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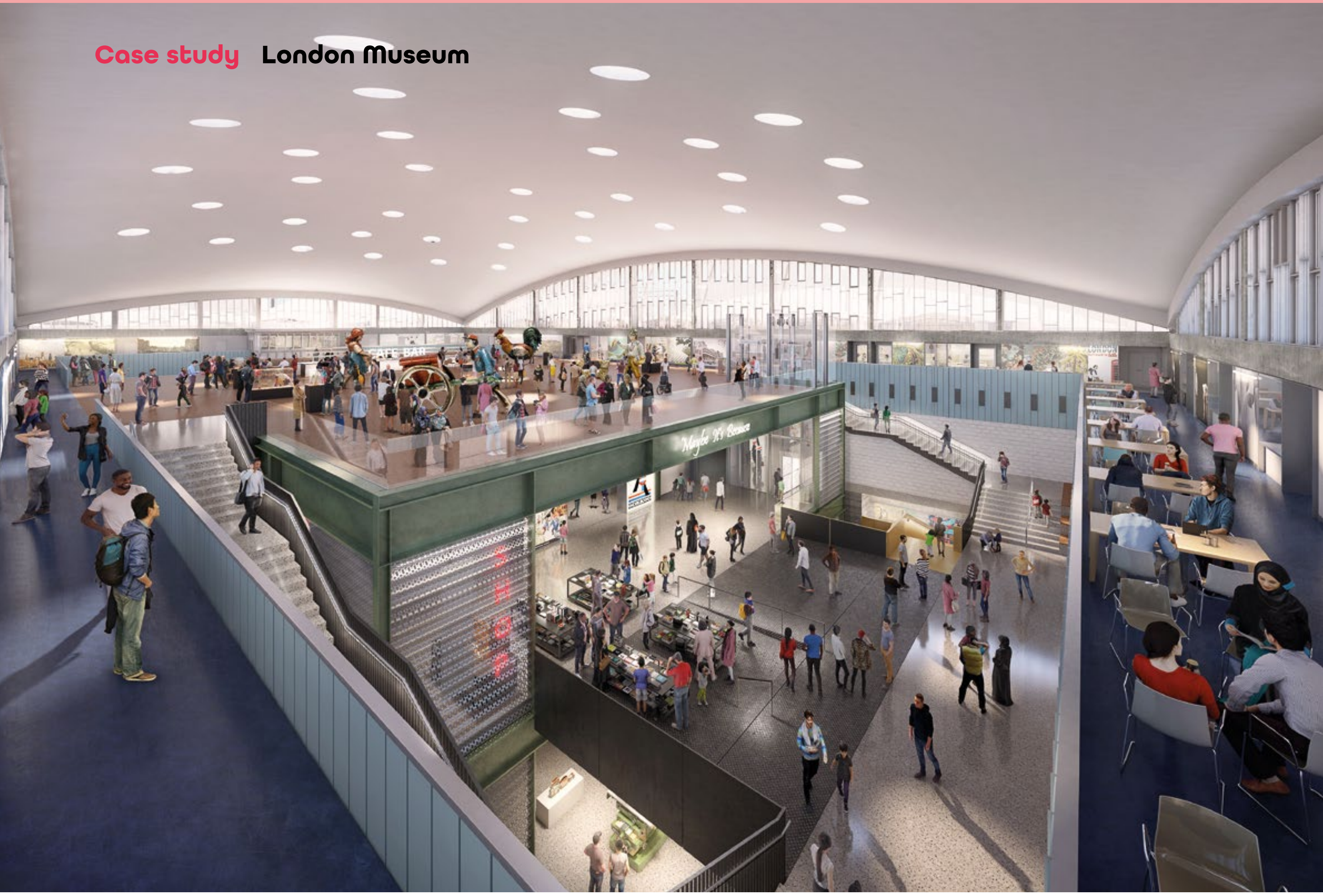
Hotel & leisure special

History in the remaking

The services challenge of transforming Smithfield Market into a smart new home for The London Museum



The museum of tomorrow

The London Museum's relocation to Smithfield Market is an ambitious £437m project to transform a series of abandoned market buildings into a state-of-the-art cultural destination. **Andy Pearson** looks at how Arup's smart services strategy will ensure energy use is 70% lower than Building Regulations

'The world's greatest city deserves the world's greatest museum.' So said London's mayor Sadiq Khan in 2017, announcing the GLA's £70m contribution to the £437m project that will transform parts of Smithfield's historic market into a new home for The London Museum.

This ambitious project will see the dilapidated General Market building, which dates back to the Victorian era, and the domed Poultry Market building, built in the 1960s, both being brought back into use with the addition of contemporary interventions, to create exciting and flexible exhibition spaces.

The servicing and sustainability strategy for these two historic buildings that will form the heart of the world's greatest museum has been developed by Arup. Working with lead architect Stanton Williams, together with Asif Khan and conservation architect Julian Harrap, the engineer has devised a building services solution sympathetic to the heritage buildings without compromising visitor comfort.

