volume 2-port control systems have largely superseded constant volume 3- and 4-port control systems, and units with direct current (DC) or electronically commutated (EC) fan motors are becoming increasingly common. In all LTHW- and CHW-based systems, efficiency gains can also be made in the central heating and cooling plant – biomass boilers, ground source heat pumps, heat recovery and high efficiency or free-cooling chillers can all significantly reduce the building's carbon footprint.

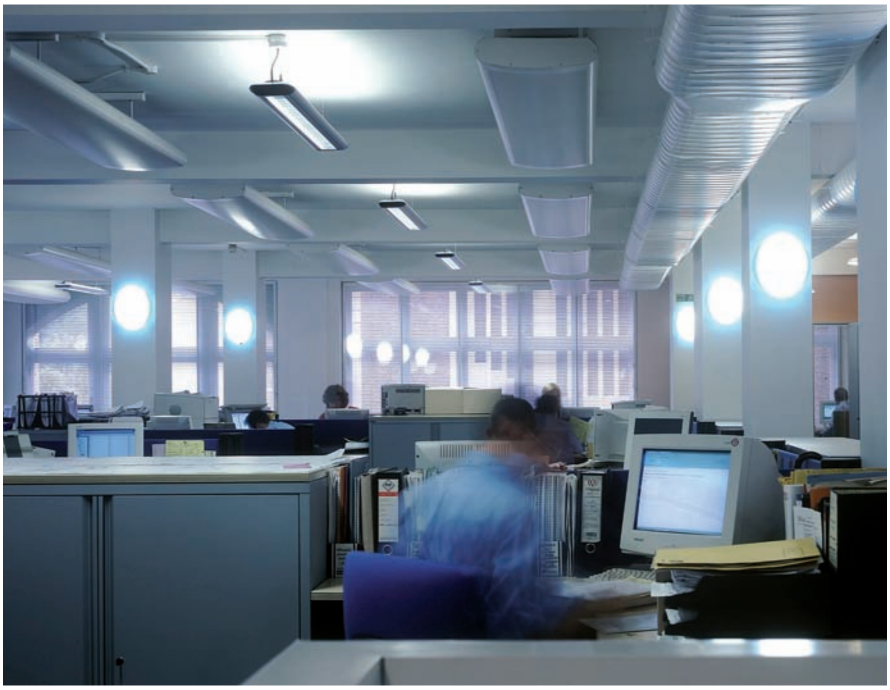
There are an enormous number of fan coil unit manufacturers in the marketplace and a wide range of products are available in terms of quality and price. The noise and efficiency of the fan are key issues to consider when selecting new units and reputable manufacturers will be able to provide full thermal and acoustic test data to help with decisions. Problems that can be experienced in older systems include vibration and noise issues, control valve failures and blocked coils. Decisions on repair or replacement of existing fan coil units would be partly based on the age of the units and the prevalence and severity of problems such as these.

Coil blockages and some control valve problems may be caused by inadequate or ineffective water treatment in the LTHW and CHW systems. This could also adversely affect the flow rates of LTHW and CHW in the system as a whole, reducing its capacity to provide heating and cooling. Depending on how far this situation has progressed, it may be rectified by flushing and re-dosing the system, installing additional filtration and rebalancing the system.

Potential energy efficiency improvements should also play a part in repair/replace decisions. For example, the energy cost savings to be made from a new variable volume DC motor fan coil system will go some way to offsetting the additional capital cost, compared to patching up an old constant volume system, as well as potentially improving the building's energy rating and earning more BREEAM points.

The typical cost of a new four-pipe fan coil system[2] is around £215/m^2. CIBSE Guide M3 lists the economic life of a four-pipe fan coil as 15 years, and the main central plant items associated with these systems have a similar or longer life.

Ceiling void-mounted four-pipe fan coil units are available in depths as small as 180mm (slightly less from some manufacturers). But it is usually the condensate pipework which determines the depth of ceiling void required because they have to be laid to a minimum fall of 1 in 100 to ensure effective drainage. Four-pipe fan coil systems have been successfully installed with a ceiling void as small as 350mm, but 500mm is a more typical size, avoiding excessive condensate drops and giving flexibility for future adaptations.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Chilled beams within an office space

Variable refrigerant volume (VRV) systems

The most prevalent alternative to the four-pipe fan coil is the variable refrigerant volume (VRV) system, also known as variable refrigerant flow (VRF). This uses a similar type of terminal unit, consisting of a filter, fan and a single, refrigerant-filled heating/cooling coil. As with four-pipe fan coil units, a number of different configurations are available.

The fan coil units ('indoor units') are linked together by a network of refrigerant pipes and connected to an outdoor unit which exchanges heat with the outside air as required. There is a limit to the number of indoor units that can be connected to each outdoor unit – this will vary depending on the manufacturer, the size of the indoor units and the configuration of the system, so it is best to seek advice from a manufacturer or installer when considering the design of a new system. Large buildings will require multiple outdoor units. Even so, this central plant is usually more compact than that required for water-based systems.

