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Achieving net-zero

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ELECTRIFYING INNOVATION

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CONTENTS

YOUNG ENGINEERS AND APPRENTICES RAILWAY SEMINAR: DELIVERING A SUSTAINABLE RAILWAY

Institution of MECHANICAL ENGINEERS

29-30 October 2019

National College for High Speed Rail, Birmingham

THE THEME IN 2019 IS 'DELIVERING A SUSTAINABLE RAILWAY'. RAIL TRAVEL MAY BE SEEN AS A MORE ENVIRONMENTALLY-FRIENDLY MODE OF TRANSPORTATION, HOWEVER THERE ARE MAJOR CHALLENGES TO OVERCOME IN ORDER NOT ONLY TO PROTECT THE ENVIRONMENT, BUT ALSO TO MAKE THE SUPPLY CHAIN MORE SUSTAINABLE AND COMPETITIVE.

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Electrify everything

This exhortation to electrify everything concerns much more than railways. It is one of the main thrusts of the report 'Net Zero: The UK's contribution to stopping global warming' produced by the UK Government's Committee for Climate Change. This explains how, by using mostly known technologies, the UK can achieve net-zero carbon emissions by 2050 without significantly affecting the nation's economy.

The report sees electrification of, for example, domestic heating, industrial processes and road transport, through the provision of electric vehicles, as the only way of weaning the nation off its fossil fuel dependence. Our feature on the net-zero report is essential reading for anyone with an interest in climate change and provides the context for the recently published final report of the rail industry decarbonisation taskforce.

Although this report concludes that there needs to be "additional progressive electrification of more intensively used routes", our review concludes that it understates the benefits of electric traction and overstates the potential of non-diesel self-powered vehicles. We also conclude that Government requires a short clear statement of the key issues. For this reason, our report includes an open letter on rail decarbonisation to the Secretary of State for Transport, explaining why a rolling programme of electrification is essential for significant rail carbon reductions.

Yet there must be a business case for electrification. For intensively used lines, this should not be a problem. However, on less well-used lines, the financial case for electrification is not so strong, as current appraisal rules do not adequately value the carbon savings that the Government requires.

Furthermore, electrification must be affordable. In this respect the Railway Industry Association's electrification cost challenge report demonstrates how the industry has now got electrification costs under control. This includes descriptions of various initiatives to reduce costs, such as the use of surge arrestors to avoid bridge reconstructions.

We feature other novel techniques, with Alstom and Siemens explaining how their overhead line systems offer cost, design, installation and maintenance savings. Malcolm Dobell also explains how the bits and pieces that bind overhead line equipment together have been the subject of considerable innovation.

A novel approach that will significantly reduce the cost of electrifying the lines north of Cardiff will use tri-mode trains that are battery-powered under permanently earthed sections, so avoiding the need for costly civil engineering work, as Graeme Brindle and Nathan Sealy explain.

New trains require extra power for their improved performance and air conditioning, as is the case on Merseyrail, where 40-year old trains are soon to be replaced with a new fleet. As our feature shows, upgrading the third-rail DC system power supply for these new trains is a complex task.

Electrification must also be utterly reliable. To this end, we also report on the improvement of OLE reliability in Anglia and Thameside from the replacement of 1960s fixed-tension OLE with auto-tensioned systems, while Peter Stanton describes how the OLErt system, using an intelligent camera, has been developed to monitor the critical pantograph/OLE interface.

A very different monitoring technology uses acoustics to monitor the condition of bearings on passing trains. As Clive Kessell explains, this offers significant benefits by supporting a predictive maintenance regime whereas hot axle box detectors can only detect failures.

The commissioning of 26 kilometres of new double track railway marks the end of the three-year first phase of the Aberdeen to Inverness (A2I) improvement project. We describe how the second stage of this redoubling was completed in a 15-week blockade and the significant passenger improvements that it will provide.

The 137 kilometres of new cable laid by the A2I project shows the need for cable protection, for which we feature one solution. It also highlights the need for cable cleats, the design and manufacture of which has been investigated by Graeme Bickerdike. His report reveals unexpected complexities and shows how installation time and whole-life costs can both be reduced by using the right cleat.

People need protection too, and user-worked crossings have, statistically, a higher rate of collisions and fatalities than other types of level crossings, when the usage rate is taken into account. Paul Darlington has been investigating plans to improve safety at the 2,500 such crossings on the network.

Finally, we report on the successful launch of LNER's Azuma trains between Edinburgh and London and the passenger benefits that these new trains will provide. Like many new trains, their service introduction had been delayed due to unforeseen issues, including the fact that one of the route's OLE power feed stations will not be upgraded until at least 2021. However, as we explain this is mitigated by the Azuma's bi-mode capability, which also delivers carbon savings as LNER trains from London to Inverness and Aberdeen will no longer be diesel-powered under the wires for most of their journey.

Our feature includes an interview with Hitachi's head of engineering, Koji Agatsuma, who offers his thoughts on battery and hydrogen traction. He also explains the design philosophy of the bi-mode Azuma trains, which will have a useful transitional role if there is to be widespread electrification. However, as the rail decarbonisation report makes clear, there can be no long-term role for bi-mode trains in a zero-carbon railway. ●

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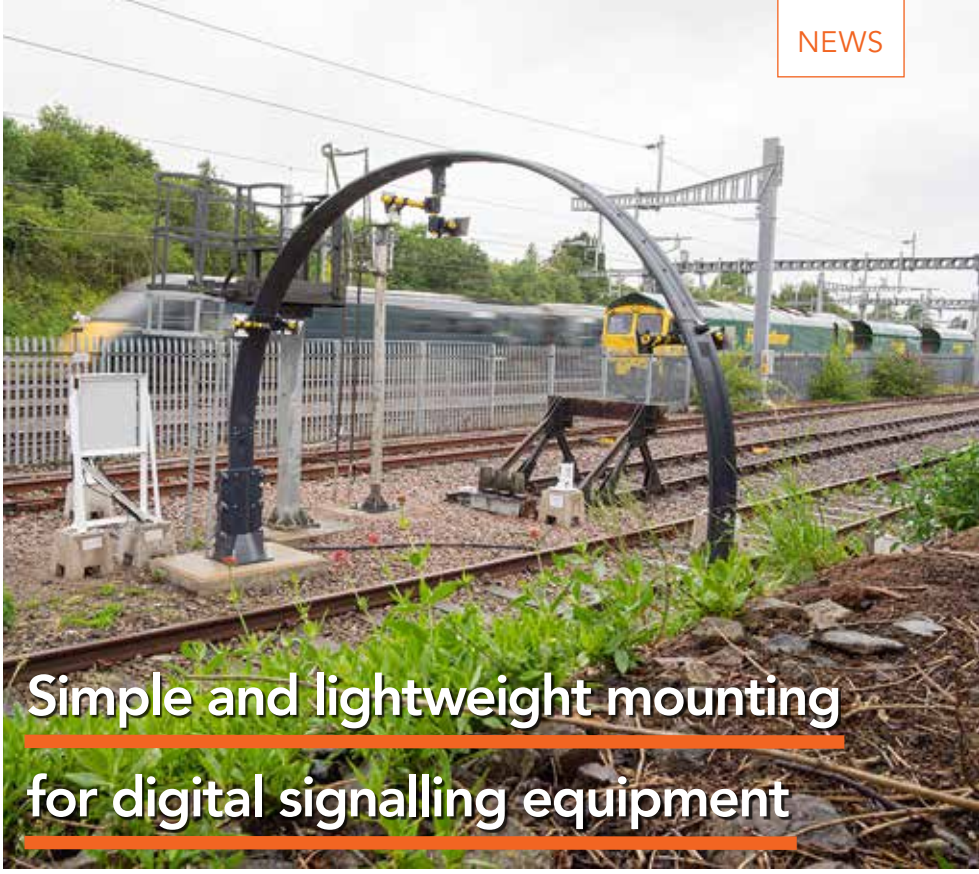


Simple and lightweight mounting for digital signalling equipment

AECOM, the global infrastructure services firm, is developing one of the UK's first 3D-printed commercial products made from graphene-reinforced polymer. The company's CNCTArch is designed to drive down the costs associated with installing digital signalling systems on transport networks, using a graphene arch that sits over rail tracks and eliminates the need to attach new digital equipment to existing infrastructure.

