CIBSE JOURNAL

The official magazine of the Chartered Institution of Building Services Engineers

October 2016
www.cibsejournal.com

HOTEL AND LEISURE SPECIAL

TRIP ADVISOR
Ensuring optimum designs for CHP systems in hotels

STATE OF THE ART

Innovative services at the Tate Modern extension mirror progressive art within

Fan coil unit CPD with this issue
See page 15


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ART MEETS DESIGN

The Tate Modern extension hasn't just been making waves in the art world – its cooling and heating strategies are as cutting-edge as its contemporary art (page 4).

The gallery's previous incarnation as a power station is mirrored in Max Fordham's services strategy, which uses waste heat from a large arrangement of transformers on site.

It also uses ground water pumped from a five-metre-deep bed of river gravel beneath the gallery. The gravel has been deposited by the nearby River Thames over thousands of years, and is saturated with water, which is used to provide cooling directly to the building's air handling units (AHUs).

With almost five million visitors each year, close environmental control is essential in the Tate Modern to protect the exhibits. Max Fordham used a desiccant dehumidification solution to ensure the Duchamps and Picassos can withstand the crowds .

On page 8, Gary Stoddart makes the case for using correctly sized combined heat and power plants for heating, hot water and electricity in hotels. When the monthly electricity bill for a typical 200-room hotel in central London comes in at around £50,000, Stoddart claims CHP could be an appropriate energy- and cost-saving measure.

Many hotels boast wellness facilities, such as spas and pools, so it is important that they take water hygiene seriously. On page 10, Steven Booth explains that many businesses are tempted simply to increase the dosage of chemicals to prevent the risk of legionella, but that non-chemical alternatives to water treatment are often a more effective and sustainable option.

As well as spas, developers are using high-end bars to attract well-heeled clientele to hotels and apartment schemes. On page 12, our cost model covers the fit-out of a bar on the 15th floor of a development in the City of London, while the evolution of fan coils is explored in this month's CPD (page 15).

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Editorial copy deadline: First day of the month preceding the publication month

Printed by: Warners Midlands PLC

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Tel: +44 (0) 20 8675 5211. www.cibse.org
©CIBSE Services Ltd. ISSN 1759-846X

Subscription enquiries

If you are not a CIBSE member but would like to receive *CIBSE Journal*, subscribe now! Costs are £80 (UK) and £100 (international). For subscription enquiries, and any change of address information, please contact Nicola Hurley at nhurley@cibse.org or telephone +44 (0)20 8772 3697. Individual copies are also available at a cost of £7 per copy plus postage.

The 2016 US annual subscription price is £100. Airfreight and mailing in the US by Air Business, C/O Worldnet Shipping NY Inc, C/O Air Business Ltd / 155-11 146th Street, Jamaica, New York, NY11434. Periodical postage pending at Jamaica NY 11431. US Postmaster: Send address changes to *CIBSE Journal*, C/O Air Business Ltd / 155-11 146th Street, Jamaica, New York, NY11434.

Cover image: Ron Ellis / Shutterstock

ABC audited circulation: 18,625 January to December 2015

PEFC/16-33-775


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THE ART OF COOLING

Its façade is not the only thing that's cutting edge about the new Tate Modern extension – it uses water from the gravel below to cool and heat the galleries inside. **Andy Pearson** explains the innovative strategy

The Tate wanted the environmental design of the Switch House extension to London's Tate Modern gallery to be as cutting-edge as the art installations it showcases.

'The client's brief was for the building to be agenda-setting and to take a leading role in sustainability,' says Mark Nutley, senior partner at Max Fordham, the project's environmental engineers.

Max Fordham's scheme does not disappoint. It uses ground water pumped from river gravel below the site, desiccant dehumidification and even waste heat from electrical transformers to create the ideal environmental conditions for the Tate's priceless works of art, while ensuring millions of visitors are comfortable.

Max Fordham's first involvement with the Thames-side gallery was in autumn 2007, after architect Herzog & de Meuron had radically changed the design for the extension from a jumbled collection of glazed boxes to a folded, perforated brick façade, wrapped around a 10-storey-high truncated pyramid.

Herzog & de Meuron was also the architect that transformed the 1950s power station into a contemporary art gallery for the millennium. At the time, It was designed to be a fully air-conditioned box.

With almost five million people passing through the Tate Modern each year, air conditioning and humidity control are essential in the galleries, to protect exhibits. The circulation areas, toilets and members' areas are also all air conditioned.

But given concerns over climate change, air conditioning the entire

PROJECT TEAM

- **Client:** Tate Modern
- **Building services engineer:** Max Fordham
- **Architect:** Herzog & de Meuron
- **Lighting:** Arup

building was no longer appropriate for the extension's environmental strategy, says Nutley. 'For Switch House, we adopted a different approach that is pioneering in a gallery environment,' he adds.

Creating the right conditions

Max Fordham developed solutions specific to each type of space – be it a gallery, restaurant or circulation area – to ensure the most appropriate low-energy design. 'The heating and cooling strategy was driven by an ambition to reduce energy consumption to as low a level as realistically feasible,' says Nutley.

Because of their critical importance, the Tate was very prescriptive about the environmental conditions that had to be maintained in the galleries to protect the artwork and ensure that works

> The engineer has pioneered the use of ground water trapped in a five-metre-deep bed of river gravel beneath the site as a source of cooling for the AHUs

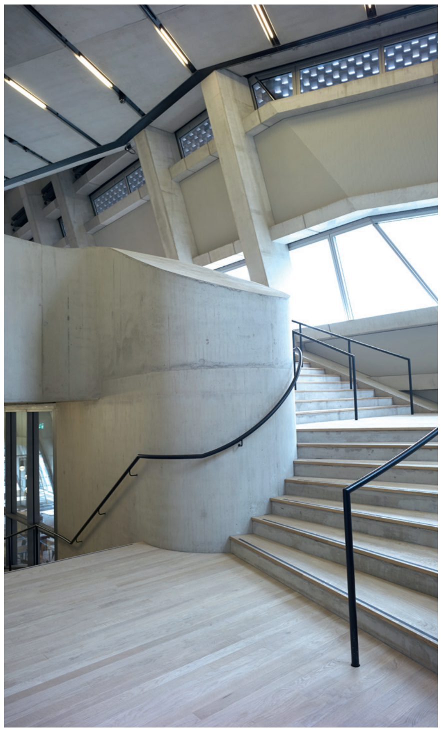
continue to be loaned to the Tate from other galleries. As per the international loan standards for art, the temperature is maintained between 18°C and 25°C, and the relative humidity (RH) between 40% and 65%. 'People won't lend to a gallery unless appropriate conditions can be maintained,' says Nutley, who adds that the Tate is happy to 'vary conditions slightly' to save energy as the seasons change.