Operational performance of building services will be further enhanced by a smart building strategy where every item of plant and equipment is data-enabled to optimise the running of the museum and minimise its carbon emissions.

Fundamental to developing an energy efficient services solution was the thermal performance of the buildings' historic façades. At the project's outset, the teams worked to enhance the thermal performance of the existing envelope by adding insulation and double glazing where possible. Fritting was also applied to some glazing elements to help control solar gains.

Beneath this historic envelope will be the museum's 8,000m^2 of permanent gallery spaces and 1,500m^2 of temporary exhibition spaces, alongside extensive storage, research and education areas.

Arup's servicing strategy has been to work with the fabric of the buildings to help deliver the environment needed for the various spaces with the minimum amount of energy.

'We were fortunate with these buildings because their former purpose was to keep products fresh while allowing traders access; this overlaps with the museum's requirement to preserve artefacts and provide entry for

> **“Credit to the museum, it accepted a much wider temperature and humidity band for most spaces than is the norm in the arts and culture world”**
> Vasilis Maroulas, Arup

visitors,’ says Vasilis Maroulas, associate director at Arup and lead mechanical engineer on the project.

Central to this approach is the distribution of the various spaces and galleries. Arup developed a solution based on positioning galleries and spaces where environmental conditions were most critical at the core of the buildings. The temporary galleries, to host loaned exhibitions, is the space with the tightest environmental conditions: it’s on the ground floor at the centre of the Poultry Market, sandwiched between the basement art storage and the multifunctional space on the first floor. ‘It is effectively a box within a box, completely protected from solar gains,’ explains Maroulas.

The HVAC system used to serve the temporary galleries is an all-air centralised ventilation system with high-level supply and extract to provide mixed and uniform conditions within the entire volume of the galleries.

For the remainder of the spaces, Maroulas says Arup has adopted ‘an adaptive comfort approach’ to the servicing. ‘Credit to the museum, it accepted a much wider temperature and humidity band for most spaces than is the norm in the arts and culture world, which helped us immensely,’ says Maroulas.

Beneath the temporary galleries, the former basement cold stores are currently being transformed into a store for the museum’s seven-million-strong collection. The store includes a publicly accessible space, where visitors will be able to glimpse the collection. This area is served by a mechanical ventilation system with air conditioning from high level supply and extract terminals. ‘This is a low air volume air conditioning system, with minimal operational energy, because this is a collection store and the lights will be off for most of the time,’ Maroulas explains.

The space above the temporary galleries is open to the building’s dramatic, domed reinforced concrete roof – once the largest single-span concrete roof in Europe. This space will be for a wide variety of uses, from exhibitions to evening events, lectures, receptions and so on.

Here, Arup is looking to exploit the thermal mass in the roof combined with a natural ventilation solution. Maroulas says: ‘We have adopted the simple strategy of opening the lunettes windows at high level to help create air movement during the day.’

In winter, the space is heated by an underfloor system using pipes concealed in the new floor slab. This is designed to keep the space at a temperate 18°C – 20°C during occupied hours. On hot summer days, the exposed thermal mass of the giant domed roof will be supplemented by cooling the floor slab. ‘Rather than introduce a cooling system, we decided to run cool water through the underfloor pipes to activate the floor’s thermal mass to take out the temperature peaks,’ explains Maroulas.

The museum’s main entrance is off the canopied West Poultry Avenue, the covered street that runs between the two buildings. The entrance channels visitors on to the ground floor of the General Market building. This floor is intended to be the museum’s sociable space, complete with restaurant, bookshop and galleries, which are all open to the glazed roof with its central dome. This space, too, is naturally ventilated throughout the year, supplemented with underfloor heating.

An additional challenge is that the large, naturally ventilated spaces in the General Market ground floor had to be able to host evening events, including formal dinners. For these events, air is brought into the space through attenuated low-level openings to keep external/outside noise to a minimum while rooftop fans will assist air movement through the space.

Beneath the bustle of the ground-floor entrance is the space for the permanent galleries. These contain the majority of the museum’s exhibits housed within the high brick-vaulted basement and the previous Salt Store spaces, parts of which were only discovered once restoration was under way. In these subterranean galleries, the museum's curators were prepared to accept temperatures of between 16°C–24°C.

Two different methods are used to supply conditioned air to the 30m-wide, labyrinthine space. For the entrance area, which is open to the floor above, a high-level mixing system supplied from either side, is used to provide a buffer at the entrance to the galleries. Beyond this, the rear two-thirds of the space is supplied with air from an extensive network of floor trenches, using a displacement system. 'Our mechanical engineers had to work with the exhibition design team and our CFD building physicists to develop physical mock-ups to reach a compromise solution that would allow sufficient air movement to create uniform conditions within that space,' explains Maroulas.

In Victorian times, deliveries arrived by rail to this level. The tracks are now used for Thameslink trains, which themselves will become a moving exhibit, viewed through a window in the basement wall.

Heating and cooling for both buildings is being provided by E.ON's Farringdon energy centre – see 'Greening the City', April 2022 *CIBSE Journal*.

