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SERIES **16** | MODULE **05** | **AIR CONDITIONING**

Air conditioning

By Adetunji Lawal principal consultant of BSSEC

The recent heatwave has shown that UK power demand rises by 350MW for each degree the average temperature rises above 20°C (Staffell, 2018). This trend makes a compelling case for greater awareness of space cooling technologies and efficiency opportunities.

Air conditioning is defined as a system that has the ability to control room temperature, humidity and air quality. The term air conditioning is often applied to systems which only provide cooling; which in reality are 'comfort cooling' systems. This article uses the term 'air conditioning' to refer to both types of systems with technical distinctions being made where relevant.

The primary mechanism central to all mechanical cooling systems is the refrigeration cycle. The principle is the same whereby heat is removed from one area and replaced with chilled dry air. A chemical refrigerant in the system absorbs the unwanted heat and pumps it through a system of piping to the outside coil. The fan draws ambient air over the condenser similarly to a 'radiator' on motor vehicles, but instead of water running through the system it contains a refrigerant gas, effectively transferring heat from the refrigerant to the outdoor atmosphere.

Typical air conditioning systems comprise:
- compressor;
- condenser;
- evaporator coil;
- blower/fan; and
- refrigerant.

In an average office, air conditioning can account for 30 per cent of energy consumption, making it a significant energy end use (Carbon Trust, 2012a).

There are several types of air conditioning systems:

Local systems are generally used to serve a single zone or small proportion of a building, usually cooling the immediate space where they are located; they are not linked to a centralised air handling system. Local systems are often used to provide comfort cooling and are employed for cooling spaces which have a different cooling schedule from the rest of the building i.e. server rooms.

Split unit air conditioning systems are the most common type of local systems, where a single indoor cassette is linked to an outdoor condenser.

Monobloc or packaged air conditioning units deliver cooling from a single unit (metal casing), inclusive of a condenser within the same casing. They are generally wall mounted with no outdoor unit; only two air vents are visible from outside, plus a small condensate pipe. They are useful where there is limited room for an external condenser.

Centralised systems are based around a packaged air handling unit (AHU) which typically contains heating and cooling coils, a filter, fans and sometimes a dehumidifier. The incoming fresh air is drawn into the AHU and passed over the coils to heat or cool the air as required. This 'conditioned' air is then supplied by ductwork to the zones/rooms within the building usually via constant volume or variable air volume systems.

Constant volume (CV) single zone systems are simple, relatively low cost and easy to commission, but cannot provide adequate control for areas or 'zones' with different/simultaneous heating or cooling needs.

Variable air volume (VAV) systems address the problem of zones with different requirements by varying the quantity of air (and hence the amount of cooling) supplied to each space.

VAV systems can be particularly energy efficient as they are able to operate the main supply and extract fans at reduced speeds. They deliver best in buildings with a year-round

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cooling demand. This often operates via a VAV terminal unit commonly called a VAV box.

Displacement ventilation systems provide cool air from a central plant, supplying it at low velocity to low-level ventilation terminals. The supply temperature is slightly cooler than the room temperature so the air rises to ceiling level by natural convection as it picks up heat from occupants and equipment. The warm air is then removed at high level.

Chilled ceilings and beams are a type of partially centralised system; they consist of ceiling-mounted panels of pipes cooled by chilled water. They transfer their cooling effect to the space by radiation or natural convection without using fans to encourage air movement.

Variable refrigerant flow (VRF) systems are where refrigerant is the only coolant material in the system (contrary to chilled water systems, where refrigerant is used for cooling/heating the water that is circulated throughout the whole system). They comprise an outdoor unit (one or multiple compressors), multiple indoor units serving different areas/rooms, and refrigerant piping running from outdoor to indoor units.

Fan coil units (FCU) are partially centralised systems which typically comprise a fan and heating and cooling coils, all housed in a metal casing. The fan draws air in a space into the unit then blows it over a cooling coil supplied with chilled water from a central plant.

Room-based reversible heat pumps are individual units which can be floor standing or concealed in the ceiling void, linked together by a piped water circuit that runs around the building. Each unit operates independently and is able to heat or cool the air in the immediate area. s

Absorption chillers use heat to drive the refrigeration cycle. They produce chilled water while consuming just a small amount of electricity to run the pumps on the unit. Whereas regular compression cooling depends on electricity, absorption cooling can run on various heat sources; making it an environmentally friendly and low electricity demand means of comfort cooling. They are now a feature in city centre locations where electrical capacity is limited.

Ground source heat pumps circulate a mixture of water and antifreeze around a loop of pipe buried underground. It transfers heat to or from the ground and then passes through a heat exchanger into a reversible heat pump. In winter, the same system can be operated to transfer heat from the ground to the building, typically via a low temperature heating system such as underfloor heating.