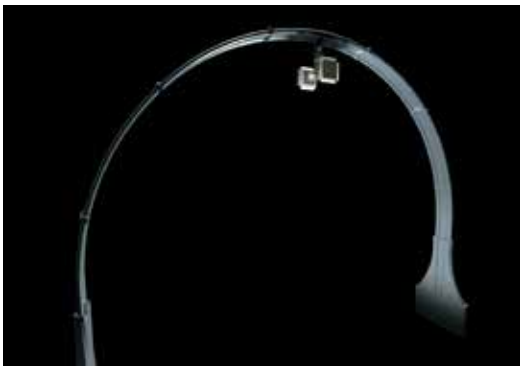
Derived from graphite, graphene is one of the strongest materials in the known universe. It was first isolated by researchers at the University of Manchester in 2004.

The AECOM team came up with the concept of CNCTArch in response to clients' concerns about the cost and time of digitising the signalling systems on their networks. The company looked at replacing the traditional 'bolt and screw's method of deploying digital systems in tunnels, which takes four shifts to install, by developing an arch on which the digital technology is attached that doesn't bolt to any existing infrastructure and would take only one shift to install.

While developed for use in tunnels, the CNCTArch can also be used in open environments and has the potential to transform the deployment of digital traffic management systems.

An example of this new lightweight arch, 4.5 metres high, is currently being tested on an outdoor track at Network Rail's workforce development centre in Bristol, where AECOM is working with Network Rail's Western region team and its Bristol Parkway signalling training school to test the arch. Sensors have been installed to monitor, in real-time, how the arch performs in different weather conditions, measuring oscillation and deflection.

The six-month trial is the next step towards commercialising the product, with the results enabling AECOM to further validate the feasibility of using the arch as an alternative to traditional methods of installing digital equipment.



Levenmouth re-opening taken forward

On 8 August the Scottish Cabinet Secretary for Transport, Michael Matheson, announced the go-ahead for detailed design work to support the proposed reopening of the 9.5km railway serving Levenmouth, in Fife, at an estimated cost of £70 million.

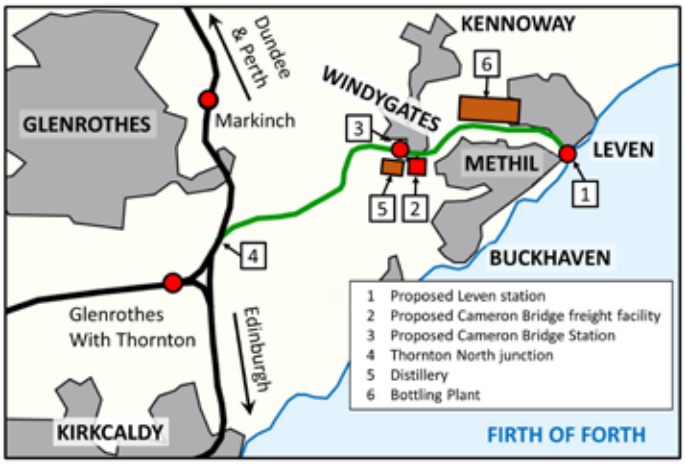
The mothballed-single track line was closed to passengers in 1969 but remained open for freight up to 2001. It is owned by Network Rail, though out of use under Short Term Network Change (STNC) provisions. Thus, the line has no blockages. It has four river bridges but no major structures and connects with the main line from Edinburgh to Perth and Dundee at Thornton North Junction, which is still operational but secured out of use.

The re-opened line will have stations at Leven and Cameron Bridge. Levenmouth is the largest settlement in Scotland without a rail service and the new line would provide a rail head for East Fife and its tourist attractions. Furthermore, as Europe's largest grain distillery, owned by Diageo, is at Cameron Bridge, there is significant potential for freight traffic.

In his announcement, Matheson noted that: "The detailed appraisal work that has been carried out suggests that improved transport links, which give Leven a direct rail link to Edinburgh, will lead to an enhanced local economy, bringing better access to employment and education and the potential for new investment. Easier and more sustainable travel options will make it easier for people to reach hospitals, schools and visit other areas of the country as well as giving better access to Levenmouth."

Matheson also committed an additional £5 million to a Levenmouth Blueprint fund available to partners to maximise the benefits of the Scottish Government investment in the area.

His announcement is the culmination of the long-running Levenmouth Rail Campaign's work to persuade the Scottish government of the need to reopen the line. It is expected that, when it opens in a few years' time, trains to Edinburgh will take 70-75 minutes.



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Work to restart on Rastatt

German national rail infrastructure manager DB Netze has announced that construction work to complete the tunnels under the town of Rastatt will recommence in 2020, with the tunnels now due to open in 2025.

The Rastatt tunnels are a key part of the long-term plan to quadruple the entire line between Karlsruhe and the Swiss border at Basel. This is one of the busiest sections of railway anywhere in Europe, with lengthy double track sections used daily by nearly 400 trains, more than half of them freight, in 2019, according to DB.

The previous collapse of one of the tunnels underneath the existing main line on 12 August 2017 (issue 156 October 2017) led to a seven week closure of the line and caused major disruption to European logistics services as no alternative routes were readily available. The costs of the closure and disruption to rail users and wider industry have been estimated at up to €2 billion.

Construction of the twin bore tunnels, designed for 250km/h operation, began in 2013 using tunnel boring machines (TBMs) at shallow depths in alluvial sedimentary rocks. However, work ceased from 12 August 2017 when a landslip into the newly constructed eastern tunnel bore not only disrupted construction but severed the existing main line on the surface. A 160-metre-long section of the tunnel including the TBM was then filled with concrete to stabilize the site.

The route re-opened on 2 October 2017, after a 275-metre-long concrete slab had been laid to support the railway on top of the area that collapsed.

DB has now agreed its plans to complete the Rastatt Tunnels. The remaining 200 metres of the undamaged western bore will be completed by the ARGE Tunnel Rastatt consortium using the TBM that is already in position (having been shut down in August 2017). The existing surface main line is protected from any unexpected tunneling issues as it is on the concrete slab built in September 2017.

To permit construction of the eastern tunnel under the existing main line without danger of further disruption to the route, DB will first move a 700-metre

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section of the line so it follows the course of the completed western bore (on the surface) to slew it away from the construction site; approval for this has been granted by the German Federal Railway Office (EBA).

DB and ARGE Tunnel Rastatt then plan to excavate the remaining part of the eastern bore using open excavation methods (cut and cover) having first inserted concrete walls to the required depth. This will include removing the 160-metre-long concrete plug and the remains of the TBM. A concrete line trench 17 metres deep will be dug and the tunnel constructed in it before it is back filled. This work is expected to commence in 2021; DB Networks has applied for the necessary planning approvals to the EBA.

Once the two tunnel bores are completed, the surface line will be moved back above the eastern bore. Construction of remaining cross passages and entrance portals plus fit out will take until 2024. DB currently expects the Rastatt Tunnel to open in 2025 along with approach lines on either side, resulting in a four-track railway from Karlsruhe to Offenburg.

