Are you sitting comfortably?

In his final article on air-conditioning systems, Keith Horsley looks at other common indoor climate control systems

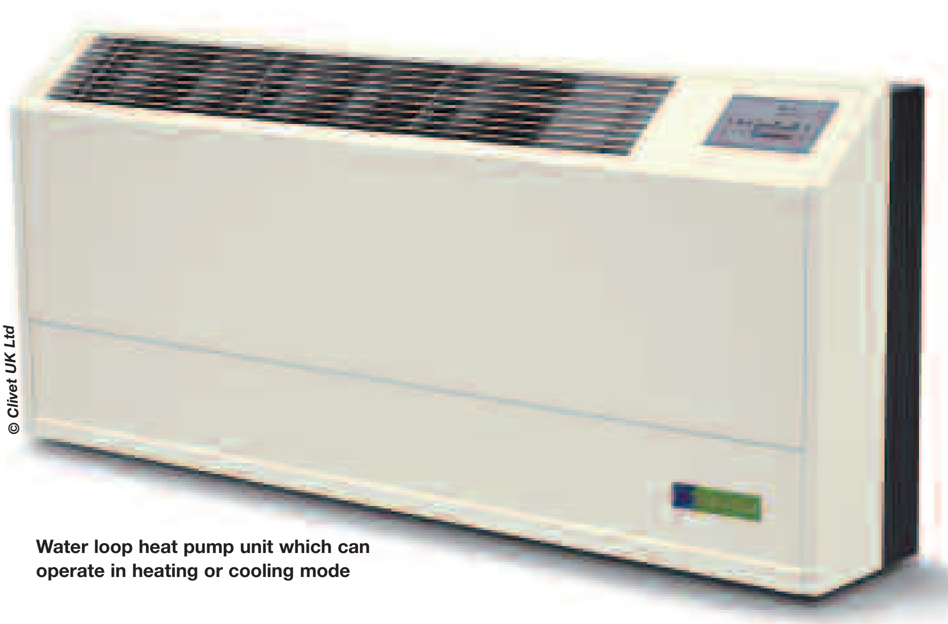
My previous article* introduced three of the indoor climate control systems most commonly specified in new buildings: four-pipe fan coils, variable refrigerant flow (VRF or VRV) and displacement ventilation with static cooling and heating (DVSCH). This article will look at a number of other types of system, less prevalent but still commonly encountered, that are capable of providing a similar level of control of minimum and maximum temperatures and, in some cases, providing fresh air ventilation requirements and control of relative humidity.

CIBSE[1] classifies comfort cooling and air-conditioning systems into three categories:

Centralised all-air systems

These employ central plant and duct distribution to treat and move all of the air supplied to the conditioned space. The use of air as the main heat transfer medium, rather than a fluid of higher thermal capacity, such as water or refrigerant, results in the need for large air-handling plant and big ducts requiring more distribution space (ceiling voids and risers) than many other systems. In essence, there are two types of all-air system. Constant volume systems supply a constant volume of air and vary its temperature to meet the heating or cooling loads of the space. Variable air volume (VAV) systems supply air at a constant temperature and vary the air flow rate to match the loads.

The use of air as the main heat transfer medium, rather than a fluid of higher thermal capacity, results in the need for large air-handling plant and big ducts requiring more distribution space



© Clivet UK Ltd

Water loop heat pump unit which can operate in heating or cooling mode

Variable air volume

VAV was a popular system in the UK until around 15 years ago, particularly in offices. It is now much less commonly used in new buildings, but still has its adherents, particularly among North American and other overseas clients.

The network of supply air ductwork terminates, in each zone, in a VAV terminal unit or 'VAV box' containing a throttling damper to control the air flow rate. Pressure controls vary the primary air flow rate accordingly. Older systems tend to use inlet guide vanes on the fans for this purpose and efficiency savings can often be realised by replacing this arrangement with a variable speed, inverter-driven fan.

An obvious limitation of the constant temperature/variable volume principle is that such a system can only provide either cooling or heating at any point in time. Sometimes the primary air temperature is varied on a seasonal basis, but in cooling-dominated buildings heating is typically provided by either a completely separate perimeter heating system, or by re-heat coils on zone supply ducts.

One problem that needs to be overcome in the design of VAV systems is that of achieving effective air distribution over a range of flow rates. Variations on the basic system, including fan-assisted and induction VAV, have evolved in response to this issue. Humidity control and provision of sufficient fresh air can also be problematic.

CIBSE Guide M[2] lists the indicative life expectancy of a VAV terminal unit as 15 years; the same as a fan coil unit. One of the most common problems in operation is failure of the dampers in the terminal units. These can easily be repaired or replaced as required. However, VAV systems of this age or older may have other disadvantages which would make it necessary to consider replacing the entire system. Due to the large quantities of air they move around the building and the high pressures required to allow the terminal units to operate effectively, VAV systems typically have very high fan power consumption. Depending on how their controls are configured, they may also provide an inefficient means of cooling. For these reasons, building owners under pressure to reduce their carbon emissions may consider replacement with a fan coil, DVSCH or VRV system.