Some VRV systems can provide heat recovery when different parts of the building require heating and cooling at the same time, and this can lead to very efficient operation if the systems are configured in a suitable way. Despite this, some consider VRV to be a less environmentally friendly system due to the relatively large amount of refrigerant required (up to five times as much as a packaged water chiller of equivalent cooling capacity) and the increased risk of refrigerant leakage. Another potential pitfall is that it can be more difficult to control maximum and minimum supply air temperatures; this can lead to air distribution problems. »

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Daikin VRVIII outdoor units

A major advantage of VRV is that the space required for pipework distribution is much less, so it can be easier to fit in where space for services is limited. The typical depth of ceiling void-mounted VRV fan coil units is just a few millimetres more than the slimmest four-pipe units. VRV is also cheaper, at around £170/m², than a four-pipe fan coil system[2]. But the economic life of a VRV system, given in CIBSE Guide M as 10 years, compares unfavourably to a four-pipe fan coil system.

The factors likely to influence the decision on whether to repair or replace an existing VRV system are similar to those relating to four-pipe fan coils. Noise and vibration tend to become a problem with older systems, as does the failure of active control components. Energy efficiency gains can also be made by replacing a system that is several years old with its modern equivalent. Maintenance records should be consulted to identify other problems that might be relevant to the repair/replace decision, such as unexplained refrigerant leakage.

Because it contains refrigerant, there is another factor to consider in the repair/replace decision for a VRV system. Many existing VRV systems contain refrigerant R22 which is subject to phase-out due to its ozone depletion potential (ODP), and as of 1 January 2010 it is illegal to use virgin R22 to service such equipment. (It will be legal to use recycled R22 until 2015 but the limited quantities available are likely to be in high demand, with a price tag reflecting this.) Modern VRV systems use refrigerant R410A and have higher efficiencies than the previous generation of systems which were on the market even five years ago. It is possible to convert R22 systems to run on a zero ODP refrigerant while retaining existing pipework, but many of the components of the system would need to be replaced.

Research and development work on alternative refrigerants continues apace, since there is concern about the global warming impact of refrigerants as well as their ODP. Some manufacturers are in the process of developing VRV systems using carbon dioxide as the refrigerant. In reality, the risk of refrigerant leakage is closely related to the quality of the installation work on site, particularly pipe jointing.

Having generation, distribution and delivery of heat all carried out by a VRV system can have both advantages and disadvantages compared to a fan coil system working in conjunction with boilers and chillers. VRV offers a simpler, packaged solution, is easier and cheaper to install and commission, but is less flexible as a result.

Both four-pipe fan coil and VRV are mixing systems: they mix heated or cooled air with room air to produce the required room condition. This means that a large proportion of vitiated air is recirculated back into the space. Such systems have poor ventilation effectiveness.

Displacement ventilation systems

Such systems, where fresh air is supplied at low level, via either a floor void or through low level terminal units, have much better ventilation effectiveness than mixing systems. The air is usually supplied at just below room temperature so it tends to form a 'lake' of fresh air at low level, which rises when it meets a heat source (such as an occupant or computer) and is extracted at high level; consequently occupants generally breathe fresh air rather than recirculated room air.

Displacement ventilation systems provide limited heating and cooling and so are often employed in conjunction with static heating and cooling systems that use LTHW and CHW. Examples of static heating systems include radiators and natural convectors. Examples of static cooling systems include chilled ceiling panels and chilled beams. To prevent condensation from forming, these use CHW at higher temperatures than for four-pipe fan coil units and this CHW can be generated more efficiently.

Displacement ventilation with static cooling and heating (DVSCH) systems provide a higher quality indoor environment than either four-pipe fan coils or VRV, but this comes at the expense of greater cost (typically £285/m²) and greater distribution space (for underfloor supply, a floor void of around 400mm in addition to a 400mm ceiling void for chilled beams, slightly less for chilled ceilings).

CIBSE gives the economic life of chilled beams as 20 years and 25 years for chilled ceiling panels, however, these units are often connected to the CHW pipework system using flexible pipework connections which can have a much shorter life (10 years). As with fan coil units, there is a risk of control valve

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failures, often as a result of a lack of maintenance, and a risk of coil blockages if water treatment is inadequate. However, the chilled beam units and chilled ceiling panels themselves contain no fan or other moving parts, hence their much longer life compared to fan coil units and VRV. For this reason, other factors may be of more relevance to repair/replace decisions: static cooling systems are an integral part of the ceiling design, and displacement ventilation terminals often need careful integration with the walls or floor, so the decision on whether to repair, replace or modify such systems could be driven by interior design considerations.

Four-pipe fan coil, VRV and DVSCH are the three most common types of active indoor climate control systems in today's office market and they are also employed in many other types of building. Each has different strengths and weaknesses in terms of cost, quality of environment, space requirements, sustainability and economic life. The best choice, in a new build, will depend on an understanding of the client's priorities in relation to these factors. In a refurbishment, the restrictions imposed by the existing building are also likely to be a significant factor.

The next article will consider some less common indoor climate control systems, and others which are less commonly installed but still in use in many existing buildings.

Further information

[1] *CIBSE Guide B: Heating, Ventilating, Air Conditioning and Refrigeration*, The Chartered Institution of Building Services Engineers, 2005

[2] From *SPONS Mechanical and Electrical Services Price Book 2009* for a building up to 3,000m^2

[3] *CIBSE Guide M: Maintenance Engineering and Management*, The Chartered Institution of Building Services Engineers, 2008

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