This ambitious project had originally targeted Breeam Excellent: it is currently on target to achieve Breeam Outstanding.

What's more, Maroulas says by being lean with the design and using passive techniques, the current estimate is that the museum's energy consumption will be 70% lower than that of a baseline building representing the proposed end use. This calculation includes the existing building fabric and assumes the building services systems is compliant with the latest Part L minimum requirements.

The General Market building is due to open in 2026, and the Poultry Market building two years later.

Already, there is a presumption that the scheme might actually achieve the targeted levels of energy consumption predicted using CIBSE TM54 as it has the added benefit of smart-enabled building services (See panel 'Connected curiosities').

When it opens, it is expected the building can be tuned to get the energy use down to the predicted figure, and the smart data means it will be much easier to know what to tweak to get energy to those levels. ●

Connected curiosities

The London Museum had aspirations for its new building services to be 'smart' to enable it to maintain and operate plant efficiently.

Steve Watson from the London Museum has driven the smart agenda. 'Steve was focused on the operational performance of the building services systems in order to get the building to speak to the FM team so that they can get ahead of any problems,' says Adam Jaworski, a smart buildings consultant at Arup.

A major challenge for a building with smart services is enabling the different systems to talk to each other. Arup's starting point has been to ensure consistent naming of every single item of building services equipment, including individual light fittings and fan coil units, by allocating each a unique code. Arup developed a naming code protocol based on the Building Device Naming Standards by the Open Data Institute. This ensures that device and asset names and codes are consistent whenever a device appears on a CAD drawing, in a BIM model, in control software, in asset management systems and asset databases.

Jaworski says many devices, such as light fittings and inverter drives on motors and fans, already have all the telemetry built in.

'The key thing we are doing with this building is to bring the data from heterogeneous systems back to one internet-enabled intermediary device called an IoT broker. The IoT broker receives device data as JSON files – text files that both humans and machines can read. Once the data is standardised, it can be combined with data from other sources such as a construction BIM model that uses exactly the same device tags.'

The data will enable workflows such as performance analysis and computer-aided facility management.

'When people ask what a smart building is, I say it's about getting things online,' says Jaworski.

On site, construction manager Sir Robert McAlpine is using One Sightsolutions as a smart building contractor. As master systems integrator, it is responsible for aligning the trade contractors' digital delivery. 'They are policing devices; they are making sure that the things that are going on the smart building side are in the correct format,' explains Jaworski.

Working with fans

A study monitoring CO_2 in food and drink kiosks at major venues revealed the poor air quality in busy periods. A summary of work by UCL's **Filipa Adzic** highlights the importance of flexible ventilation strategies

The Covid-19 pandemic caused disruption to live events, with the sports and entertainment industries being particularly hard hit during the lockdowns.

To help the UK safely lift restrictions on large gatherings, the government initiated the Events Research Programme (ERP). One key area of focus was identifying risks associated with event venues, particularly focusing on ventilation in high-traffic areas, to better understand how indoor air quality (IAQ) might influence the spread of airborne viruses such as SARS-CoV-2.

The results of the study were presented at the CIBSE Technical Symposium in Cardiff earlier this year.

A significant portion focused on monitoring air quality in food and drink concession stands because they often experience transient, yet high occupancy. CO_2 monitoring was used to assess ventilation performance, as elevated CO_2 levels serve as a proxy for poor ventilation and potentially higher concentrations of exhaled breath.

The study used non-dispersive infrared CO_2 sensors capable of measuring concentrations up to 5,000ppm with an accuracy of 30ppm. Loggers were installed at breathing height (1.6m to 2.3m) to provide high-resolution data.

Ventilation was monitored at 10 venues in England, covering 179 spaces over 90 events. These venues included a range of indoor spaces, from seating areas and concourses to toilets, restaurants, private boxes, and food and drink concession stands.

The research team recorded CO_2, temperature and relative humidity levels, noting times of high occupancy and verifying this data with CCTV footage. The research was observational, with the team present during most events but refraining from intervening in venue management.

CIBSE Guide A recommends a provision of 10 l/s per person of outdoor air in spaces like concession stands, but post-occupancy evaluations are rare. To assess whether ventilation strategies are adequate during peak occupancy, CO_2 levels were closely monitored in concession stands at Royal Ascot, Wembley Stadium, and the O2 Arena.

At Royal Ascot, a single bar was monitored over five events with an 18% occupancy (12,600 attendees). Similarly, 16 bars and kiosks were monitored at Wembley Stadium during Euro 2020 football matches, with occupancies ranging from 3% to full capacity (90,000). Lastly, four bars were observed at the O2 Arena during a music awards ceremony with 18% occupancy (3,532).

Air-quality classification bands were developed to rapidly assess ventilation effectiveness and the associated risk of airborne virus transmission. The bands, ranging from A to G, classified spaces based on average and maximum CO_2 concentrations, with 'A' indicating good ventilation and 'F' or 'G' suggesting ventilation improvements were needed.