In winter, for example, the extension's galleries are maintained at the lower end of the temperature and humidity range, but still within loan standard criteria. This means that the galleries aim for a temperature of 19°C +/- 1°C and an RH of 50% +/- 5%. In summer, the limits are increased to 22°C +/- 2°C, with an RH of 55% +/- 5%. 'The important thing is limiting the speed of variation – you want a maximum of 10% variation in RH and a 4°C change in temperature in any 24-hour period,' says Nutley.

A displacement ventilation system supplies conditioned air to the extension's three gallery floors; conditioned air is supplied through floor grilles and extracted at high level. This is a similar strategy to the one used in the original Tate Modern building. The main difference is that air is ducted to the floor grilles in the extension, whereas conditioned air in the power station reaches the floor-mounted grilles through a pressurised, raised-floor void.

'The problem with floor voids in galleries is that they can get dusty, so by ducting the air, it makes the system easier to clean,' Nutley explains.

Ductwork supplying air to the floor grilles is run at high level in the gallery below – along with that gallery's high-level extract ductwork – from where it punches up through the floor slabs to the grilles. In



the larger, lower-level galleries, the supply and extract ductwork have been painted white and left exposed. 'The ductwork in the ceiling can be seen, but it doesn't detract from the artwork,' says Nutley. On the upper floors – where the smaller galleries are situated – the extract ducts are hidden above a suspended ceiling.

Innovative cooling

Each gallery has a dedicated air handling unit (AHU). In an unusual low-energy solution, the engineer has pioneered the use of ground water trapped in a five-metre-deep bed of river gravel beneath the site as a source of cooling for the AHUs.

The gravel has been deposited over thousands of years by the meandering of the adjacent River Thames. It is saturated with water permeating into the ground from soft landscaping, leakage from the Thames and from sewers, and from several of London's buried rivers. The water the gravel contains flows very slowly eastwards towards the sea. 'In the past, schemes have used water from the chalk aquifer beneath London for ground-water cooling, but using the river gravel on this scale is pioneering,' says Nutley.

Water is extracted from the gravel at a rate of up to 30 litres per second – at a 'useful' temperature of 14-15°C – via two boreholes situated close to the Tate's western entrance. The gravel is between 5m and 12m beneath the surface, so pumping water up from them does not consume a significant amount of energy.

Once at the surface, the water passes through a heat exchanger to keep it separate from the sealed gallery systems. The borehole-cooled water is then passed through large coils fitted to the extension's numerous AHUs. 'Although it passes through a heat exchanger, we effectively use it to provide cooling directly to the AHUs,' says Nutley.

The scheme also features three water-cooled chillers. These supply higher-grade chilled water to cool some of the basement spaces and other ancillary areas.

Heat rejected by the chillers is removed by the borehole water and returned to the gravel via three boreholes sunk into the landscaping to the north of the gallery. 'Compared to using air-cooled chillers, it is a very efficient solution,' says Nutley.

In winter, the borehole water is also passed through a heat pump. The heat generated is used to satisfy part of the building's heat demand. Backup heat is obtained from spare capacity in the existing gallery's boilers. 'The boreholes provide all of our cooling and a fair bit of our heating as well,' says Nutley.

Another pioneering approach is the design of the building's systems to maximise the use of waste heat produced by UK Power Networks' large arrangement of transformers that supplies the City of London with 11kVA of power.

The transformers' Bankside location is a relic of the Tate Modern's previous incarnation as a power station. They were originally housed in the entire Switch House, but were relocated to its east end, enabling the extension to be built. They are water-cooled, and relocating them gave the engineers the opportunity to use the rejected heat in the new extension.

Controlling humidity

Humidity control is critical in the galleries. The conventional approach to dehumidifying fresh air is to over-cool it so the water vapour condenses from the air, before reheating it to bring it back up to a comfortable supply temperature. This process uses a large amount of energy.

However, the significant quantity of low-grade cooling and heat available from the boreholes and the transformers enabled desiccant dehumidification to be applied to remove moisture from the extension's fresh-air supply.

Desiccant material easily attracts and holds water vapour. A 4m-diameter desiccant wheel is used to dehumidify the fresh-air supply to the Switch House extension. The moisture absorbed by the wheel is then driven from the desiccant using the low-grade heat in the reactivation air stream, which recharges the desiccant. The dehumidified air is ducted to each of the dedicated gallery AHUs, where it mixes with the recirculated gallery air.

Outside of the galleries, the above-

Illuminating art

Jeff Shaw, SLL president and associate director at Arup, explains the lighting strategy at the Switch House extension

Having worked on the original Tate Modern in the late 1990s, Arup was appointed for all lighting design for the new Switch House extension.

A key challenge for the design of the internal lighting was to develop a scheme that integrated with – and accentuated – the architecture of the new spaces, while maintaining a feel consistent with the existing building.

The scheme for public circulation comprises bare fluorescent lamps slotting between precast concrete panels, both to complement the form and finishes of spaces, and to help draw people through the vertical building towards the galleries and other public areas.

This approach is adapted to take into account the lighting requirements for the wide variety of social and educational spaces for patrons, enhancing the overall visitor experience. LED cast-glass decorative pendants add character and sparkle to the dining spaces without distracting from the spectacular views over London.

The Switch House includes a variety of new gallery spaces, giving it flexibility to display a wide range of artworks. Galleries on Level 3 are more intimate spaces with track and spotlights only. The larger galleries on Levels 2 and 4 are supplied with homogenous ambient light using high colour rendering fluorescent lighting, with exposed lamps on Level 2 and backlit ceilings on Level 4. Half of the Level 4 gallery space also has generous – but controlled – levels of daylight through a system of skylights above the ceiling, with the sunlight blocked by external shading and the daylight diffused to create a comfortable and appropriate daylit environment for viewing and for protecting the art on display.

