Cooling the

It's getting hot in here, as the hip-hop song goes. But London Underground has a swathe of cool plans to make the tube much more comfortable, as it ramps up passenger capacity. Brian Tinham reports

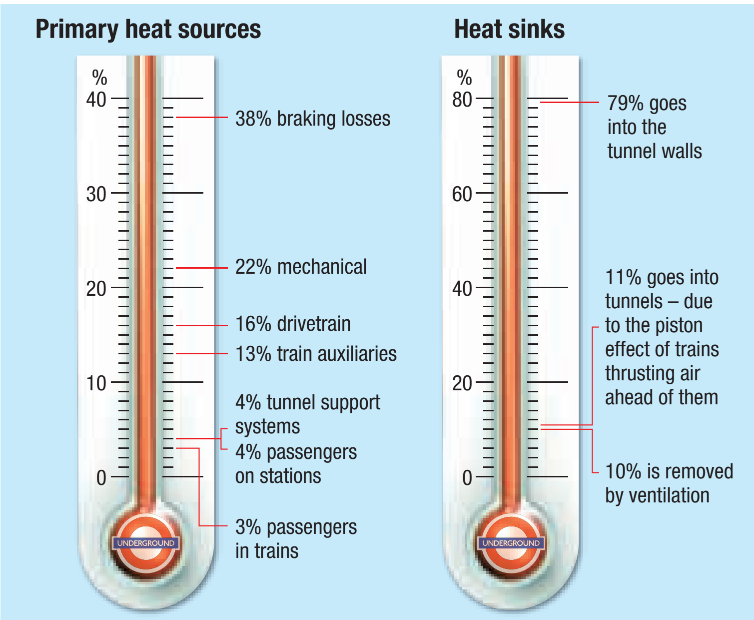
Anyone who travels on London Underground knows that the tube is too hot, particularly on the deeper central area lines. When Transport for London's (TfL) Cooling the Tube programme director Kevin Payne tells you: "We're going to move from warm, to uncomfortable, to a place we certainly don't want to be, if heat dissipation remains unmitigated," it's clear the problem is getting acute.

And when he explains that London Underground is well on the way to honouring its commitment to significantly improve capacity – meaning more and faster trains dissipating yet more energy – it becomes downright urgent. The issue, though, is how to deal with it – and that was the subject of an IPlantE seminar last month in London.

In fact, tube temperatures have been rising steadily from stone cold since underground construction started in the late 1800s. When the Bakerloo line opened in 1906, for example, advertisements paraded the tube as the coolest place to be in the hot summer weather. Two years later, that campaign stopped as platform and train temperatures started to get uncomfortable.

Today, there's a distribution of temperatures around the Underground network, with an average of about 11°C above outside ambient, and some areas much hotter. In August this year, the temperature at Chalk Farm, for example, hovered around 30°C – and this was hardly a warm summer! Meanwhile, computer modelling for the Victoria line upgrade, due for completion in 2012, shows that, without serious mitigation, there will be a heat uplift of a staggering 60%.

A little detail: primary heat sources are 38% braking losses, 22% mechanical, 16% drivetrain, 13% train auxiliaries, 4% tunnel support systems, 3% passengers in trains and 4% passengers on stations. As for thermal losses, 79% goes into the tunnel walls, while 11% goes into tunnels – due to the piston effect of the trains – and the remaining 10% is removed by ventilation. The nub of the problem is that the biggest heat sink is failing as the temperature behind the walls rises way back into the clay. It's now sitting at between 5°C and 11°C above the natural ambient of 14°C.



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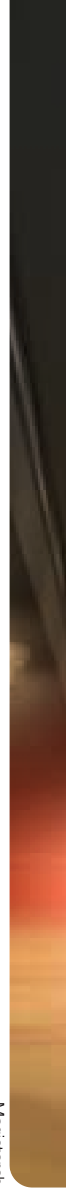

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Urgent attention

"The other problem is that we have big, big plans to improve capacity on the tube," reiterates Payne, "to accommodate passenger journeys that are forecast to grow from 1 billion per year now to 1.4 billion per year by 2030." And that's not just about more trains. They will also have to run faster, accelerate more quickly and brake more smartly, so it's clear that dissipating heat from the system is only going to get tougher and more urgent.

So there you have it. And the most obvious solution (large-scale air conditioning) is a non-starter. Partly that's because of the massive cost involved – Payne estimates that removing heat from the network this way costs the upper end of 10 to 50 times as much as putting it in. Partly, also, it's because warm air from the heat exchangers would have to go somewhere and, given the restrictions on building new ventilation plant across central London, it simply can't.

It's a taxing one. So taxing that, in 2005, Mayor of London Ken Livingstone offered £100,000 to anyone with a solution. To date, that prize remains unclaimed. However, London Underground isn't waiting for ideas: it has plenty of its own, and is farther along the line of modelling, piloting and implementing them than most realise.

Payne lists TfL's preferences as: first, reducing heat input, because subsequent extraction is so

expensive; second, maximising the existing ventilation options, because they offer best cooling value for money; and then third, going for some form of mechanical cooling. "But that starts to get expensive – not least because most of the work has to be done between 1.00am and 5.00am, and it's also a difficult and cramped environment," he says.