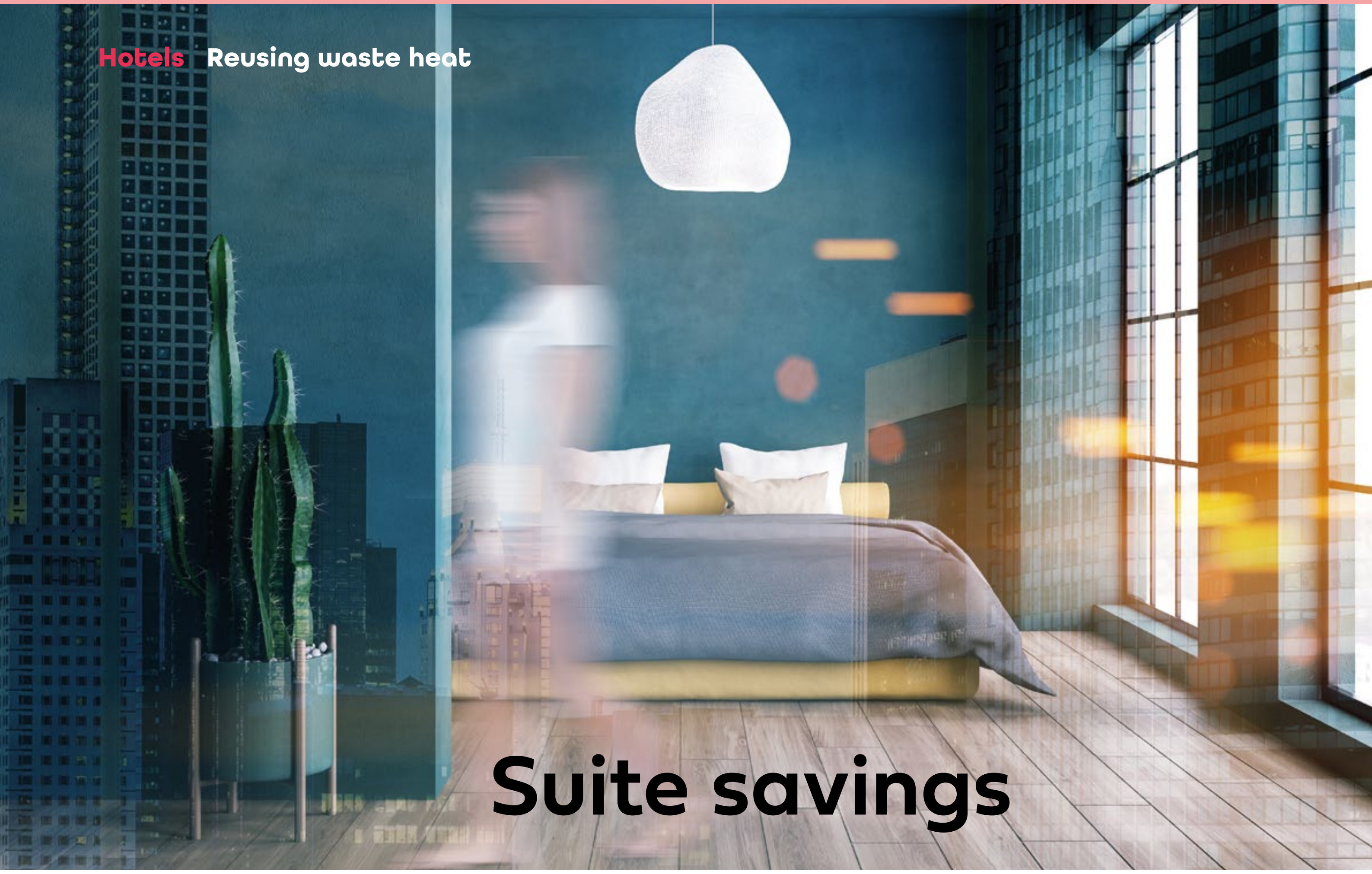
Results showed that 86% of kiosks had good ventilation when considering the average CO_2 levels at the event, which included high and low-occupancy periods. However, at maximum CO_2 levels during peak occupancy, only 45% of kiosks maintained good ventilation, while 12% were in F and G bands, indicating ventilation could not cope.

One outcome was the influence of event management and structure on ventilation performance. For example, the O2 Arena and Royal Ascot had more frequent breaks, which allowed for a more even distribution of people in concession stands, resulting in relatively flat CO_2 levels. However, Wembley, where fans are not permitted to take drinks into the seating areas, saw significant spikes in CO_2 before the match and during half-time, reflecting higher concentrations of people.

Here, the research also showed that ventilation strategies differed across levels. Level 1 and 2 concourses, which are naturally ventilated, maintained CO_2 concentrations below 1,500ppm even at full capacity. But level 5, with natural and mechanical ventilation, experienced higher concentrations at occupancies above 72%, suggesting ventilation was insufficient for peak demand.