The LED spotlights used in the galleries – barely distinguishable in quality and appearance from traditional halogen lighting – more than halved the gallery energy demand from that of traditional galleries.

ground circulation spaces in the extension – along with the office and education spaces – are predominantly naturally ventilated. Max Fordham's decision to use natural ventilation was, in part, because of the large areas of concrete in the extension's soffits, walls and lift cores. 'It is almost cathedral-like in the quantity of exposed mass,' says Nutley.

To boost the performance of the thermal mass, the engineers embedded cooling pipework into the concrete floor slabs in the circulation, office and education areas. In fact, thousands of metres of pipework is installed in the precast concrete floor slabs, significantly enhancing their thermal-storage capability to help keep conditions comfortable for visitors.

The thermal mass is cooled at night. Outside air enters the spaces through high-level automated, opening windows on one side of the building, and exits on the opposite side. The opening windows are secure because – as well as being high up – most are located behind perforations in the brick façade.

Heat is removed from the floor slabs by running chilled water through the embedded coils at night. The system uses the low-grade chilled water extracted from the river gravel via the borehole system. 'Cooling the slabs using the borehole water supplements the natural ventilation in summer, when visitor numbers and air temperatures are at their peak,' says Nutley.

Away from the galleries, the majority of the services in the tower had to run within the floor void to maximise the amount of thermal mass in these areas. The sprinkler pipework – plus the lighting, fire alarm, security and data cabling – drop from the floor void, through the concrete slab integrating into the 'slot detail'.

The slots are located between the precast concrete soffit planks, housing all the services. 'It is an elegant solution; it looks simple, but was a very difficult coordination exercise.'

Buffer spaces have been designed to separate the carefully controlled environment of the galleries and the circulation spaces. 'The problem with a gallery as popular as the Tate is that doors – which would be open for much of the time – cannot be used. Instead, buffer spaces are installed,' says Nutley.

These rooms act as introductory areas, which visitors pass through when entering a gallery. They are over-pressurised with air, creating 'a curtain' between the two areas. 'It is a zone where you cannot guarantee the environmental conditions,' says Nutley.

The Switch House opened its doors to visitors in June. It is early days for the environmental systems but, over the course of a year, Max Fordham's scheme is expected to use 50% less energy than a typical gallery – which should see the Tate meet its objective of taking a leading role in sustainability.

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> The problem with a gallery as popular as the Tate is that doors – which would be open for much of the time – cannot be used. Instead, buffer spaces are installed

STAYING POWER

With a 24/7 demand for heating, hot water and electricity, hotels are good candidates for combined heat and power – but they must be sized properly and have a suitably high load, says Senertec's **Gary Stoddart**

According to the Carbon Trust, annual energy costs for the hospitality sector are in excess of £1.3bn, and carbon emissions equal to more than eight million tonnes per year. With hospitality businesses – especially leading hotel brands – expanding rapidly, energy consumption in the sector could increase dramatically.

As with many UK buildings, heating and hot water are the biggest users of energy in hotels,[1] and the monthly electricity bill for a typical 200-room hotel in central London will be £50,000.[2] Combined heat and power (CHP) can be an appropriate energy-saving measure, and hundreds of units are already installed in hotels across the UK.[3]

Hotels are suited to CHP because they are, generally speaking, always open and have high, year-round, 24/7 requirements for heating, hot water and electricity; CHP units with long-running hours achieve the most efficient operation. CHP units use natural gas or LPG to generate electricity – although some units use alternative fuels, such as biomass – replacing electricity drawn from the grid. With an energy cost ratio of around 3.5/1 (electricity 15p per kWh/gas 4p per kWh), the savings are calculated using the cost of energy input to the unit (natural gas), the value of the heat output (thermal) and the electricity produced. Typical payback periods are around seven to 10 years, but five is possible. The increasing difference between the price of electricity and the cost of natural gas – the 'spark gap' – is making the case for CHP even stronger.

The Carbon Trust has data from hotels using CHP. A large luxury hotel with 400 rooms, a heated indoor swimming pool and a gym, for example, achieved annual savings of more than £50,000 and reduced CO_2 emissions by 1,000 tonnes per year. Meanwhile, a medium-sized hotel – with 60 bedrooms, a swimming pool and fitness facilities – realised savings of £7,000 per year, with payback of less than five years.

> Worryingly, a large number of CHP units installed are not running as intended

However, savings of this nature can only be achieved if systems are designed and commissioned carefully and correctly. Worryingly, a large number of CHP units installed are not running as intended – but this situation could easily be rectified by all parties being involved from the start to ensure systems are sized correctly. The CIBSE AM12 document urges designers to seek the advice of CHP suppliers 'at an early stage of the design'.

A key point to remember is that CHP needs to be as small as possible. If the heat demand is not present, oversized CHP will not run, and the anticipated electricity will not be generated. If a unit is not running, the payback period is not reduced and energy savings are negated. Unfortunately the '10 per cent for luck' rule is often applied, so many buildings have larger plant than required. This not only costs more to buy, but will not operate efficiently, leading to higher operational expense.

When looking at the feasibility of CHP, we review the base load for electricity and heat. For example, the heat produced on a mini-CHP unit is between 12.5kW and 15.5kW – depending on the return temperature to the unit – and the electrical output is 5.5kW. If the base load is above these figures, the CHP will run continuously, and the heat and electricity will be used in the building – which is the ideal.

Heating is, of course, very seasonal, so care has to be taken not to oversize the heating contribution from the CHP. Oversizing can result in the unit having far too much capacity for the hot-water system in the summer, leading to long shut-down periods and extending the payback. Ideally, designers need to consider running CHP 24/7, and

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storage is often the best solution, especially if a site has peak demands for hot water – as is the case with hotels. The heat produced by the CHP unit can be stored in a preheat cylinder, and the hot water used over the hotel's peak periods – 7.30am until 9am, and 4.30pm until 7pm, for example. If the peak periods are greater than this, the storage capacity can be reduced.

Hotels with swimming pools are particularly suitable for CHP, as they offer another way to dissipate the heat successfully. An onsite restaurant and/or laundry will add to the hot water load and increase the preheat cylinder size, allowing for larger CHP to be installed and run 24/7.