Following the 2017 accident, detailed evaluation of ground conditions, including 70 bore holes, and other factors has been underway to ascertain responsibility for the tunnel collapse and subsequent disruption to the railway line through Rastatt, which resulted in substantial financial costs for both DB and multiple private freight operators. A conciliation and arbitration process is underway to establish responsibility and financial damages, with the aim of avoiding lengthy legal action.

New kid on the block

East Midlands Railway is the new name on the UK rail network, following its successful bid to run the East Midlands franchise.

The new franchise came into being on Sunday 18 August 2019. One day later, the first EMR-liveried train, Class 222 Meridian number 222104, was revealed to stakeholders and the press at Derby station.

The expected speeches were made, by the managing director of Abellio UK Dominic Booth ("Abellio is delighted…") and the City Mayor of Leicester and chairman of the East Midlands Councils Sir Peter Soulsby ("We're pleased to welcome East Midlands Railway…"), but there were some serious promises for the future being made as well.

A fleet of 33 new five-car trains is being ordered from Hitachi at Newton Aycliffe for delivery in 2022. They will be AT300 trains, similar to the Class 800/802 units already being supplied to GWR and to LNER. However, they will have coaches only 24-metres long, rather than the 26 metres of the other two classes, and they will have one extra diesel engine, four spread over the five carriages.

In addition, Class 360 all-electric trains will be brought in for the London to Corby service once electrification is complete, and Class 170 diesel multiple-units will be used for cross-country services.

Julian Edwards, managing director of East Midlands Railway, was keen to stress that passengers would get improved services as well as new trains.

The timetable will change from December 2021, correcting some of the current anomalies. Catering will be sorted out and improved Wi-Fi will be available throughout all trains. The current offering is seen as being sub-standard and it will be improved.

There is more of course - £20 million investment in stations, easier ticketing, more customer assistance, better staff training - but customers want comfortable trains that are on time and provide decent catering and good connectivity, and that's what EMR has pledged to offer.

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DAVID SHIRRES

Achieving net-zero

The 2008 Climate Change Act was the first in the world to make a government legally accountable for delivering its greenhouse gas (GHG) emissions target, which was at least 80 per cent lower than the 1990 baseline. The Act is the basis for the UK's approach to tackling and responding to climate change. It requires five-yearly carbon budgets to be set and established the Committee on Climate Change (CCC) to provide independent, expert, evidence-based advice.

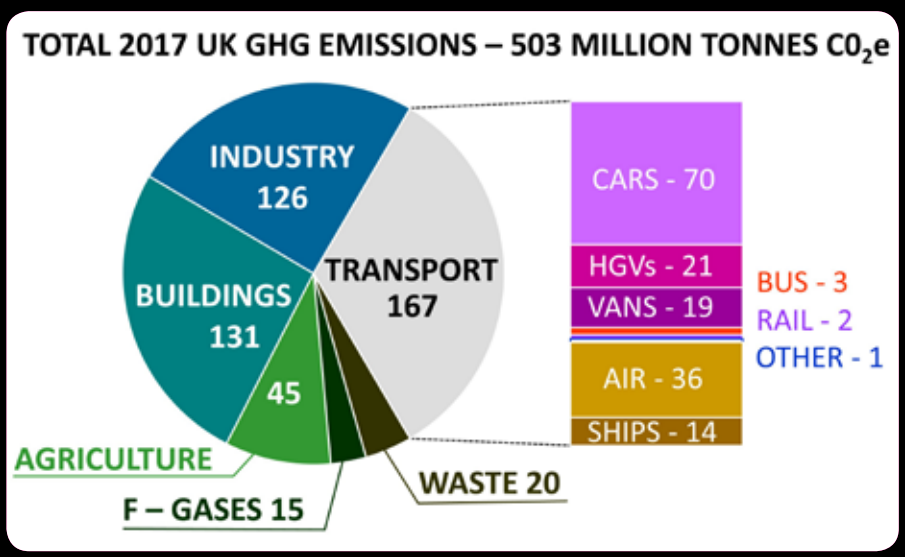
By 2017, the UK was over half-way to meeting its 2050 target with GHG emissions 43 per cent below those of 1990. However, this was not good enough as this was largely achieved through the relatively easy measures of burning gas instead of coal and using more renewables to generate electricity. Furthermore, it was becoming increasingly clear that the 80 per cent reduction target was not enough.

In May 2019, the CCC published its report 'Net Zero: The UK's contribution to stopping global warming'. This reviewed the latest scientific evidence on climate change and concluded that the UK should adopt a target of net-zero GHG emissions by 2050 which, if replicated across the world, would deliver a greater than 50 per cent chance of limiting the global average temperature increase to 1.5°C.

The report considered this target was achievable as the technologies and approaches to achieve net-zero are understood. However, it was also considered to be hugely demanding and only achievable if there is urgent government action to drive the significant urgent policy changes required.

In June, the CCC's net zero 2050 target became legally binding as the Climate Change Act was amended to adopt it.

Achieving net zero will affect everyone in Britain and require some lifestyle changes. Yet, whilst some might believe that reducing emissions requires an economic slow-down, the good news is that it need not make the UK poorer. The CCC report explains the technologies needed to both reduce emissions and maintain



economic growth as well as the policies that the government must adopt if these technologies are to be deployed.

The technical report that supports the CCC's recommendation is available online and is a daunting 304 pages. For this reason, we thought our readers might appreciate a summary, especially as this report provides the context for rail decarbonisation.

Electrify everything

As fossil fuels have a high energy density and can be readily stored and transported in fuel tanks, tankers and pipelines, it is not surprising that the modern world is utterly dependant on them. However, if net zero is to be achieved, we must be weaned off them. To do this, the CCC report stresses the need for extensive electrification, particularly in respect of transport and heating.

The obvious reason for this is that electricity can also readily transport huge amounts of energy, albeit only to fixed locations. An exception to this is electric trains, which are thus the only form of high-speed and mass transport that offers potentially zero emissions. No doubt for this reason, the report recommends a rolling programme of railway electrification, otherwise rail transport is hardly mentioned except for the need for modal shift from road and air to rail. Yet any significant modal shift would require a huge increase in rail capacity, such as that HS2 will provide.

The CCC report considers that the electrification of road transport (19 per cent of the UK's GHG emission) will be by battery and hydrogen-powered vehicles. Advances in battery technology and the provision of the required charging infrastructure will make electric cars increasingly practicable, so that no more petrol or diesel vehicles should be sold after 2030. However, the report points out that the solution for HGVs is not clear and is likely to be a combination of hydrogen and battery technology, such as extremely fast chargers at motorway service stations. It also moots the use of a motorway pantograph system to continuously charge HGVs.

Electrical industrial and domestic heating is also essential to reduce fossil fuel consumption. The report notes that there is an urgent need to engage with the public on a strategy to move away from gas heating as GHG emissions from buildings accounts for 17 per cent of UK emissions. It envisages that electricity should be used to power heat pumps to heat buildings as this would produce three units of heat for one unit of electricity. There is also the potential to use hydrogen in the existing gas distribution system to heat buildings.

By 2050, the UK will require a low-carbon electricity generating capacity of 150GW to generate a total of 645TWh to satisfy this extensive electrification. This compares with today's 104GW which produces 300TWh. The CCC envisage a vast increase in solar, off-shore and on-shore wind generation. However, its scenarios take a cautious approach, limiting the share of variable renewables to under 60 per cent as these are not suitable for base load and peak power which needs to be supplied by nuclear power and gas turbine plants with carbon capture and storage (CCS).