Ground coupling is a smart heat exchange system that utilises the natural storage of the earth to cool air passed through underground pipes or large ducts. The cooled external air can be used directly in the building when in direct mode or, for buildings that demand strict internal conditions, it can be used to pre-cool the air in a conventional system.

Air conditioning control has significantly improved with advancements in the field of micro-computers. The compressor is the primary mechanical component that is controlled; ON/OFF only controls were historically used but are now being replaced in modern systems as inverter-controlled compressors become common place. The inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature.

The inverter air conditioning units have increased efficiency in comparison to traditional air conditioners; they are quieter, have extended part life as sharp load fluctuations are eliminated and lower operational costs.

The user control device of modern air conditioning systems varies with the type of system; local systems typically have hand held wireless controllers (with temperature, louvre opening, fan speed and power on/off buttons). Wall-mounted wired controllers are also a common option, with many being used to control multiple split unit or VRF systems and incorporating programmable timer control plus fault alarms. Centralised systems are often integrated into the building management system, although offering no more than programmable timer controls.

The control of centralised systems is set to change with the EU Directive 2018/844 which mandates higher levels of control as a minimum package for systems ≥290kW from 2025.

The efficiency of cooling systems is defined in terms of Energy Efficiency Ratio (EER). For chillers it is the ratio of the cooling energy delivered into the cooling system divided by the energy input to the cooling plant. In the case of packaged air conditioners, the EER is the ratio of the energy removed from air within the conditioned space divided by the effective energy input to the units.

In view of part load conditions across a year, systems efficiency is generally based on seasonal energy efficiency ratio (SEER) which is the ratio of the total amount of cooling energy provided divided by the total energy input to the cooling plant (which may comprise more than one cooling unit), summed over the year. Manufacturers will provide the EER whilst the SEER is specific to application (building) based on four steps of load control (25, 50, 75 and 100 per cent, as below:

$$SEER = a(EER25) + b(EER50) + c(EER75) + d(EER100)$$

Where EERx is the EER measured at the defined partial load conditions of 100, 75, 50 and 25 per cent.

Where the part load data is not available, the SEER is the full load EER (Eurovent, 2014)

For plants with multiple chillers, a Plant Seasonal Energy Efficiency Ratio (PSEER) can be calculated based on the sum of the consumption of all operating chillers, but all factors that may influence the combined performance i.e. control mode (parallel or sequential) and degree of oversizing should be considered.

Within buildings there are a number of strategies with the potential to reduce energy consumption associated with the use of air conditioning, although solutions will depend on individual circumstances presented in a building, location, as well as occupant requirements.

Passive cooling strategies prevent a building from overheating by blocking solar gains and removing internal heat gains (e.g. using cooler outdoor air for ventilation). Naturally occurring air flow patterns around and in a building introduce outdoor air into the space, thus controlling heat gain and heat dissipation, with the objective of using low or no energy to improve indoor thermal comfort. Wind and buoyancy caused by air temperature differences creates air pressure differences throughout occupied spaces. Buildings can be designed to enhance these natural air flows and take advantage of them rather than work against them. An example is the Lanchester Library in Coventry University, although having a 10,000m^2 area spread over four floors, it is almost entirely naturally ventilated except for one very small area with a high density of PCs. This was achieved following a sustainable architectural brief prior to construction.

Night cooling is an established technique where cool night air is passed through the building to remove heat that has accumulated during the day. The cooler night time air flushes and cools the warm building structure/mass.

Avoid simultaneous heating and cooling, most air-conditioned areas need not be cooler than 24ºC, therefore a good temperature gap should be set between the heating and cooling set points; say between 19-24ºC, to create a comfortable 'dead band' where no heating or cooling is operating. When implemented, both systems will not operate simultaneously.

Improving the building fabric will reduce cooling energy costs as poor insulation resulting from gaps or holes in the fabric leads to energy waste.

Consider replacing window glazing with special heat-reflective glass or adding anti-glare film to prevent heat build-up. With solar reflective film applied to windows, the 'greenhouse effect' can be prevented, enabling a

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reduction of solar rays by up to 60 per cent.

Install passive infra-red sensors (PIR) on individual cooling units. This has proven effective in many buildings. The PIRs work by switching off air conditioning systems when occupancy is not detected after a set time.

User awareness and training are vital as buildings have multiple split units but no operating manuals or guidance. Therefore. occupants operate controls inefficiently, commonly setting temperatures to the lowest possible. Easy to understand instructions should be provided for systems across board.

Air Conditioning Inspection Report (ACIR) recommendations should be followed through and incorporated into the maintenance plan, rather than being treated as a regulatory tick-box exercise. ACIRs highlight potential issues with plant operation, review sizing and how the energy consumption of the systems could be reduced. ACIRs are currently required in buildings with a combined installed cooling capacity of 12kW, with the threshold expected to rise to 70kW by 2020.