The Carbon Trust suggests that the best time to consider CHP for an existing building is when the heating plant is being replaced, so the technology can be integrated with the heating system (a CHP unit works with existing boilers and/or water heaters, with the system always drawing on the storage first). This will also enable a hotel to more easily accommodate the CHP equipment – typically comprising the unit, a buffer vessel and preheat cylinder(s). The components don't have to be located together, and leading manufacturers should assist with plantroom sizing and layout.

For long-term operational success hotels should arrange a long-term CHP maintenance contract, to ensure systems continue to perform efficiently. CHP engines are maintained on a running hours basis –the maintenance period for the Dachs Mini-CHP is 3,500 operating hours. Putting an effective remote-monitoring system in place can also keep track of how the CHP unit is performing, and alert the end user when a service is due.

CHP has a huge role to play in improving the efficiency of UK buildings, particularly those with high and continuous, year-round heating loads, such as hotels. But if savings are to be achieved, correct sizing must become a priority, along with effective maintenance and monitoring.

References:

1 Hospitality: Saving energy without compromising service, Carbon Trust, July 2015 **bit.ly/2defcFT**

2 Four pillars for energy savings in hotels, Carbon Trust 2015 **bit.ly/2cGH3Ty**

3 CHP Statistics: Industrial and Buildings CHP, Association for Decentralised Energy **www.theade.co.uk/chp-statistics_2865.html**

SPA TREATMENTS

Leisure facilities are wise to take water hygiene seriously, but this does not excuse the overuse of chemicals. **Steven Booth**, at Guardian Water Treatment, explains how hoteliers can take a more effective and sustainable approach to water treatment

Hotels use a lot of water – for drinking, heating, laundry and hot water – and many boast wellness facilities, such as spas and pools. So it's not surprising that legionella risk is high in the hospitality industry. Improper design and maintenance can lead to serious water-hygiene issues that not only affect efficiency, but also pose a very real risk to human health.

Many businesses are tempted simply to increase the dosage of chemicals as a preventative measure, but this is not always the right answer. Legionella prevention should be approached holistically – with actions based around a specific system and how it is used – and a non-chemical alternative to water treatment will often be the more effective and sustainable option.

Chemical treatments

Chlorine – one of the more common water purifiers for pools – can cause reddening of the eyes, allergic reactions and irritation of the skin, and over-chlorination of swimming and spa facilities is a common complaint among hotel guests. It may be an effective bacteria killer, but the odour of excessive chlorine is enough to put anyone off a return visit.

Often, a simple adjustment to the filtration or backwash settings will be more effective than just throwing in chemicals. Where chemicals are used, excessive dosing can be avoided by tailoring amounts to a specific system and its use.

Cutting chlorine

Non-chemical water treatments – such as photocatalytic water purifiers – are effective at treating legionella and other pathogens, so bacteria levels in systems are greatly reduced without the use of harmful biocides.

A specific frequency of light and photocatalytic surfaces are used to create free radicals that break down harmful micro-organisms and other pollutants in water. The knock-on effect is that the

amount of chlorine required can be reduced significantly – in some cases by two-thirds. Pool and relaxation areas will smell less chemical, and organic odours are prevented.

With less dosing comes less maintenance and – as water is cleaned continually – it needs to be flushed out less frequently, thereby contributing to water saving.

Ideally, care must be taken at the specification and construction stage, but it's never too late to get serious about water hygiene. In most cases, a non-chemical treatment system can be installed alongside existing filtration equipment.

Water-system design

Water-hygiene issues can be combated in the first instance by good design, plus an understanding of risk and how to mitigate it. Low-flow fittings and thermostatic mixing valves for taps and showers, for example, are often installed to reduce water consumption and enhance safety in leisure environments. They do pose a risk, however, allowing water to stagnate and creating conditions for legionella to thrive.

Where hotel bathrooms haven't been used for some time, it's important to flush out taps and showers before the next occupants arrive, to remove stagnant water.

When it comes to on-going treatment, cost-effective 'fit and forget' solutions – such as magnetic water conditioners – are a popular choice at the construction stage because of their low-energy and low-maintenance credentials. Unfortunately, in practice, we see varied results. Problems usually present themselves several months or years after commissioning, because limescale formation is not controlled throughout the entire water system as effectively as with traditional, salt-based water softeners.

Seasonal risk

Hotels are often seasonal businesses, and intermittent water use during low season creates plenty of opportunity for water to collect in bacteria strongholds, such as pools, Jacuzzis and showers. Flushing systems, and making sure taps, plugholes and showerheads are clean after periods of inactivity is essential.

In the UK, cases of Legionnaires' disease increase during the summer, according to Public Health England* and, in 2013, more than a fifth of cases reported the onset of symptoms during August. Special care must be taken to alleviate the risk of infection during high season, when the weather is at its warmest and hotels are at their fullest capacity. Whether you have plans to expand your leisure business, or protect an existing site, non-chemical water treatment options can help to create a pleasant environment for your guests, as well as boost the building's sustainability credentials and efficiency.

Taking a bespoke approach to water hygiene will ensure that you develop a complete plan – from construction through to ongoing maintenance – that will safeguard guests and staff, while cutting costs, chemicals and maintenance requirements.

- *Legionnaires' disease in England & Wales 2014 bit.ly/2d5LMcu

Further reading

X Yang et al, *Alternative solutions for inhibiting Legionella in domestic hot-water systems based on low-temperature district heating*, Department of Civil Engineering, Technical University of Denmark, Brovej, Lyngby, Denmark, November 2015, BSERT **http://bit.ly/2cplAI7**

BARS

Developers are using high-end bars to attract well-heeled clientele to hotels and apartment schemes. This month, Aecom's **Andrew Freeman** and **Garry Burdett** look at the fit-out of a bar on the 15th floor of a mixed-use development in the City of London

Increasingly, high-end bars are featuring interiors designed by renowned architects, with schemes ranging from a heavy industrial look to opulent and luxurious, with bespoke lighting and finishes.

They often have highly experienced staff and mixologists preparing unique drinks. It is not usual for them also to have large wine cellars storing rare wines and spirits; this requires very close control of temperature and humidity – plus a high level of security. Additionally, microbreweries and small-scale distilleries are being incorporated into such venues.

These bars represent more than just places to buy a drink; it is now more important to consider the views, the surroundings, the interiors and their ambience. Competition for customers is extremely fierce, and the level of fit-out and servicing reflects this.