Aviation and shipping

Aviation and shipping accounts for 10 per cent of UK GHG emissions and, unfortunately, cannot be electrified except perhaps for short distance domestic shipping. Aviation makes up seven per cent of the UK total, of which 96 per cent is international flights from which emissions have increased from 15 to 35MtCO_2e (Metric tons of carbon dioxide equivalent) between 1990 and 2017.

By 2050, there are unlikely to be any commercially available zero-carbon planes. Measures to manage aviation emissions will therefore include more efficient engines and airframes, improved airspace management, the use of sustainable alternative fuels and measures to reduce growth in demand. While biofuels could be a substitute for aviation fuel, this might not be the best use of this scarce resource for which there are alternative uses that may save »

more emissions. Synthetic carbon-neutral fuels are another alternative, although it is likely their costs will be very high.

There are a range of options to reduce shipping emissions, some of which may allow shipping to get to near-zero emissions. These include more efficient hull and engine designs, improved operations and the use of alternative fuels such as ammonia and hydrogen.

CCS and BECCS

One key technology that has yet to be developed is Carbon Capture and Storage. In contrast, the production of biofuels is a well-developed technology and accounts for three per cent of road fuels. However, there is a finite limit to its production, given land constraints and the requirement for food production, and growing biomass requires a significant carbon input. Therefore, the production of bio energy with CCS (BECCS) is required if biofuels are to contribute to the net-zero target.

CCS can capture and store up to 90 per cent of the GHG emissions associated with fossil fuel power generation and industrial processes. The UK's first carbon storage facility is expected to be operational by the mid-2020s. This will capture 200,000 tonnes of CO_2 from a gas terminal near Peterhead and use the existing pipelines to store it in a depleted gas field.

By 2050, the CCC expect the annual UK storage requirement is expected to be about a thousand times this amount (i.e. 176 million tonnes of CO_2). Storage potential is not considered to be a constraint for the UK, which has sufficient geological capacity to store CO_2 at this rate for 500 years. Exhausted oil and gas fields and their pipeline infrastructure present significant CCS opportunities.

The net-zero report also envisages that hydrogen should be produced by methane reforming with CCS for the resultant CO_2 emissions. Hydrogen needs to be produced in this way as if it was all produced by electrolysis. This would increase annual electricity production by 400TWh (more than 50 per cent of the projected 2050 demand). It predicts that, by 2050, UK hydrogen use will be the annual equivalent of 270TWh (compared with 27TWh in 2017).

Most of this hydrogen is required for heating, both to satisfy industry's requirement for high temperature gas heating and to be used in existing domestic gas distribution networks. Buses and trains would require respectively 3TWh and 0.3TWh, a small fraction of total hydrogen production. Unlike heating, the hydrogen used in fuel cells must be of a very high purity and so is better produced by electrolysis. This would be a more appropriate option where train depots may be some distance from a large steam reforming plant but could be close to a wind farm and use otherwise unwanted energy during the night, for example.

Land and lifestyle

In 2017, the UK's woodlands absorbed two per cent of Britain's GHG emissions or 10MtCO_2e. The report envisages that annual afforestation rates of between 30,000 and 50,000 hectares would increase woodland cover from its current 13 per cent of the UK's land area to between 17 and 19 per cent, so increasing this carbon sink to between 16 and 36MtCO_2e by 2050.

In contrast, the biological processes inherent in crop and livestock production make it impossible to reduce agricultural non-CO_2 emissions to zero. Currently, agriculture accounted for nine per cent of all UK emissions, half of which were from ruminant livestock. The report considers that there is significant potential to reduce emissions by more efficient use of nitrogen, better manure management, improved crop productivity, better thermal efficiency of agricultural buildings and low-carbon alternatives for tractors and other machinery.

The report shows how consumer lifestyle choices can help to reduce agricultural emissions as healthier diets rely less on carbon-intensive animal products (like lamb, beef and dairy). Reducing food waste is also a key step that individuals can take to reduce emissions as a significant amount of agricultural land is devoted to the production of the 10 million tonnes of food which are wasted each year, of which 70 per cent is binned within households.

Other lifestyle choices to support net zero emissions are indicated by the current breakdown of average household emissions which are: heating (31%), transport (27%), diet/agriculture (18%), aviation (12%), electricity (9%) and waste (3%). Whilst the reduction of GHG emissions from heating and electricity will largely come from technological improvements, other aspects require changes in consumer behaviour such as

diet and waste. The CCC report mentions the requirement to make more use of public transport and to fly less, noting that the growth in air travel cannot be unfettered.

Who pays?

Net zero by 2050 is estimated to cost between one and two per cent of GDP, which is the same cost of the 80 per cent target which Parliament accepted when the 2008 Climate Change Act was passed. Incidentally, it is also similar to the entire defence budget (1.8 per cent in 2018).

As well as savings from the avoidance of climate damages, the CCC considers that there are likely to be significant benefits from the required decarbonisation programme. These include better air quality, energy self-sufficiency, with little demand for imported fossil fuels and their associated price volatility, and industrial opportunities from the UK being the first to adopt such a radical carbon reduction programme. For example, delivering the goals of the Paris Agreement will require annual $2 trillion global investment in low-carbon technologies up to 2050.

Delivering this ambitious net-zero programme will require significant capital investment for which the report recommends that HM Treasury undertakes 'a thorough review of the costs and benefits of meeting a net-zero target and the appropriate policy levers to achieve an efficient and fair transition' to attract sufficient low-cost capital. In this respect, it considers that 'cost-benefit analysis (CBA) is not suitable for climate change action'.

The CCC is clear that decarbonisation action must progress with far greater urgency. Of all its recommendations, perhaps the most urgent is ensuring that the right financial levers are in place. The required investment may not be forthcoming if government investment appraisals do not adequately value carbon savings.

As an example, business cases for projects that deliver the required modal transfer from road to rail are weakened under current rules which require them to take account of the cost of the resultant loss of fuel duty. No doubt such decarbonisation disincentives will be addressed, otherwise there is little chance of achieving substantial carbon reductions.

The net-zero report shows the huge changes that will need to be made across all sectors. It is a bold vision which includes the following issues relating to the rail industry:

- The benefits of electrification generally and for rail the requirement for a rolling programme;
- That there will be far greater use of battery and hydrogen technology in the automotive sector than on rail;
- That biofuels and synthetic fuels are likely to be a scarce resource, the use of which may only be justified in applications for which there are no other zero-carbon options;
- The requirement for modal shift from road and air needs a significant increase in rail capacity, such as that provided by HS2;
- The urgency to act now;
- If net zero is to be achieved by 2050, the need for Government financial policies that incentivise carbon savings.

A credible rail decarbonisation programme must address these issues.

	2020s	2030s - 2040s
ELECTRICITY	Largely decarbonise, Renewables, coal phase out	Expand system, decarbonise peak generation
HYDROGEN	Start production with CCS	Widespread industry deployment, HGVs
BUILDINGS	Heat networks, heat pumps	Widespread electrification, expand heat networks, hydrogen gas grids
ROAD TRANSPORT	Ramp up electric vehicles, HGV decisions	End sale petrol/diesel vehicles, Zero - emission fleets
INDUSTRY	Initial CCS clusters, efficiencies	Further CCS, widespread hydrogen use, electrification
LAND USE	Afforestation, peatland restoration	
AGRICULTURE	Healthier diets, reduced food waste, tree growing, low-carbon practices	
AVIATION	Operational measures, new plane efficiency, constrained demand, limited biofuels	
SHIPPING	Operational measures, new ship fuel efficiency, use of hydrogen/ammonia	
WASTE	Reduce waste, increase recycling	Limit emissions from combustion of non-bio waste
FRIDGE GASES	Move completely away from F-gases	
GREENHOUSE GAS REMOVALS	Develop options and policies	BECCS deployment, direct air capture of CO2
INFRASTRUCTURE	Industrial CCS clusters, expand vehicle charging and electric grid	Hydrogen for industry, more CCS, hydrogen/electric HGV infrastructure, expand electric grid

Rail decarbonisation

a letter to the Minister

There are hundreds of All-Party Parliamentary Groups (APPG) formed by MPs and Members of the House of Lords who share a common interest in a policy area, region or country. These informal cross-party groups have no official status within Parliament, yet they fulfil a valuable role by keeping Parliamentarians informed. APPG meetings are about asking questions rather than argument.