Dual-duct air conditioning
This is another, less common, variant of the all-air system in which both heated and cooled air is distributed separately around the building and brought together, just prior to supply, in the appropriate proportion to produce air at the required temperature to meet the load. Both constant and variable volume versions of the dual-duct principle have been employed.

Partially centralised air/water systems
These generally employ terminal units which recirculate air over low temperature hot water heating and chilled water cooling coils to provide control of room temperature; central air handling plant is used to provide fresh air requirements only. The four-pipe fan coil is such an example.

Active chilled beams (ACBs)
The key difference between active and static chilled beams (SCBs) is that supply air ductwork is connected to each ACB unit and air is supplied in such a way as to create an induction effect, which improves heat transfer. Consequently, ACBs offer a higher cooling capacity than SCBs for a given size of unit. Often the primary air flow rate required to achieve this is higher than the minimum fresh air requirement for ventilation purposes. This leads to upsized central plant and distribution ducts (and hence ceiling voids and risers) compared to a DVSCH system.

However, there is no need for a deep floor void to provide low-level displacement ventilation. ACB units can also incorporate heating coils, so the need for a separate heating system can also be eliminated. ACBs use similar chilled water temperatures to static cooling units, and can therefore benefit from the same improvements in the efficiency of chilled water generation compared to other systems. This also means, however, that any dehumidification required has to be done via the primary air at the central plant.

On the face of it, ACBs seem an attractive solution but the system hasn't taken off as much in the UK as was anticipated when it first emerged in the late 1990s. This is probably due to a combination of the increased central plant and distribution requirements, and their appearance: as with static cooling, using ACBs imposes particular requirements on the ceiling in terms of high free area grilles. Typical system costs, as quoted in SPONS[3], range from £205 to £230/m^2 for an office building up to 15,000m^2.

Despite their name, ACBs contain no moving parts and therefore the units themselves require little maintenance beyond occasional cleaning. Provided they are designed correctly to eliminate excessive noise (a potential problem due to the relatively high pressure air supply), and adequate water treatment is maintained to prevent corrosion, the units themselves have a life expectancy of 20 years[2]. Problems with the system in operation are more likely to be due to failure of control components, which will require preventative maintenance and replacement from time to time.

Underfloor air-conditioning systems
Many clients who use one of these systems express high levels of satisfaction with its performance, but it has failed to become one of the most common air-conditioning solutions for a number of reasons. The system is marketed by a relatively small number of manufacturers in the UK and constitutes something of a niche market.

The system utilises 'downflow' air-conditioning units located at floor level within the occupied space. These are essentially large four-pipe fan coil units. They mix return air from the space with ducted fresh air (from central air handling plant or directly from outside) and discharge conditioned air into an underfloor supply air plenum. Air from this plenum is introduced into the space via a network of 'fan-tile' units, set into the raised floor. These discharge the air in an upward direction at high velocity which induces rapid mixing with room air.

Each downflow unit can only provide either cooling or heating to the area it serves so the supply air temperature is determined by the zone with the largest cooling requirement. Fan-tile units are provided with electric reheaters to provide heating when and where required. The return air path can either be through a separate zone in the floor void or at high level.

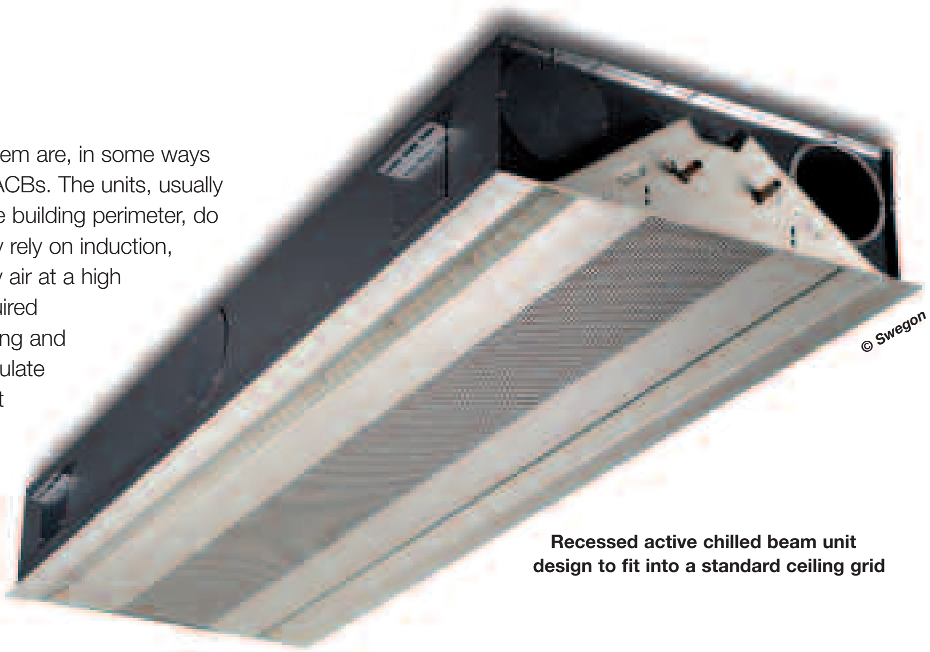
The need to locate downflow units in the occupied space leads to a loss of lettable floor area and a potential loss of flexibility. The noise from these units also has to be considered. Conversely, the ease with which fan-tile units can be relocated enhances the flexibility of the system. The use of electric reheaters reduces the system's carbon efficiency but the use of variable speed DC motors on the fan-tiles and in the downflow units can lead to low fan power consumption.