This has important implications for event management and building design. Ensuring sufficient ventilation in high-occupancy areas is critical. Organisers and venue designers should consider the layout and structure of events when planning ventilation strategies. It's vital that solutions can adapt to occupancy levels and event structures. ●

● **Filipa Adzic, is a research associate in fluid mechanics at UCL**



Suite savings

Hotels ask guests to reuse towels to save energy, but installing waste-water heat pumps to reuse heat would have a much bigger impact, reports **Andy Pearson**

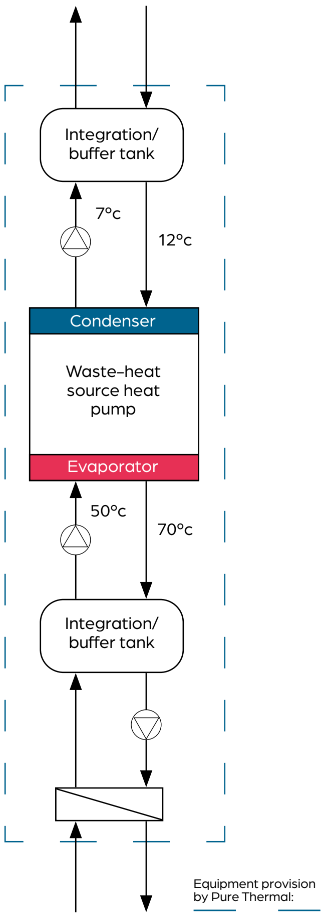


Figure 1: Single source (chilled water return only) waste-heat source heat pump delivering to the secondary hot-water return

In hundreds of hotels across the country heat from cooling systems is being rejected at the same time as fossil fuel is being burnt to heat domestic hot water.

Throwing away valuable waste heat at the same time as the boilers are in operation is deplorable, says Garry Broadbent, operation director and founder of Pure Thermal, given the increasing cost of energy and the urgent need to cut carbon emissions.

It is unfortunate because, he says, large hotels offer an ideal opportunity to recycle heat that is being wasted and they also have a continuous demand for domestic hot water.

In a typical hotel, Broadbent says, heat is rejected from three main systems: food service refrigeration; data room; and air conditioning.

The merit of these loads is that they are predominantly independent of outside ambient temperature, so the quantity of heat rejected by the packaged chillers serving the hotel's main chilled-water circuits will be available 52 weeks a year.

In addition to the chillers, the boilers will run continuously year-round to provide heat for the domestic hot-water services. 'If you imagine a large hotel, the secondary return on the domestic hot-water circuit will circulate continually, which could result in up to 60kW of heat lost from the system that will require replenishment,' Broadbent says.

The solution developed by Pure Thermal links the two systems with a waste-heat source heat pump. The heat pump can be connected to the return legs of a chilled-water circuit, cooling tower and condenser circuit where valuable waste heat is being rejected. Generally, the temperature of the return leg of a chilled-water circuit will be between 12°C–14°C depending on system criteria.

Using the waste heat recycling system, Pure Thermal's system takes the heat from the chilled-water return that would otherwise have been

> **“The opportunity to recycle wasted heat at a micro level should not be overlooked, because it represents a major cost and carbon reduction opportunity”**

rejected, and uses this recycled waste heat to raise the temperature of the return leg of the domestic hot-water circuit up to 70°C.

The benefit of this solution is that absorbing heat from the chilled-water return reduces its temperature to 7°C or 8°C, which means the chiller no longer needs to run, saving chiller input power. Similarly, because the domestic hot-water return is being heated by the waste-heat recycling system, using heat that would otherwise have been rejected – means the boiler is not consuming gas.

What’s more, because demand for cooling and hot water are year-round, these carbon and energy savings will also be year-round.

As the waste-heat source heat pump is cooling and heating simultaneously, the solution is similar in operation to using a 4-pipe chiller but, Broadbent says, this system is ‘very flexible and is able to work at a high temperature’. The heat pump is manufactured by Oilon as part of its ChillHeat range, which has been designed specifically to produce hot water at temperatures of up to 120°C from low-grade waste heat.

In addition to the heat pump, the system will usually include a hot-water storage tank, which acts like a thermal battery and gives the heat pump a working volume. ‘The tank allows us to make hot water when waste heat is available, but at times when there is little or no demand for hot water,’ says Broadbent. And, while the system would connect directly to the chilled water circuit, a heat exchanger is usually required for the interface with the domestic hot-water return.

In Figure 1, a Pure Thermal single source heat pump, with low GWP refrigerant R1234ze, delivers a total thermal output (heating and cooling) of 176kW with an input power of 35kW. This gives a TER of 5.03 or 503% efficiency at a temperature of 70°C.

However, this TER does not yet account for the existing chiller’s input power that would be displaced by using the waste-heat source heat pump because the heat pump is providing cooling. Assuming an average SEER of 4 for a chiller and deducting its input power from the heat pump, the adjusted actual TER of the heat pump now becomes 10.2.

Broadbent says the system could also be used to take heat from a general ventilation extract, say from a hotel swimming pool, which might be at a constant 15°C. However, the downside of using a ventilation extract is that there is no efficiency benefits to cooling the air compared with a chilled-water circuit where absorbing heat displaces chiller input power.