DAVID SHIRRES

On 9 July, the All-Party Parliamentary Rail Group (APPRG) considered rail decarbonisation. In a packed meeting room, its members questioned Professor Jim Skea, co-chair of the working group of the Intergovernmental Panel on Climate Change (IPCC); Helen McAllister, Network Rail's head of strategic planning (freight and national passenger operators); the Railway Industry Association's technical director David Clarke and RSSB's head of sustainable development, Anthony Perret.

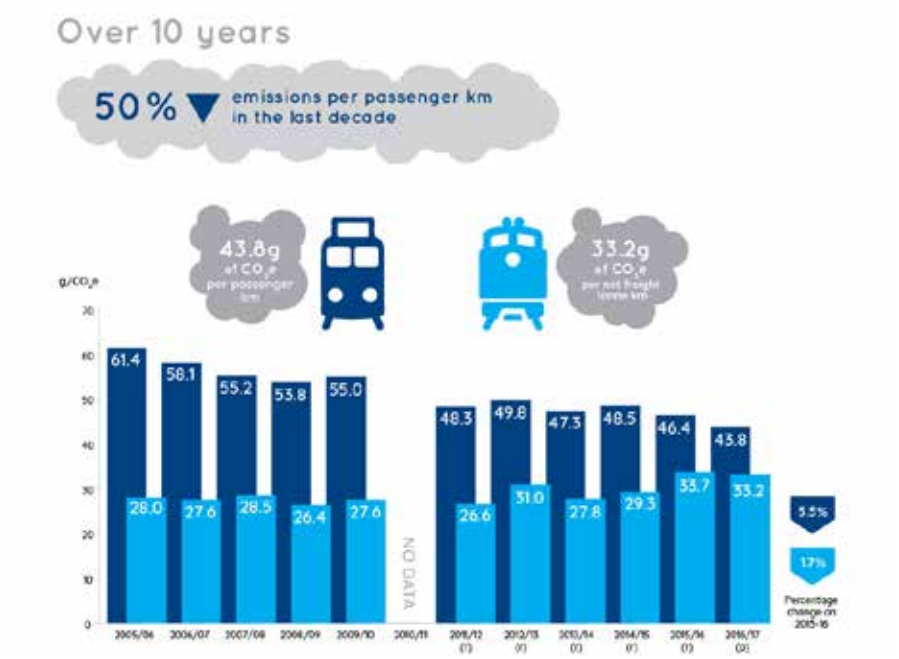
APPRG presentations

Jim Skea made the point that we have 12 months to start saving the world. He stressed that net zero by 2050 was "humongously" challenging and stressed the need for urgent action. He felt that that role of rail has been a blind spot in climate change reports as it has a big contribution to make by modal shift, noting that, globally, rail carries eight per cent of passengers, seven per cent of freight and consumes two per cent of transport energy. He referred to the net-zero Committee for Climate Change (CCC) report, which assumed that those sectors which can relatively easily decarbonise should support others.

Helen McAllister noted that the technology already exists to deliver a zero-carbon railway. However, there was a need to determine where electrification is most appropriate considering deliverability, affordability, operation and efficiency. She felt that appraisal techniques needed to factor in carbon reductions.

David Clarke acknowledged that some electrification programmes, especially Great Western, had not been well delivered. He felt that, after 20 years with no electrification, too much was done too quickly, with 11 electrification projects spreading resources too thinly. However, RIA's electrification cost challenge report had identified what went wrong and shown that recent programmes had been well delivered. He was convinced that, if we want to decarbonise the rail network, a rolling programme of electrification was essential.

Anthony Perret, advised that the soon-to-be-published final report of the rail industry decarbonisation task force would show



(Left) The largely electric passenger fleet has reduced its emissions by taking advantage of the comparable reduction in power station GHG emissions over the last decade. In contrast over this period there was no reduction in emissions from the, largely diesel, freight locomotive fleet.

how the rail industry can decarbonise. He noted that rail was already a low-carbon mode, but a lot more needed to be done. He advised that the report would show that the existing electrified network needed to be used as much as possible and that there should be more electrification where it makes sense. The report also considered that there were no alternatives to diesel traction for freight but, for passenger services, batteries allowed for discontinuous electrification and hydrogen was a feasible alternative to diesel traction. He did not mention the limitations of hydrogen traction.

Rail decarbonisation report

The final rail industry decarbonisation report was published 10 days after the APPRG meeting and was welcomed by industry stakeholders. It stressed that rail was already a carbon friendly form of transport, for example, per tonne kilometre, rail freight has only 25 per cent of the GHG (greenhouse gas) emissions of road freight. Amongst its recommendations was one for "additional, progressive electrification of more intensively used routes", which was welcomed by the Department for Transport. This indicates a policy shift in favour of electrification as the interim report, published in January, stated that "we recognise that the lowest cost and lowest carbon impact whole system solution may identify some additional electrification."

However, the report, which took 17 months to produce, recommended the development of strategic plans to deliver against the agreed targets, of which the first step is a Traction Decarbonisation Network Strategy that will probably take a similar period to finalise (three years since the start of the decarbonisation report).

This would not seem to be the urgent action that Professor Jim Skea emphasised was required, especially as the technology for rail decarbonisation already exists.

It took some time to review the 20,000-word rail decarbonisation report, which covered traction, property and infrastructure, of which traction is the greatest carbon source. This showed that the report does not address issues discussed at the APPRG meeting or in the CCC net zero report. Instead, it takes the stance: "Our focus throughout this report has been to challenge whether electrification is the best solution to achieve a net zero carbon railway in a manner consistent with delivering passenger benefits."

The report also fails to stress the limitations of alternative self-powered traction, for example that hydrogen trains require 2.5 times more electrical energy than electric trains. There was no mention of Alstom's Breeze hydrogen train concept, which would modify a Class 321 EMU to give a 140km/h train with a range of 1,000 kilometres. As an indication of the constraints of hydrogen's energy density, hydrogen tanks take up almost a third of the three-car Breeze, although it is possible that the tanks on a bespoke UK-gauge hydrogen train might not encroach into the passenger space.

It is noteworthy that, when giving presentations on Alstom's hydrogen trains, the manufacturer's representatives always stress their benefits for use where appropriate and acknowledge that they are not a universal solution.

Perhaps the greatest flaw in the decarbonisation report is that its analysis table, which categorises rolling stock to show how trains can be powered, only considers distance and maximum speed. Hence, it does not address the fundamental requirement to consider the acceleration needed to give an acceptable journey time with the required number of stops. Therefore, it would be wrong to use this table to inform the Traction Decarbonisation Network Strategy.

A high rate of acceleration is particularly important for urban and inter-city services and is essential if rail is to be sufficiently attractive to attract modal shift.

Rail Engineer understands that Grant Shapps, the new Secretary of State for Transport, has imposed a two-page limit on information he receives about Britain's railways. In view of this, and the above issues, Rail Engineer would like to offer the following short letter to the Secretary of State outlining how the rail industry can best support the UK Government in delivering its obligations under the 2008 Climate Change Act. ●

The decarbonisation task force launches its report.