The equipment involved has many similarities to fan coil units and so maintenance and repair/replace issues are similar (see previous article). The manufacturers of underfloor systems recommend a whole life cost approach to the financial appraisal as they claim the system results in cost savings in areas other than the mechanical services. These claims need to be assessed on a project-by-project basis.

Induction air conditioning
Induction units are unlikely to be encountered in new buildings in the UK, but there are many existing installations from the 1980s or earlier. Induction units are still available from a few manufacturers so there is an option for replacement in buildings where an existing induction system meets the owners' and occupants' needs but has deteriorated due to its

»

Provided ACBs are designed correctly to eliminate excessive noise… and adequate water treatment is maintained to prevent corrosion, the units themselves have a life expectancy of 20 years



Recessed active chilled beam unit design to fit into a standard ceiling grid

age. The principles of the system are, in some ways an amalgam of fan coils and ACBs. The units, usually located at low level around the building perimeter, do not contain a fan. Instead they rely on induction, caused by introducing primary air at a high pressure, to generate the required circulation of air over the heating and cooling coils. The need to circulate relatively high volumes of air at sufficient pressure results in large, and not particularly energy efficient, central plant. The introduction of air at high velocity has a tendency to cause noise and control problems.

Local air-conditioning systems

These include systems employing terminal units that use refrigerant as their heat transfer medium. VRV falls into this category.

Split and multi-split system air-conditioning systems

These utilise a similar principle to VRV but are generally smaller systems with only one, or at most a handful, of indoor units connected to each outdoor unit. They do not have the ability to provide simultaneous heating and cooling (and heat recovery) between indoor units on the same system. Refrigerant is the heat transfer medium and refrigerant pipework connects the indoor to the outdoor units in each system. Such systems are typically used in small scale projects, where only a few rooms require cooling (domestic buildings or small offices), or when a few rooms in a large building require their air-conditioning system to be separate from the main building system, perhaps due to different operating hours. Examples of this include IT server rooms and plant rooms. A further variation is the use of through-the-wall or window air-conditioning units, in which the indoor and outdoor units are effectively combined into a single piece of equipment containing the entire refrigerant circuit.

Water loop heat pumps

This system is based around room-mounted reversible heat pump units, which contain a fan drawing room air over an evaporator (in cooling mode) coil while the condenser rejects heat to a water loop circulating around the building. In heating mode, the air coil becomes the condenser and the evaporator extracts heat from the water loop. Central cooling (chiller, cooling tower or dry air cooler) and boiler plant removes or adds heat from or to the water loop as necessary to keep its temperature within set limits. There is the possibility of heat recovery between different parts of the building. A common application is in multi-tenanted developments such as shopping centres where the landlord provides the water loop and central plant and tenants connect heat pump units to it.

As it is a refrigerant-based system, water loop heat pumps are subject to the same issues concerning refrigerant phase-out as described for VRV (see previous article*). Systems with individual refrigerant circuits for each room are also likely to be more maintenance-intensive than some alternatives and require careful design to eliminate excessive noise from the refrigerant compressors. For this reason the system is not as popular in new buildings as it once was, but there are still many examples around.

These two articles have introduced a number of types of indoor climate control system. They differ in their method of delivering conditioned air to the space, and of distributing heating, cooling and ventilation to the load. Recent legislation means that energy use will usually be a key consideration when deciding what type of system to install in a new building, or when replacing an existing installation. Although some types of system are inherently more energy-efficient than others, this is only the start of the story. Desiccant cooling, evaporative cooling, ground-coupled ventilation (earth tubes), ground source heat pumps, turbocor chillers, night cooling and free cooling are all strategies that can be employed at a central plant level. In conjunction with many different indoor climate control systems, these reduce energy consumption and carbon emissions.

Although some types of system are inherently more energy-efficient than others, this is only the start of the story

Further information

[1] CIBSE Guide B2, Ventilation and Air Conditioning

[2] CIBSE Guide M, Maintenance Engineering and Management

[3] SPONS Mechanical and Electrical Services Price Book 2009

Keith Horsley is an Associate with building services specialist Hoare Lea

keithhorsley@hoarelea.com

* *Keeping you cool*, page 18, *BSJ*, March/April 2010, *www.rics.org/journals*

The April edition of the *Construction Journal* had a theme of Building Services, *www.rics.org/journals*

Related competencies include: T013, T021