This cost model is based on a high-end bar, located on the 15th floor of a mixed-use development in the City of London, with a total net internal area (NIA) of 450m^2. It allows for complete stand-alone plant located at roof level.

The model includes a displacement ventilation system, heating and cooling

provided by a variable refrigerant flow (VRF) installation via terminal units, and an air handling unit (AHU). Also included are two lifts servicing the bar from ground level to the 15th floor. Excluded are the bar itself and the back-bar unit.

Costs for providing electrical, comms, water and drainage, plus active IT equipment connections to the bar only are included.

● This cost model has been written by **ANDREW FREEMAN**, trainee surveyor and **GARRY BURDETT**, director, engineering services, Aecom

ASCHINDL / SHUTTERSTOCK

ABOUT THE AUTHORS

The engineering services cost management group of Aecom specialises in the cost estimating, procurement and cost management of building services installations. It is producing a series of cost models for CIBSE Journal in 2016, on areas such as data centres and London's commercial buildings.

AECOM

Bar fit-out costs	Based on NIA of 450m²		
	Total (£'000)	£/m² of NIA	% of total MEP cost
Sanitary installations Sanitary appliances, including WCs, wash-hand basins, cleaners' sinks, water fountains, urinals, experience showers, ice fountain and the provision of disabled toilets and accessible showers.	26.5	58.59	2.10
Disposal installations Connection to base builds foul disposal system. Soil, waste and vent installation to all sanitaryware points. Capped connections to bar areas. Condensate drainage for fan coil units, including insulation. Rainwater gullies to terrace areas.	30	66.67	2.38
Water installations Installation of mains cold water services, including meter, storage tanks, pumps, electromagnetic water conditioner, and connections to sanitaryware. Hot water generation, plant bulk storage, distribution, pump sets and connections to sanitaryware. Miscellaneous water points and plant supplies. Capped connections to bar area.	51	113.33	4.04
Heat source Not applicable – Heating provided via VRF installation.	0	0	0
Space heating and air treatment AHU and ductwork to bar area, VRF installation serving the AHU and terminal units provide heating and cooling to bar areas. Standalone cooling-only VRF units to bar cellar and stores. Specialist temperature control and humidity control units to wine cellar.	110	244.44	8.72
Ventilation systems Supply and extract installations to WC areas and back-of-house areas. Extract to cleaners cupboard, stores and the like.	29	64.44	2.30
Electrical installations Installation of LV distribution system, including switchgear, containment and cabling. Provision of power to mechanical plant, installation of small power and lighting, including emergency lighting and controls. Provision of enhanced lighting to lobbies, bar areas and toilet areas. Allowance for statement lighting, full lighting control and scene setting, Earthing and bonding. Capped electrical supply to bar area.	230	511.11	18.23
Gas installation Gas supply to hot-water generation plant.	25	55.56	1.98
Fire and lightning protection Connection to base build installations, zone valve, concealed fast-action sprinkler heads throughout.	27	60	2.14
Communication, security and control systems Fire alarm and PA/VA installation, interfaces to base build systems. Security system comprising cameras, access control and intruder alarms to back of houses. Induction loops to bar areas. Disabled WC alarms. TV and data installations throughout equipment. Complete sound system, including speakers, cabling and central music generation. Installation of central building management system (BMS), including central control panels and BMS to plant and equipment.	163	362.22	12.92
Lift and conveyor systems/installations 8- and 13-person lifts serving the bar floor from the ground-floor entrance.	510	1133.33	40.43
Builders' work in connection with services BWIC for services installations, including fire stopping.	60	133.33	4.76
Total bar fit-out	**1,261,500**	**2,803.33**	**100%**

MEP costs of high-end bar fit-out on 15th-floor of mixed-use development in the City of London

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The evolution of fan coils for efficient conditioning of room air

This module explores how fan coil unit applications are offering improved opportunities for flexible and efficient operation

The application of fan coil units (FCUs) is widespread and – because of a combination of user expectation, climate and fashion – a system that was once associated with commercial applications is increasingly being applied to residential locations. This CPD will consider the basic function of – and recent developments in – fan coil units that provide improved opportunities for flexible and efficient operation.

As with the selection of any air conditioning system, the application of a fan coil system will follow the assessment and comparison of the relative benefits of other centralised and decentralised (unitised) systems, as well as hybrid systems, natural ventilation and passive systems.

In the UK in the 1980s, FCUs found favour for air conditioning office blocks and – although originally intended for installation as free-standing, cased units – they are commonly located above suspended ceilings.[1] Today, FCUs are available in many configurations[2], including:

- Chassis units – normally horizontal units for mounting in a ceiling void
- Cased units – usually vertical configuration for floor mounting against a wall
- Cassettes mounted through a false ceiling

They are applied to a wide variety of building types, including a growing number of residential properties. The flexibility of locating an FCU is part of its attraction as a means of comfort conditioning a space and, as units are commercially available with up to seven air outlet spigots – for connections to flexible ductwork – several supply diffusers can serve large areas – with a uniform load profile – from one unit. There is normally a single, filtered inlet to the unit that is used both to draw in the air – often using a ceiling plenum, as in Figure 1 – and potentially to induce centrally conditioned fresh air that has been ducted towards that inlet. Manufacturers also supply additional inlet plenum arrangements, which allow the ducted inlet of air while also providing some acoustic benefit.