Looking at operational improvements, trains draw 4,500 amps at 630V as they accelerate, dissipating 2.8MW of heat energy – so better management of acceleration is one of the key solutions. "If you accelerate more rapidly and then do a controlled coast to slow down into the next station, you optimise energy usage," explains Payne. "Adding firmer controlled braking then also maximises the regenerative effect for the network. If we do this well, we can expect to cut that energy uplift on the Victoria line, for example, from 60% down to 35%." And he believes that by working on the schedule recovery time margin – spreading train running and dwell times throughout journeys – London Underground will be able to push that down to 25%. Still worrying, but a huge improvement.

Now looking at cooling, if water is available – and especially if it's free – that's the preferred option. At Victoria station, for example, there's a huge underground sump and pump system removing water that seeps in from the submerged River Tyburn – so million of litres of water at ground ambient. "We can extract and circulate that water to ceiling-mounted fan cooling units," explains Payne. "That would provide excellent cooling value, because the energy used is minimal: just a small pump and relatively small fans. Victoria will be the trial site and, if the technology is successful, that can be rolled out to similar sites."

Better boreholes

Although sadly, there aren't many, because of problems such as pollution or ground water flow rates that vary too much with the seasons. Also, there can be silting difficulties that are challenging for filtration – not just on the water side, but also with air movement plant. Fin clogging, due, for example, to dust from civil engineering work, has a significant negative impact on cooling unit efficiency.

Another option, however, is boreholes into the aquifer beneath the London clay – extracting water via pumps, with similar (although larger) air handling on platform ceilings, followed by re-injection of spent water into the deep chalk, as per the Royal Festival Hall project. "The approach is reasonably green and provides good cooling, but there are challenges here too," comments Payne. "For example, the water is moving slowly, so you have to be careful where you bore. You don't want to re-

Cooling the tube is a serious plant engineering challenge – and London Underground is trialling solutions

uptake the re-injected warmer water."

However, the technology is due to be trialled at Stockwell early next year, and air-handling units are already being type tested. "I can personally see the day when we sell our waste heat to domestic and commercial users," says Payne. "We are in early discussions with Swim London for pre-heating swimming pool water and helping warm sports halls. Heat pump heating systems for office blocks also offer possibilities."

After water comes air and TfL is already on the case, using portable industrial fans, although Payne agrees this is not a long-term solution. "We need much larger air-handling equipment and we need to make better use of our ventilation shafts," he says. And that means "big-time engineering work" where shafts and fan plant have fallen into disrepair. So far, 92 have been brought back online and three more large ones will be repaired by next year, leaving 22 to go – although Payne indicates that blank shafts (those built to relieve pressure as trains pulse through the network) could also be brought into service.

Re-engineered ventilation

To put this into perspective, on the Victoria line upgrade, Payne reveals that all tunnel shafts need their old equipment removed and replaced with double-capacity fans, using modern plant and materials with better sound attenuation, as well as SCADA (supervisory control and data acquisition) systems to orchestrate all that cooling. Meanwhile, the Northern line could do with new ventilation shafts and fans throughout – which is a serious challenge on the land side. Suitable property in central London isn't that easy to come by.

Another option, however, is under-platform exhausting where, when trains arrive at stations, air is blown across the traction and braking equipment and drawn out along the underside of the platform lip, via ducting, and into the ventilation shafts.

And then there's evaporative cooling – where air streams pass through wet pads to effect adiabatic cooling. "We can engineer wet pads at the top and bottom of shafts, and force air through to provide that kind of cooling. It's simple, cheap and relatively problem-free. That is being tested now and we're also looking at injecting ultra fine mist sprays into the tunnels."

Payne makes the point that modern evaporative cooling plant ensures that water can't stagnate and maintains pads below 20°C, so that Legionnaire's disease is not a problem. The trick is to control relative humidity, so that the cooled air stream remains comfortable and invisible.

Now, we're running out of ideas. Conventional chillers are being used at places like Oxford Circus ticket office, but in the deep tubes there simply isn't the space and, again, nowhere to vent extracted heat. "Where we can use this technology, however, we are using a water-based medium, because it has the right phase change temperature, is inert, not flammable, has the right energy to mass ratio – and means we can connect to better water-based mechanisms at some point in the future," comments Payne.

And he adds: "We haven't given up on conventional cooling, but a hybrid arrangement looks more promising. Using a chiller, we can force the medium to the solid phase, using conventional chiller plant at the surface, and then pass it back through the phase change to cool the trains in transit underground. It could work on the Piccadilly line, for example, because, for much of its length, it travels at ground level. We're building a six-metre mock-up of the tube with this hybrid equipment now and that will be trialled later this year." PE

Pointers

- Cooling presents challenges in all sorts of plant and there are several potential engineering solutions
- Evaporative cooling is a serious contender: think of the Moors' Spanish castles, designed with towers and surrounded by fountains and ponds to draw water-cooled air into the buildings
- If at all possible, operations should be reviewed, since reducing heat sources is always best, cheapest and greenest