Since this is designed as a retrofit system, the cost and carbon case for its application can be made relatively easily based on historical data. Using metered and BMS data should enable a comparison between the amount of heat that could be recovered with the amount of heat required for water heating. This will ensure the system is configured to deliver maximum payback.

If the data is not available, Pure Thermal can provide a survey service that includes fitting metering equipment temporarily to record required and rejected heat to help establish the viability for a retrofit waste-heat source heat pump.

Broadbent is frustrated that more opportunities to reuse waste heat are not being pursued because they are ‘outside the main carbon reduction agenda’. It is a problem made worse, he says, because, historically, the specification of heating and hot-water systems in hotels was separate from the specification of air conditioning and refrigeration equipment.

While he acknowledges that this system is unlikely to be applicable to new all-electric hotels, Broadbent says there are still plenty of legacy large hotels where this technology could be successfully applied. ‘What are constantly overlooked are those applications that, by design, are producing heat that goes to waste,’ he says.

‘As an industry, we need to take a step back from the multi-megawatt replacement of boilers with heat pumps to save carbon and also tackle areas where there are easy gains to be had.’

While he admits that often the quantity of heat wasted might be relatively small – say 50kW or 100kW from a 2MW chiller – he says the opportunity to recycle wasted heat at a micro level should not be overlooked because it represents a major cost and carbon reduction opportunity.

‘When an end user understands that they are wasting costly heat energy and emitting carbon unnecessarily they immediately become interested in the possibility of heat recycling.’ ●

Hotel systems that generate waste heat

- **Food service refrigeration: this might comprise a suite of cold rooms in the basement including freezers, chillers, and a chocolate preparation room, which together might be rejecting up to 70kW of heat**
- **Data rooms: where up to 70kW of heat might be rejected from servers and IT systems controlling hotel operations**
- **Air conditioning systems: providing cooling to common areas, atria, gyms, basement spaces, guest rooms, and so on.**

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Safe application of modern refrigerants in RACHP systems

This module explores the factors that determine flammability categorisation of refrigerants and key standards for safe low-flammability refrigerant applications

The growing focus on environmental sustainability has driven the refrigeration, air conditioning and heat pump (RACHP) industry towards adopting refrigerants with lower global warming potential (GWP). The new applications of refrigerants, while beneficial for the environment, often come with new risk considerations compared with traditional choices. While traditional refrigerants are considered non-flammable (although most of them can burn under certain circumstances), some modern options are classed as flammable. This necessitates stricter safety protocols throughout the entire life-cycle of the RACHP system, from selection and installation to maintenance and disposal.

The presentation by Takizawa[1] provides a useful overview of the properties that impact refrigerant flammability, which include the limits for upper and lower concentrations in air (upper flammability limit (UFL) and lower flammability limit (LFL)); the burning velocity (higher burning velocity signifies a faster burning rate, translating to a faster spread of fire); the minimum ignition energy (MIE) (higher means more difficult to ignite); the quenching distance (the closest a flame can get to a cool surface, such as a metal cabinet, before it goes out); and the flame extinction diameter (which helps explain how heat loss and flame size influence flame stability).

According to the 2020 paper[2] that followed on from an ASHRAE and AHRI-funded research project involving extensive laboratory testing of A2L refrigerants, it was discovered that when the refrigerant concentration was increased slowly, open flames from candles, matches and cigarette lighters extinguished rather than initiated significant explosions (deflagrations). (The study excluded lubricating oil and high humidity effects on ignition, and did not account for open flames from gas hobs or room heaters.)

However, a still mixture of refrigerant and air (known as a 'quiescent premixture') above the LFL can ignite when exposed to very hot (740°C) elements (compared with a cooker element at 480°C) and open flames (matches and butane). This highlights the need for appropriate ventilation for spaces with A2L refrigerants to ensure that the LFL is never reached. The researchers discovered that other sources likely to be found in occupied premises did not ignite the A2L refrigerant even when in a quiescent premixture. These included a smouldering cigarette, a butane lighter, friction sparks, a mains plug and socket, a light switch, a bread toaster, a hair dryer, a hot plate, and a space heater. The difficulty in igniting an A2L in air is partly attributable to its relatively long quenching distance of approximately 8-25mm that compares with propane at approximately 1.5mm. Additionally, the minimum ignition energy for a typical A2L is 10J, compared with approximately 0.0003J for methane[3] and propane. Under some conditions, the tested A2L refrigerants were observed to act as flame suppressants. (There are interesting videos linked from the paper[2] that illustrate the test results.)

Several standards influence the application of refrigerants that have their origins in standards organisations, such as the International Standards Organisation (ISO), the International Electrotechnical Commission (IEC), the European Committee for Standardisation (CEN), and the American National Standards Institute (ANSI). Although some standards are considered global, they are frequently adopted by national, regional, and local standards authorities, sometimes with local deviations. Also, since the development timeline for standards is not common, they do not necessarily agree on specific guidance at any one time. Standards are informally referred to as 'vertical' when applying to a specific industry or group of products and 'horizontal' when they are referenced by a wide range of industries. Horizontal standards will, for example, likely account for the requirements of a wide range of system types during the design, installation, commissioning, servicing and end-of-life processes.