Upgrading controls to those that take advantage of connective technologies are now easy to implement. Several manufacturers now offer Wi-Fi enabled wall mounted controllers enabling individual Air conditioning systems to be linked with a remotely monitored platform. This ensures they can be programmed on a time schedule and are all coordinated, eliminating scenarios where few units operate excessively to cool large spaces out-of-hours.

Install variable speed drives (VSDs) on fans and pumps which do not need to operate at full speed all of the time. Fans used to move cool air around a building consume a major part of the energy used by conventional centralised air conditioning systems. The amount of energy used by the chiller is generally much lower than the fan energy in air-conditioned buildings in the UK.

Installing sub-metering to chiller plant and AHUs will enable detailed consumption data to be collected

Table 1: Minimum EER for comfort cooling as recommend in the Non-Domestic Building Services Compliance Guide. Source: HM Government (2013).

Recommended minimum EER for comfort cooling		
Type		Cooling unit full load EER
Packaged air-conditioners	Single duct	2.6
	Other types	2.6
Split and multi-split air conditioners >12KW		2.6
Split and multi-split air conditioners ≤12KW		SCOP 'D' rating for median temperature range in BS EN 14825:2013
Variable refrigerant flow systems		2.6
Vapour compressions cycle chillers, water-cooled ≤750 KW		3.9
Vapour compressions cycle chillers, water-cooled >750 KW		4.7
Vapour compressions cycle chillers, air-cooled ≤750 KW		2.55
Vapour compressions cycle chillers, air-cooled >750 KW		2.65
Water loop heat pump		3.2
Absorption cycle chillers		0.7
Gas engine-driven variable refrigerant flows		1.0

and analysed. The data analysis will help identify control failures, unnecessary plant start-ups and set performance targets.

Many air conditioning systems use HFC refrigerants, with most commonly used HFCs being R-404A, R-134a and R-410A. These refrigerants all have a very high global warming impact if they are released into the atmosphere.

The 2014 EU F-Gas Regulation (517/2014) aims to further control and phase down the use of fluorinated greenhouse gases across Europe. From 2025 F gases with a GWP >750 will be banned in 'single split' systems that contain less than 3kg of refrigerant. The ban excludes larger Air conditioning or heat pump systems e.g. chillers or larger split systems.

Building owners need to ensure compliance with the F-Gas Regulation and understand its impact when selecting new equipment.

Other important mandatory requirements relate to:

- leak checking frequency linked to CO_2 equivalent of the refrigerant gas;
- leak detection equipment required where 500 tonnes of CO_2 equivalent or more of refrigerant is installed;
- recovery of HFCs during plant maintenance and at end-of-life;
- detailed record keeping; and
- using F-Gas trained technicians for installation and maintenance.

Further reading

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AIR CONDITIONING

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

1 By how much does the UK power demand rise by for each degree that the average temperature rises above 20°C?

☐ 50MW ☐ 150MW ☐ 250M ☐ 350MW

2 In mechanical cooling systems, what is responsible for absorbing the unwanted heat and pumping it through a system of piping to the outside coil?

☐ LPHW
☐ Oxygen
☐ Chemical refrigerant
☐ Solid matter

3 In a typical office, air conditioning can account for how much of the total energy consumption?

☐ 10% ☐ 20% ☐ 30% ☐ 40%

4 Which of the following types of air conditioning systems addresses the problem of zones having different requirements by varying the quantity of air supplied to each space?

☐ Variable air volume systems
☐ Displacement ventilation systems
☐ Air source heat pumps
☐ Ground source heat pumps

5 What is the recommended minimum EER for packaged air-conditioners?

☐ 1.0 ☐ 2.6 ☐ 3.9 ☐ 4.7

6 Which of the following definitions correctly defines passive cooling strategies?

☐ Cool night air is passed through the building to remove heat that has accumulated during the day.
☐ Circulating a mixture of water and antifreeze around a loop of pipe buried underground.
☐ Partially centralised systems which typically comprise a fan and heating and cooling coils.
☐ Preventing buildings from overheating by blocking solar gains and removing internal heat gains (e.g. using cooler outdoor air for ventilation).

7 Which of the following is NOT a renewable method of cooling?

☐ Fan coil units
☐ Absorption chillers
☐ Ground coupling
☐ Ground source heat pumps

8 Applying solar reflective film to windows can help to prevent the 'greenhouse effect'. By how much can it reduce solar rays entering buildings?

☐ 20% ☐ 40% ☐ 60% ☐ 80%

9 Air conditioning inspection reports are currently required in buildings with a combined installed cooling capacity of how many kW?

☐ 4kW ☐ 6kW ☐ 8kW ☐ 12kW

10 Many Air conditioning systems use HFC refrigerants, which all have a very high global warming impact if they are released into the atmosphere. From 2025, F gases with a GWP of how much will be banned in 'single split' systems that contain less than 3 kg of refrigerant?

☐ >350 ☐ >750 ☐ >1,150 ☐ >1,550

Please complete your details below in block capitals

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