1 September 2019

Rt Hon Grant Shapps MP
Secretary of State for Transport
Department for Transport
Great Minster House
33 Horseferry Rd
Westminster
London SW1P 4DR

Dear Secretary of State

The rail industry's contribution to the 2050 net zero greenhouse gas emissions target

With the recent amendment to the 2008 Climate Change Act giving the UK Government a legally binding target of net-zero by 2050, this letter is intended to be helpful in explaining how the rail sector can help you deliver this target. It is based on the conclusions of the Committee for Climate Change's net zero report, discussions with senior rail engineers and articles in Rail Engineer written by our expert engineering writers.

As the transport sector has hardly reduced its greenhouse gas (GHG) emissions, despite an overall UK reduction in emissions of 42 per cent since 1990, your contribution to the government's climate change obligations is particularly onerous. Furthermore, transport decarbonisation presents significant challenges, particularly in respect of aviation and HGVs. In contrast, decarbonisation of the rail industry is relatively straightforward.

This is because the rail sector, which already has a low carbon footprint, offers the only potentially zero-carbon transport for freight, mass transit and high-speed passenger flows in the form of electric trains, whose power is only limited by the current they can draw from the overhead wires/third rail. Unlike self-powered trains, electric trains do not have to carry fuel, nor the plant to power the train which involves unavoidable energy conversion losses, takes a great deal of limited space and adds significant weight.

Hence, electric trains are far more powerful and efficient than self-powered vehicles. Their use is also consistent with the CCC net-zero report which emphasises the general benefits of electrification and, for rail, mentions the need for a rolling electrification programme. This is the result of the underlying physics of transport and energy storage rather than any lack of technology.

Electric trains already offer significant benefits, as GHG emissions from electric rail passenger vehicles are, on average, 26 per cent those of diesel vehicles. These emissions are entirely from electricity generation which, according to DfT projections, will be halved by 2028 and, by 2050, will be eight per cent of the current emissions. Railway electrification is needed to realise these benefits.

The reduction of transport sector emissions by modal shift from air and road to rail, as required by the CCC net zero report, must also be an essential element of your decarbonisation strategy. For this to happen, the rail network must have the capacity to accept this shift, for which HS2 and other capacity improvements are essential. To attract custom from other modes, trains must also offer an attractive alternative and so need the required acceleration and speed for commuter services and inter-city services. Electrification is the only decarbonisation option that can provide this performance.

On lightly used lines, where electrification cannot be justified, there is a role for battery and hydrogen passenger trains. However, these have significant energy storage limitations. For the same volume, a diesel tank can store 36 times the energy of a traction battery pack or eight times the energy of hydrogen stored at 5,000 pounds per square inch in a heavy pressure vessel. Hence, battery trains can only be suitable for short distance applications and the space available for passengers may be reduced due to the volume required for fuel storage on hydrogen trains.

Furthermore, hydrogen trains are intrinsically inefficient. Taking into account the production of hydrogen, they require 2 ½ times more electricity than conventional electric trains for the same power, as explained in the Institution of Mechanical Engineer's January 2019 report 'The Future for Hydrogen Trains in the UK'.

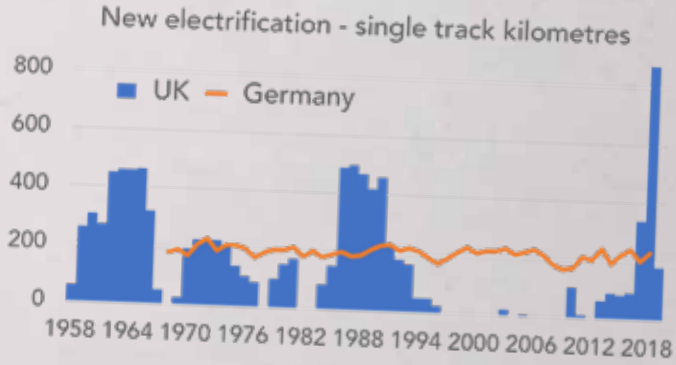
For rail freight, electrification is the only decarbonisation option due to the limitations of battery and hydrogen traction. A recent study for the National Infrastructure Commission - ´Better Delivery: the challenge for freight´ - showed that electrification of 515 kilometres of track would allow nearly two-thirds of existing freight services to be electrically hauled. Currently, only 17 per cent of freight locomotives are electric.

Clearly, further electrification needs to be justified in a business case that reflects the significant capital investment. However, Treasury appraisal rules do not adequately value carbon savings and, indeed, penalise proposals that deliver the required modal transfer from road to rail, as their business cases must show the cost of the resultant loss of road fuel duty. If net-zero GHG emissions are to be achieved, it is essential that Government ensures the right financial levers are in place to incentivise the required investment.

Electrification also must be affordable. In this respect, your predecessor was right to act in response to the unacceptable cost and time overruns of the Great Western Electrification Programme (GWEP). However, since then, other programmes have run to time and budget and electrification costs have fallen sharply, as explained in the Railway Industry Association's ´Electrification Cost Challenge´ report which explains how electrification costs are now 33-50 per cent of the GWEP cost. This also describes how new technology can further reduce costs by, for example, avoiding the need for bridge reconstruction.

The graph below indicates how the ´stop-go´ nature of UK electrification was an underlying cause of GWEP's high cost. Electrification is a specialist activity, requiring its own design and installation skills. Unlike countries such as Germany, the UK has had an intermittent electrification programme. Each time it halts, expertise is permanently lost, and supply chains need to be recreated.

With no further electrification authorised, this wasteful cycle is about to repeat itself as successful teams disband and the supply chain focuses on markets outside the UK. When the electrification programme is eventually restarted, as it must be if Britain's railways are to be decarbonised, hard-won lessons from recent schemes will have been forgotten and will need to be relearnt.



Thus, the high GWEP electrification costs were an aberration, but the industry has since shown itself capable of delivering affordable electrification. Both this, and the decarbonisation imperative, show that there is an overwhelming case for a strategic electrification rolling programme.

Such a programme takes advantage of the greening of the grid and, for almost all passengers and freight customers, is the only way to both decarbonise rail transport and offer an acceptable service. In the long-term, diesel traction, including on bi-mode trains, must be eliminated except for freight and engineering trains on unelectrified lines, for which carbon offset measures are required.

There is clearly a role for battery and hydrogen trains. However, as their performance limitations make them unsuitable for intensively used routes, they are only suitable for a small proportion of passenger traffic.

This letter is intended to show clearly how and why electrification is, for almost all rail traffic, the only long-term rail decarbonisation option. I am confident that this reflects the views of the rail engineers I know and respect.

I do hope you find this helpful,

Yours sincerely,

David Shirres

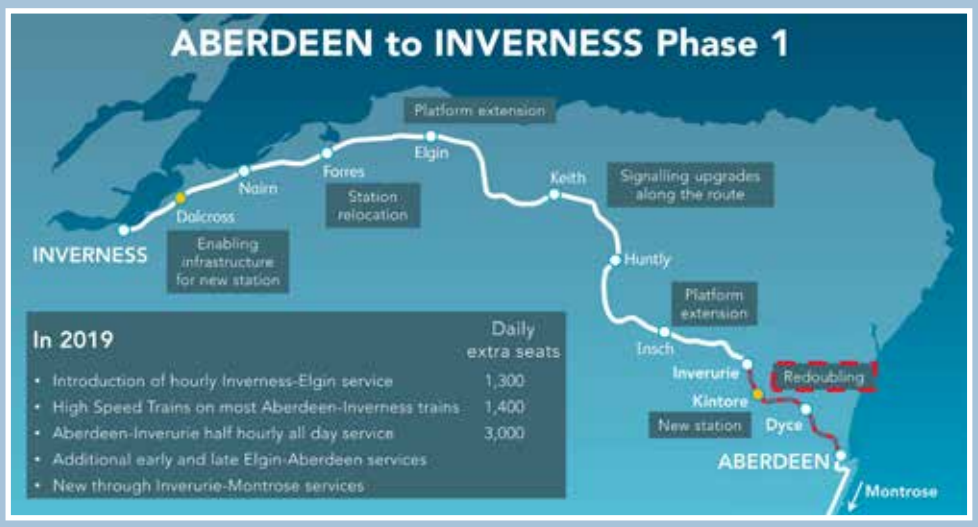
Editor, Rail Engineer -

FINISHING THE JOB

redoubling Aberdeen to Inverurie

DAVID SHIRRES

Last year, the Aberdeen to Inverness Improvement Project (A2I) redoubled 8.5km of track between Aberdeen and Dyce as reported in issue 168 (October 2018). However, this redoubled track could not carry any passenger trains until this year's completion of the 25.5km Aberdeen to Inverurie redoubling work in August on which we report this month.