A key benefit of using a unitary-based system, such as the fan coil, is that the energy for meeting the room heating and cooling loads is transferred to the conditioned space

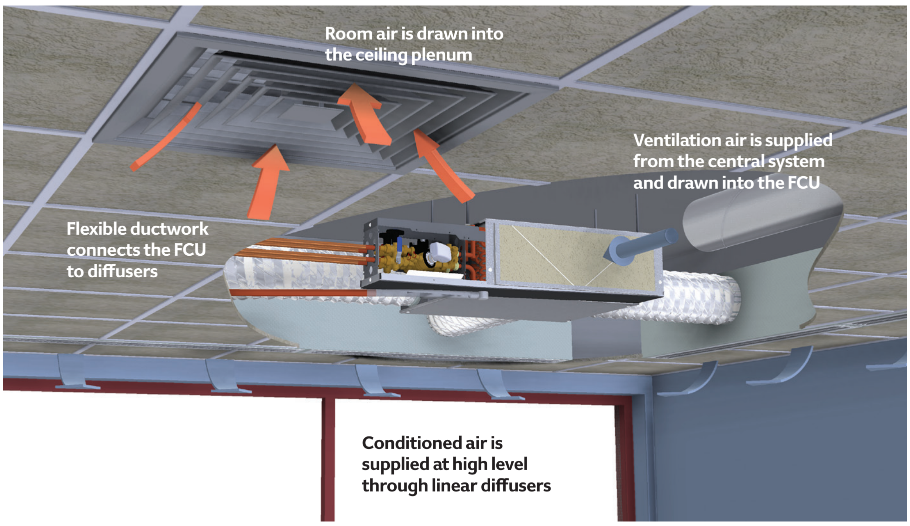

Figure 1: Example of fan coil unit installed in ceiling void, supplying linear diffusers and drawing room air through ceiling plenum, as well as ventilation air from a centrally supplied system (Source: Ruskin)

through pipework – normally with heated or cooled water – which requires significantly less space and transport energy than would be used to convey the same amount of heating or cooling by air. Additionally, unitising the supply of heating and cooling, simplifies zoning for different occupancy and applications, local control, and subsequent reorganisation of room layouts.

The term 'fan coil' is applied to many configurations of appliances, but – as the name suggests – the unit will always include a fan and at least one heat-transfer coil plus some form of control) and, normally, a filter. The FCU's function – that is, cooling or heating and possibly ventilation – will be controlled to meet the demands of the area being supplied, so that the unit can provide cooled (and potentially dehumidified) or heated air. An FCU would not normally be able to humidify air but, in other ways it is, effectively, a compact air handling unit (AHU). However, unlike most AHUs, many FCUs do not supply any outdoor air, but simply recirculate – and condition – the room air. This type of FCU is likely to be used in conjunction with a central AHU that will be used to supply the ventilation air from outdoors (often known as 'fresh air'). The term 'dedicated outdoor air system' (DOAS) is increasingly used to describe the associated type of central AHU system.

The DOAS system can be sized to supply the required ventilation air for the building (for example, based on a peak design occupancy) at a vapour content – as determined by the supply air dew-point temperature – low enough to offset the indoor latent load, so controlling the indoor humidity level. Although the central system may be designed to deal with the design latent load, the FCU coil should be fitted with a properly orientated condensate tray and, where the FCU system is designed to provide dehumidification, proper condensate drainage – possibly including condensate pumps.

The typically steel FCU enclosure will be insulated to prevent condensation on the outer surface when the unit is cooling, and heat transfer to and from the void where the FCU is mounted, as well as to reduce noise transmission from the unit. The insulation should have been selected by the manufacturer to balance the needs of good acoustic and thermal performance. Additional acoustic lining may well be added to the discharge airways to reduce noise transmission through the ductwork.

The performance of the fan/motor assembly will be a function of the fan configuration, impeller type and the motor. The fan type is typically a double inlet centrifugal (forward-curved) or tangential (cross-flow) fan with an efficiency somewhat lower than the larger, heavier, backward-curved and aerofoil-bladed fans that would commonly be used in the supply of a central AHU – forward-curved fans are better suited to low-pressure applications.[3] However, unlike the central AHU fan, the pressure required from a fan in an FCU is relatively low, and the system can be designed with reasonable certainty – since the components of the whole assembly are fixed by the FCU manufacturer – who can select a fan that operates most efficiently across the FCU's normal operational range. Modern FCU designs are optimised to reduce pressure loss, with careful design of airways, connections, filters and coil configurations.

Motors in FCUs have generally changed from being traditionally mains AC-powered to, more recently, EC (electronically commutated) DC (direct current) brushless motors. The AC to DC electronics are integrated into the motor assembly so the system is only fed by mains voltage AC power. Such motors are likely to be significantly more efficient than AC motors – by around 30% – and have a reasonably flat efficiency characteristic across the range of motor speeds. These motors are simple to speed control, so fan speed can be used creatively – in conjunction with the waterside controls – to modulate the output of the unit. A simple example, for maintaining similar air distribution patterns across the year, would be to reduce the fan speed automatically when cooling – compared with when heating – as the cooler supply air will not have the buoyancy of the heating air.

The specific fan power (SFP) – the sum of the design circuit-watts of the system fans, including losses through switchgear and controls, divided by the design air flow rate through that system – of the FCU will be influenced by both the fan and motor types, and the frictional losses from the casing, coil(s), filter, and the inlet and outlet connections. In the UK, the SFP is limited in new and replacement commercial FCU applications through the Building Regulations [Non Dom BS Compliance Guide 2013] to 0.5 $W{\cdot}L^{-1}{\cdot}s^{-1}$. Where there are multiple FCUs, an average SFP is determined, weighted by the electrical power consumed by each unit. This is significantly lower than the maximum SFP allowable for, say, a centralised fully ducted air conditioning system (1.6 $W{\cdot}L^{-1}{\cdot}s^{-1}$ for new installations). However, this value includes both supply and exhaust air. An FCU installation will also probably be installed in conjunction with a DOAS that will have a separate, additional, allowable SFP.

FCUs that can directly draw in outdoor air, as well as recirculate room air are available. This type of FCU blurs the boundaries between the comfort conditioning AHU and includes those that have traditionally been referred to as a 'unit ventilator'. These are typically mounted on the perimeter wall to allow access to outdoor air, and have a combination of airside controls (dampers) to ensure optimum fresh air supply to a zone – for example, by making use of 'free cooling' – as well as managing the heating and cooling input through control of the supply to the coil. The recent edition of Faber and Kell's seminal textbook[4] notes that for units relying on direct connection through external walls for fresh air, the 'hazards of dust and noise pollution, to say nothing of unit overload caused by wind pressure, cannot be exaggerated'.