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BS ISO 817:2014[4] establishes a system for assigning the safety classification commonly used for refrigerants based on toxicity and flammability data, and provides a means of determining refrigerant concentration limits. The classifications – shown in Table 1 – are synchronised with those of ANSI/ASHRAE Standard 34 *Designation and Safety Classification of Refrigerants*.

Ensuring a safe system may be by 'intrinsic safety' and 'extrinsic safety' methods. Intrinsic safety limits the quantity of refrigerant so that any leaks into the space cannot create an unsafe condition. Extrinsic safety employs alternative measures – such as the physical arrangement of the system, additional safety equipment, and operational procedures – to ensure that a dangerous situation cannot arise. Some equipment, such as refrigerant gas detectors and alarms, may be included as part of the product and some sourced separately and installed on site.

The horizontal standard BS EN 378 *Refrigerating systems and heat pumps – Safety and environmental requirements* (which is currently under review) is intended to minimise possible hazards to persons, property and the environment across the whole array of refrigerating systems and refrigerants. It effectively acts as a foundation for risk management, establishes safety benchmarks, and promotes best practices for working with refrigerants in systems that cover many product groups. This standard engages with the work of the various building engineering professionals when working on UK and European projects. (ISO 5149[5] may be more appropriate for work outside that geographic area.)

The vertical standard BS IEC EN 60335-2 *Household and similar electrical appliances – Safety* focuses on the specific safety requirements for the appliances (or products) themselves. (Despite its title, this standard relates to commercial applications.) The recent 2023 revision to BS EN IEC 60335-2-40,[6] which specifically covers electrical heat pumps, air conditioning and dehumidifiers, included many revisions relating to the safe application of A2L refrigerants. It provides manufacturers with a clear and concise set of guidelines to follow, ensuring that their products are safe, reliable, and efficient.

In the UK, all refrigerants are subject to Dangerous Substances and Explosive Atmosphere Regulations[7] (DSEAR). Identified risks must be eliminated or minimised as far as reasonably practicable. Conducting and documenting relevant risk assessments is essential, along with ensuring the proper provision of safety equipment such as leak detection, ventilation, shut-off valves and alarms.

As highlighted by the Federation of Environmental Trade Associations[8] (FETA) in the Pressure Equipment (Safety) Regulation (PE(S)R), A2L refrigerants are classified as 'dangerous' owing to their flammability. Split air-conditioning systems using A1 refrigerants are more likely to be in PE(S)R Category 1 (or possibly exempt and therefore only required to be constructed in accordance with 'sound engineering practice' (SEP)). For these systems, the contractor can self-certify its compliance with the regulations. In contrast, systems with A2L and A3 refrigerants are more likely to be in Category 2 or above, and so will require some form of assessment by an Approved Body before a UK Conformity Assessed (UKCA) mark can be applied to the installed system. This body must verify the design and technical information and witness a portion of the strength pressure tests. The Cool Concerns briefing note[9] advises that the contractor acts as the 'manufacturer' of the complete system and is usually responsible for the final conformity assessment (see IoR Guidance Note 36[10] for more detail).

One of many ways that manufacturers can achieve a UKCA (or CE) mark is by demonstrating conformity to the requirements of a harmonised safety standards, such as relevant parts of BS EN IEC 60335. BS EN 378-1 notes that product family standards dealing with the safety of refrigerating systems take precedence over horizontal standards covering the same subject, including limits on refrigerant quantities for a particular application. BS EN 378 applies to a far wider, generic set of applications that are outside the scope of individual product standards.

One of the key issues of employing A2L refrigerants in room units, such as would be used in split air conditioning and variable refrigerant flow (VRF) systems, is the allowable charge of refrigerant in a particular space. Fortunately, recent editions of BS EN 378-1 and BS EN IEC 60335-2 are generally consistent on refrigerant quantity limits if the same assumptions are

	Lower toxicity	**Higher toxicity**
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1

Table 1: Safety groups for refrigerants, as described by BS ISO 817:2014

applied to both standards. However, in specific applications, there may be different areas of nuance in the horizontal and vertical standards, and the standards should be consulted for full details.

Both current versions of BS EN 378-1 (equation C.2) and BS EN 60335-2-40 (equation GG.9) use the same (empirical) intrinsic safety equation to establish the minimum room floor area A_{min} (m^2) that can be used to install an appliance with refrigerant charge m_c (kg) where the room is unventilated, $A_{min} = (m_c/ 2.5 \times LFL^{1.25} \times h_0)^2$ where:

h_0 is assumed release height of leaking refrigerant, greater of $(h_{inst}+h_{rel})$ or 0.6m

h_{rel} is distance (m) from bottom of appliance to point of release

h_{inst} is the reference installed height of the unit (0m for floor-mounted, 1.8m for wall-mounted, and 2.2m for ceiling-mounted)

For example, applying a floor-mounted room unit, such as that shown in Figure 1, charged with 2.4kg R32 (an A2L refrigerant) that has an LFL of $0.307 kg\cdot m^{-3}$,the minimum allowable room area for the room unit where there is no ventilation would be $(2.4/(2.5 \times 0.307^{1.25} \times 0.6))^2 = 49.02 m^2$ in unventilated areas.