The completion of this redoubling marks the end of phase one of the A2I programme which, as reported in issue 158 (December 2017) included earlier work to provide a relocated station at Forres, on a new straight 1.25km loop, and work at Elgin, which included platform extensions, the provision of a turnback facility and extension of the loop from 650 metres to 1.5km.

This work was completed in October 2017. It also included signalling and telecommunications improvements which saw the section of the line from Inverness to Keith controlled from a new Highland workstation at the Inverness signalling centre.

Prior to that, telecommunications enhancements provided a new multi-protocol label switching (MPLS) transmission network to support operational and station systems along the route. This required further network upgrade works both between Aberdeen and Dundee and between Inverness and Perth to ensure diverse routing. Other telecommunications work included the provision of an internet protocol telephone concentrator at Inverness, for the user-worked crossing phones previously controlled by the closed signal boxes, and the alteration of GSM-R call routing due to the transfer of control to Inverness.

The investment of £330 million on A2I phase one follows the 2009 Scottish Government Strategic Transport Projects Review, which concluded that A2I was one of Scotland's top four transport priorities. Over the past ten years, there has been an 87 per cent increase in patronage between Inverness and Aberdeen with most of this increase between Aberdeen and Dyce (146 per cent) and Inverurie (247 per cent).

Journey time over the 173-kilometre-long Aberdeen and Inverness route is around 2 ¼ hours with an irregular, about

Don viaduct strengthening work.

Removing original cross girders on 28 May.

two-hourly service frequency. At each end of the route there is also a roughly hourly local service between Inverness and Elgin and between Aberdeen to Inverurie.

Whilst the Scottish Government's long-term objective for the Aberdeen to Inverness line is the provision of an hourly service with a two-hour journey time, A2I also delivers the more immediate requirement of improving local services at either end of the line and the provision of additional stations at Dalcross and Kintore without affecting journey times. For this reason, the provision of the proposed new station at Dalcross will require the provision of a new two-kilometre loop.

Both these stations are subject to separate funding agreements. For Kintore, this was agreed between Transport Scotland, Aberdeenshire Council and North East Regional Transport Partnership (Nestrans) and the £14.5 million contract for the station's construction was awarded to BAM Nuttall in May. This enabled much of its construction to be done during the 2019 blockade.

Although planning permission has been agreed for Dalcross station, arrangements for its funding have yet to be finalised.

The 2018 blockade

The track laid last summer between Kittybrewster and Dyce was the first stage of the redoubling of the line between Aberdeen and Inverurie. The new double track starts at Kittybrewster, 1.5km from Aberdeen station, as redoubling the Hutcheson Street and Schoolhill tunnels would have required track lowering at significant cost and was not necessary for a 15-minute service.

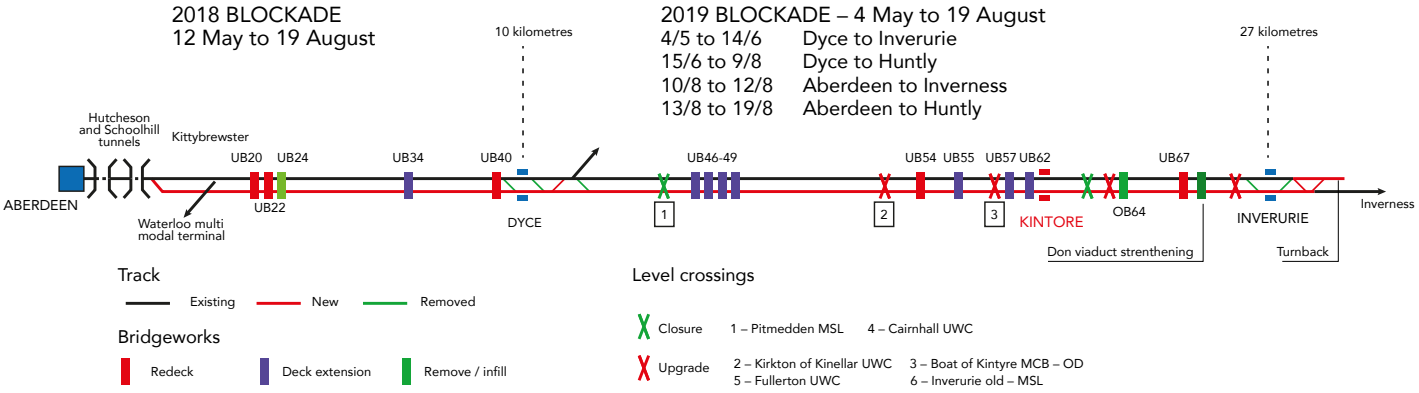
This involved much more than just putting the track back as, since it was lifted in 1968, numerous assets have been placed on the track bed, the single line now followed the double trackbed racing line and some underbridges only had a single-track deck. Moreover, the original earthworks cannot accommodate a double track in accordance with current standards and this largely built-up section required significant neighbour engagement as a result of tracks being laid closer to adjacent houses.

Earthworks retention was therefore a large part of the work. This was achieved by interlocking concrete blocks, high friction fill material or king-post retaining walls. These use H piles driven to pre-determined depths into the ground with timbers inserted between the webs of the H section.

For these reasons, redoubling this 26km corridor required significant reconstruction of the railway corridor, for which a blockade was the only option. As it was considered unacceptable to close the railway for the six months that this would take, it was decided that it would be done in two summer blockades, each of about three months, with the loop at Dyce enabling the redoubling to be staged into two parts.

On completion, the newly laid track was left unused, which presented an unusual signal-sighting problem as the new Up line could not be used by trains until the end of the 2019 blockade. Until then, »

Kintore station under construction.



what was to become the Down line remained as the single bi-directional Up/Down line. This meant that, until the 2019 commissioning, some signals for Up direction trains were relocated as temporary signals to the right of the single line as the new Up line prevented them being located on the left. These temporary signals were replaced by new permanent signals on the left of the new Up line during the 2019 blockade.

With the newly laid track left unused, the operational railway was essentially unchanged by the 2018 blockade and therefore did not require significant signalling work. This also meant that it was only necessary to bus passengers between Aberdeen and Dyce, as Dyce station could stay open during the blockade.

The 2019 blockade

Contractual arrangements for this year's blockade were the same as for other A2I phase one works in that Network Rail engaged Siemens for the signalling and telecommunications work and BAM Nuttall for everything else. BAM Nuttall's main sub-contractors were AECOM and Jacobs for design, Babcock for track work and Stobart Rail for ancillary civil engineering work.

This year's blockade was from 4 May to 19 August and differed significantly from last year's work. It laid nearly 15km of new track, almost twice that of last year's blockade, though the complication of the racing line was not such a significant issue this time. Furthermore, instead of being in an urban area it was largely through farmland and so had various level crossings to contend with.