Aside from fan-speed control, the output

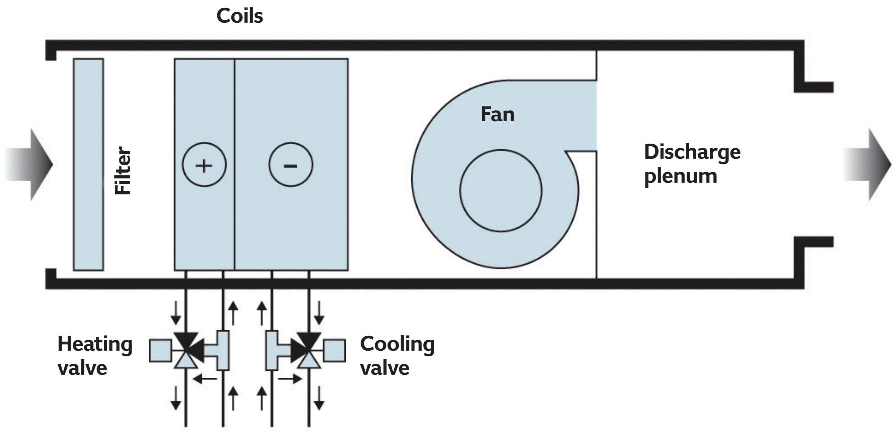

Figure 2: A generic representation of a fan coil with water-side control using four-port control valves (Source: CIBSE TM43)

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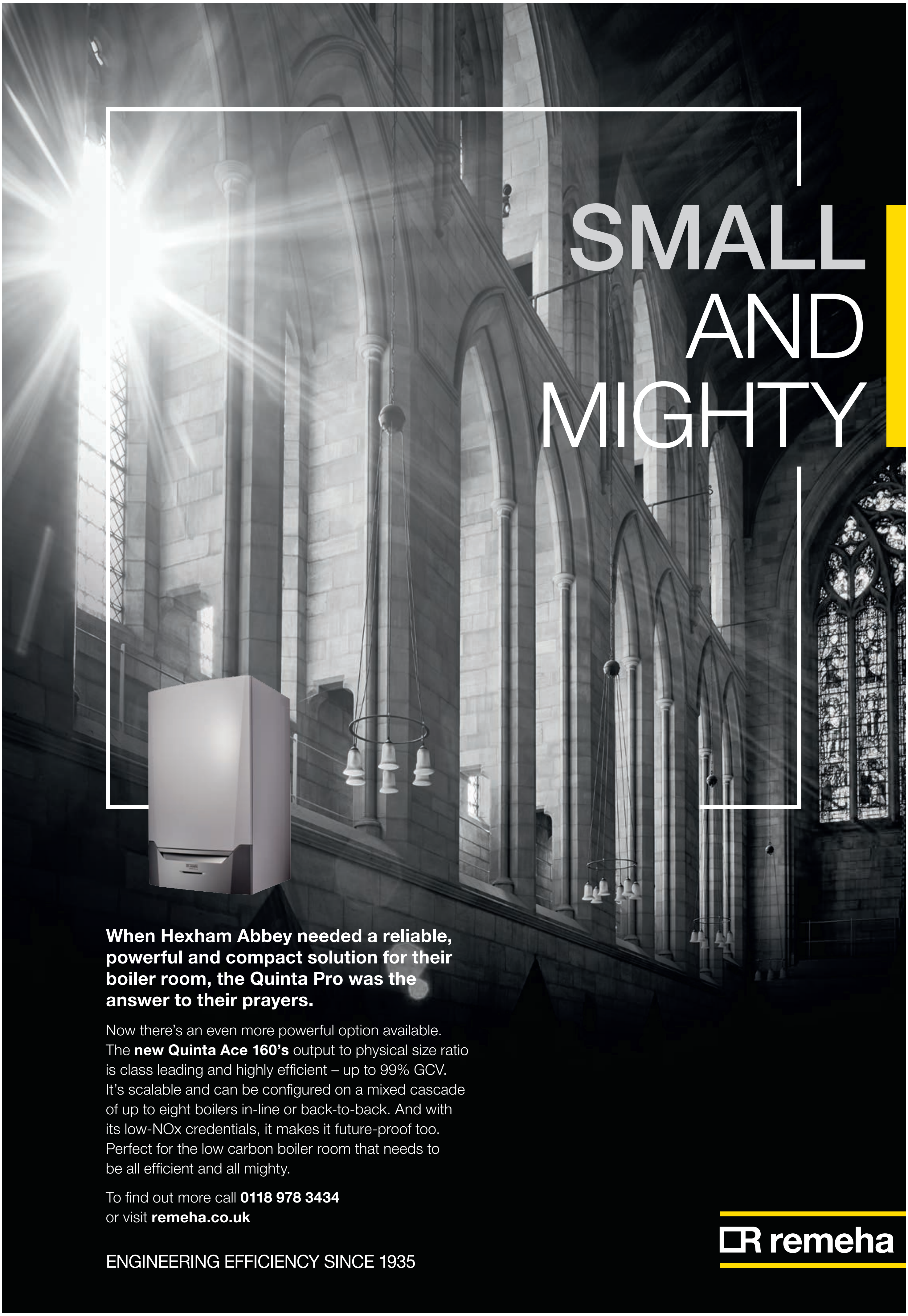
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of the fan coil unit can be controlled by altering the supply of heated and cooled water (as in the unit in Figure 2) or, less often, through the use of dampers. This alters the air flow through separate heating and cooling coils positioned in the casing to allow different air paths.

FCUs have historically been selected primarily for their cooling potential, which has often led to heating coils that are oversized when operated at the traditional flow/return of 82°C/71°C, or even the more recently favoured 80°C/60°C. This has created opportunities[5] for refurbished installations to use lower heating flow water temperatures, while still providing adequate heating output. As long as selected appropriately, new installations of FCUs can be used with wider temperature differentials, so reducing the required water volume flow (and pump power), or lower flow temperatures, to allow efficient supply from heat pump water heaters. They can also be controlled to ensure appropriate return temperatures that allow gas boilers to operate in condensing mode. These less-traditional forms of control are becoming more accessible, as FCUs are increasingly available with connections to building management systems through open protocol control networks. Cooling can also be supplied by direct refrigerant systems – often referred to as 'DX' (direct expansion) – and heating through electric resistance heating. This then shifts the genus of the FCU to that of the 'split' air conditioner, and to the family that includes variable refrigerant flow (VRF) systems.