However, when a fan that is incorporated into the unit is either continuously operated, or through an appropriate refrigerant detection system, is able to deliver a sufficient recirculation airflow rate (of at least $30 \times m_c/LFL m^3\cdot h^{-1}$, according BS EN 60335-2-40), the allowable minimum room area can be smaller, as it is assumed that the recirculation will prevent potentially leaking refrigerant reaching the LFL, while alarms will also alert users to the leak. BS EN 378 and BS EN 60335-2-40 suggest that leak detectors should be located where leaking refrigerant may stagnate or concentrate, but they (currently) differ in specific detail. However, the intent is the same in the two standards and, although using different calculation methods, they appear consistent (and the upcoming revisions to BS EN 378 may provide increased similarity in method).

From BS EN 60335-2-40 equation GG.11, the simplified empirical relationship is $A_{min} = m_c/(0.75 \times LFL \times h_{ra})$ where h_{ra} is the estimated reaching height of the airflow (m). So, repeating the previous example for a floor-mounted unit with 2.4kg R32, and an estimated reaching height of 0.6m, the minimum room area $= 2.4/(0.75 \times 0.307 \times 0.6) = 17.4 m^2$ for the unit with a circulation fan and an inbuilt leak detector. This provides opportunity for applying the unit in a smaller room by applying extrinsic safety measures where, in the event of a leak, the indoor unit must be capable of increasing the fan speed to maximum and triggering an alarm. (The installation could also comply with BS EN 378-3[11] if the system leakage alarm has an independent power source, such as a battery-backed supply.)

Figure 1: An example of a floor-mounted room unit, charged with 2.4kg R32, capable of delivering up to 5kW sensible cooling and 6kW heating (Source: Mitsubishi Electric)

In the calculations undertaken above, a key variable is the mounting height of the unit – this should be considered carefully to ensure that the minimum areas are properly representative of an installation. A site variation to the mounting height can significantly impact the installed system, as it determines the extent to which refrigerant, if it leaks out of the system, will disperse through the whole space rather than pooling in a concentrated layer at floor level.

Meeting the requirements of the comprehensive product safety standard may well be considered as appropriate for compliance regardless of the horizontal standard. Indeed, the introductory text to BS EN IEC 60335-2-40:2023 explains there is no need to refer to horizontal standards for products within its scope, since they have been taken into consideration when developing the general and particular requirements of this vertical standard.

As with any engineering solution, manufacturers, installers and operators have a responsibility to ensure that installations meet the safety levels established by industry standards. It is crucial to understand how to evaluate and mitigate risks associated with the use of refrigerants, and the systems that incorporate them. To help address concerns such as refrigerant leakage and detection, while providing flexible heating and cooling solutions, manufacturers have introduced hybrid VRF systems. These systems place all refrigerant-containing components outside of commonly-occupied spaces and use water for heat distribution, thereby minimising both leakage risks and the amount of refrigerant required.

In all cases, the designer should have a clear understanding of why decisions are made and apply the standards that are most appropriate to the application. ●

Module 237

October 2024

1. What is the primary factor driving the new applications of refrigerants?

☐ A Enhanced system lifespan
☐ B Growing focus on environmental sustainability
☐ C Improved energy efficiency
☐ D Reduced manufacturing costs
☐ E Reduce the need for refrigeration technician training

2. What is the typical minimum ignition energy for an A2L refrigerant, compared with approximately 0.0003J for methane?

☐ A 0.001J
☐ B 0.01J
☐ C 0.1J
☐ D 1J
☐ E 10J

3. Which of the following factors is NOT included in the equation to determine the minimum room floor area for installing an RACHP appliance containing refrigerant?

☐ A Assumed release height of leaking refrigerant
☐ B Lower flammability limit
☐ C Refrigerant's burning velocity
☐ D Refrigerant charge
☐ E Room height

4. What type of safety method limits the quantity of refrigerant to prevent unsafe conditions in case of leaks?

☐ A Active safety
☐ B Extrinsic safety
☐ C Intrinsic safety
☐ D Passive safety
☐ E Regulation safety

5. How do hybrid VRF systems enhance safety in applications concerned about refrigerant leakage?

☐ A By employing smaller refrigerant charges than traditional systems
☐ B By incorporating advanced sensors that can detect leaks at much lower concentrations
☐ C By locating refrigerant components outside occupied spaces and using water for heat distribution
☐ D By using a hybrid (or mixed) refrigerant that is less flammable
☐ E By utilising a novel warning system that is controlled by AI

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