The general variants of the FCU include 'two-pipe' or 'four-pipe' systems. The two-pipe FCU has one coil, so can be used for heating or cooling at any one time. If a space was to need heating or cooling consistently, then such a unit could be used as a dedicated heater or cooler. Alternatively, a 'changeover' system that switches the supply for the entire building or zone to heating mode or cooling mode might be used. The changeover from heating to cooling, or vice versa, is typically made manually (for example, in autumn and spring), so unusual weather patterns might make this point of changeover difficult to determine. In large systems, this can take some time, so is not an ideal solution where there is wide variance in room loads – particularly when combined with the vagaries of the UK weather.

The four-pipe system – as in the unit in Figure 2 – has two separate coils being served by heating and cooling water respectively.

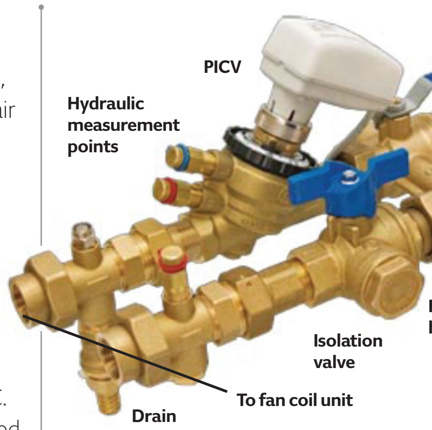

Figure 3: Example of control assembly for a fan coil unit (Source: Ruskin)

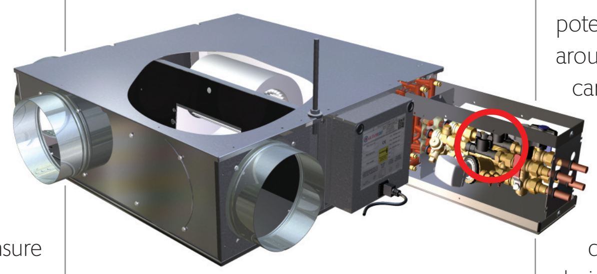

Figure 4: Fan coil unit for mounting in ceiling void showing control assembly – the sections (circled) in the assembly are piezoelectric flow measuring points (with no moving parts), for direct connection to a control system (Source: Ruskin)

Practically, the copper coils of both often share the same block of aluminium fins to make the unit more compact. As the FCU is a comfort cooling device only, one of the coils would be active at any time, with a narrow 'dead band', where neither heating nor cooling coils are active. The coil output is normally controlled by varying the water flow rate into the coil, using an 'equal percentage' control valve to provide a linear relationship between heat output and valve stem position. These were traditionally two-port valves that, ideally, should have had a valve authority of 0.5, although, practically, that was difficult to achieve. In recent years, the 'four-port valve' had become popular – effectively, a small mixing valve in a diverting application built as a complete unit, with a bypass that connected the two tails of the coil with the flow and return from the heating or cooling water systems. This type of control maintained a good valve authority, as well as a constant flow rate in the water distribution systems. However, because of the energy benefits of variable-flow pumped water systems and the coincident development – and widespread manufacture – of two-port pressure independent control valves (PICV), these are now often used. Additionally, these are realistically able to maintain a good valve authority. They are likely to be supplied as part of the FCU package, with the appropriate design flow rates set and as part of the connection assembly, which can include such options as a flushing bypass, drain connections, and measuring stations – as shown in Figure 3 and Figure 4. The measurement points on the fan coil – potentially, pressure, flow and temperature – can readily be linked through local 'intelligent' controllers to the building's management system that, in conjunction with fan speed and waterside control, can be used for energy management and comfort control.

The flexibility in positioning – as well as the potential multiplicity of the FCUs in and around the occupied space – requires a carefully considered maintenance procedure to ensure that filters, condensate drip trays and pumps, control elements and other serviceable items are properly attended. This demands proper consideration at the design, procurement and installation stages, to ensure that appropriate access can be provided with the least disruption to the building occupants. With increasing applications in residential property, there have been cases of FCUs being installed above plastered ceilings, so preventing access without destroying the finished surfaces.

The advent of this low-cost, robust technology – such as the simply controllable and efficient EC DC motor; the PICV, which provides good control as water supply pressure varies; direct links to building control systems; and optimised air paths allowing lower fan operating pressures – are all contributing to modern FCUs that are more suited to the low-energy systems needed in an increasingly wide range of applications.

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Further reading:

CIBSE TM43 *Fan coil units* offers some excellent reading on FCUs, but for explanations of more recent waterside control, see BSRIA BG 51/2014 *Variable flow valve selection*. CIBSE KS7 *Variable flow pipework systems* also provides good background on the deficiencies of older waterside control techniques.

References:

1 Jones, W P, *Air conditioning applications and design*, 2nd Edition, Butterworth Heinemann, 1997.
2 CIBSE Guide B3 *Air conditioning and refrigeration*, CIBSE 2016.
3 CIBSE TM42 *Fan application guide*, CIBSE 2006.
4 Oughton, D and Wilson, A, *Faber and Kell's Heating and Air Conditioning of Buildings*, 11th Edition, Routledge 2015.
5 CIBSE TM43 *Fan coil units*, CIBSE 2008.

Turn over page to complete module

Module 101
October 2016

Ruskin Air Management

1. According to the article, when did FCUs first become popular for office applications in the UK?

- ☐ A **1960s**
- ☐ B **1970s**
- ☐ C **1980s**
- ☐ D **1990s**
- ☐ E **2000s**

2. What does the acronym DOAS represent?

- ☐ A **Dedicated outdoor air system**
- ☐ B **Delegated outdoor air system**
- ☐ C **Direct outdoor air system**
- ☐ D **Dispersed outdoor air system**
- ☐ E **Distributed outdoor air system**

3. Which of these fan types is most likely to be used in an FCU?

- ☐ A **Axial**
- ☐ B **Backward-curved centrifugal**
- ☐ C **Forward-curved centrifugal**
- ☐ D **Plug**
- ☐ E **Propeller**

4. What value of valve authority would be considered most appropriate for a two-port control valve?

- ☐ A **0.1**
- ☐ B **0.3**
- ☐ C **0.5**
- ☐ D **0.7**
- ☐ E **0.9**

5. Which of these is least likely to contribute to improved year-round system operation of the fan coil unit?

- ☐ A **Employing PICV for two-port valve control**
- ☐ B **Integrated sensors and close coupled controllers**
- ☐ C **Optimised air paths through FCU**
- ☐ D **Using an EC DC motor in place of an AC motor**
- ☐ E **Using a single coil with seasonal changeover**

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