The programme required a large amount of bridge works, including two underbridge replacements, seven underbridge bridge extensions, one infill, strengthening six underbridges and the removal of two overbridges. This year's blockade also required significant work to strengthen the five-span viaduct over the River Don, just south of Inverurie.

Advantage was also taken of the blockade's extension to Huntly, as described below, to extend the short platforms at Insch to 160 metres to accommodate ScotRail's Inter7City sets. These are the newly refurbished five-coach High Speed Trains which now serve Scotland's seven cities.

The 2019 work also involved work on the existing railway at both ends of the new double track section which meant changes to the replacement buses during the blockade.

For the first six weeks, the bus replacement services were between Dyce and Inverurie, then buses ran for another eight weeks between Dyce and Huntly, where temporary welfare facilities had to be provided for train crews. The final nine days of the blockade saw buses between Aberdeen and Inverness for three days and then six days of buses between Aberdeen and Huntly.

Rail Engineer visited the redoubling works on 17 July during week 11 of the 15-week blockade and had an opportunity to tour the site with its programme manager, Colin MacDonald, at BAM Nuttall's project office and compound at Inverurie. This site office also includes 'Hotel BAM', which provides temporary accommodation for around thirty and has a fully equipped gym. With a shortage of hotels in the immediate vicinity, this is a cost-effective way of accommodating the workforce.

Building this temporary accommodation is one solution to the problem of the project

Redecked underbridge 54.

Redecked underbridge 54.

(Right) Kirow crane laying S&C at Inverurie on 7 July. (Left) Tamping new double crossover north of Inverurie.

being a three-hour journey from Scotland's central belt, where many of its project personnel are based. For example, as well as overseeing the work on site, the Network Rail project team must liaise with engineers, designers, operational planners and others based in Glasgow.

Touring the work

The tour started at the newly laid S&C by the Inverurie project office. This is the western limit of the new double-track section, where a new turnback facility has been provided capable of accommodating ScotRail's Inter7city sets. Two synchronised S&C tampers were seen working together to simultaneously tamp the ballast under the crossing bearers.

At the Don viaduct works, Colin explained that this presented significant challenges in view of the requirement to avoid putting significant additional weight on the substructure, as this would have required costly in-river work and could have delayed the project. For this reason, the ballasted track option, which would have added 2,000 tonnes to the weight of the bridge, was rejected. Rails over the viaduct have therefore been laid on longitudinal timbers in new timber cradle units.

Works to strengthen the viaduct were viewed from a temporary crash deck below the bridge superstructure. These included the replacement of all cross girders - replaced by deeper ones - and additional plating on the side beams. The abutments had also been strengthened to resist the worst-case scenario of the force of a braking ballast train. Further protection against such forces is provided by shock absorbers that have been installed at the pillars and abutments.

Next stop on the tour was a bridge overlooking the station work at Kintore. When built, this will be an unmanned station with a 166-space car park. The station is immediately adjacent to the A96 dual carriageway, so it is expected to be a busy park and ride station. Colin explained that, although this was a separate contract to the main blockade works, its construction was an integral part of the project as a whole. With limited access to the north side of the line, it was important to make best use of the blockade to construct the north-side platforms.

Nearby, Boat of Kintyre level crossing was being upgraded from a single line AHB (automatic half barrier) to a MCBOD (manually controlled barriers obstacle detection) double-tracked crossing. The signaller's workload was a significant factor in the choice of the MCBOD crossing as this does not require the close study of CCTV images to determine when it is safe to lower the barriers.

This level-crossing work required a road closure for the duration of the blockade, with only pedestrian access across »

(Below) Don viaduct and compound. (Insert) Before the strengthening work.


PHOTO: DEVLIN PHOTO

Re-decking UB67.

the railway. It also needed extra land by the crossing for its equipment housing, which had to be built on most of the garden of the adjacent house that the owner had agreed to sell.

The A2I redoubling works also required the upgrade of three user-worked crossings and the closure of two more - as a result of arrangements negotiated with those affected, this included the purchase of a house that could only be accessed by the crossing.

Another deal had to be made to allow the demolition of the paper mill bridge near Inverurie, the central pillar of which would have obstructed the double tracking. Colin noted that, although it is normally possible to reach suitable agreements with those affected, such issues present significant risks to major projects, such as A2I, that have no compulsory powers. There may not be an alternative design solution if someone doesn't wish to sell their land under any circumstances, a situation which could cause major problems.

The last call on the guided tour was to see the retention work at Kinaldie, where king-post retaining walls could be seen supporting the embankment to the east for a kilometre or so, a clear indication of the work required to replace a track lifted fifty years ago.

Programming the blockade

To allow track laying to commence at the start of the blockade, almost all the civil works required for track laying were completed beforehand. This included retention work that could safely be done whilst the single line was open. Night-time 'rules of the route' possessions were used for work that affected the track support zone or had plant and equipment that could not be safely separated from trains.

Other than the Don viaduct, the only bridgework done during the blockade was the re-decking of underbridge 67 over the old canal, immediately south of the viaduct.

Disruptive possessions from 20 to 22 April (72 hours) and 27/28 April (54 hours) saw work done on six underbridges, including deck renewals and extensions, retention earthworks, track formation work and ancillary civils works. The latter was sequenced to give priority to the subsequent work (equipment bases and the troughing between them) so that cables could be run out.

In this way, most of the lineside signalling infrastructure was completed prior in advance, which was key to allowing track installation to commence from the outset of the blockade.

Track laying used a seven-sleeper spreader beam to lift sleepers from wagons and place them into position with the correct spacing. Continuously welded rail, which had previously been laid

1.25 km of retention work was required at Kinaldie.


PHOTO: NETWORK RAIL


PHOTO: DEVLIN PHOTO

Rosenqvist CD400SP fastclipping machine.

alongside the existing single line, was then thimbled into position by road-rail vehicles and clipped up by a fastclipping machine.

The programme required the completion of all work requiring engineering trains and road-rail vehicles by 13 August to support the final phase of signalling commissioning and associated wheels free testing. The new double-track railway was commissioned in the early hours of 17 August to allow three days of familiarisation runs for the route's 176 drivers, with the passenger service resuming on 20 August.

Signalling black hole

Prior to the blockade, signalling between Aberdeen and Inverness was controlled by Aberdeen signalling centre, mechanical signal boxes at Dyce, Inverurie, Insch, Huntly and Keith, and the Inverness signalling centre's Highland workstation, which was commissioned as part of the October 2017 A2I works.

The 2019 blockade saw the closure of Dyce and Inverurie signal boxes with control of the line from Kittybrewster to Insch transferred to the Highland workstation. The long-term aspiration is that this workstation will eventually control the route throughout. However, for now trains between Keith and Insch disappear from the Highland workstation panel only to reappear about an hour later.

This recontrol required the modification of interlockings, changes to train describers and the provision of fringe controls at Insch, for Inverness's Highland workstation, and at Kittybrewster for the NX panel at Aberdeen signalling centre. Control of the blockade's level crossings, as well as the sidings at Kittybrewster and Raiths Farm, were also transferred to the Highland workstation.

The new signalling equipment includes 51 signals, many of which are single lens LED colour lights, and nine new switch and crossing units. It is controlled by Siemens Westrace interlockings and train detection is by a combination of 92 newly installed Frauscher axle counters and some DC track circuits between Aberdeen and Dyce. »

Doubling and upgrade of Boat of Kintore crossing where equipment required extra land.

On the Don viaduct, Up line timbers ready to receive their rails.

Job done

Completion of the blockade marked the end of the Aberdeen to Inverness phase one works. 25 kilometres of track had been laid on 39,000 sleepers using 110,000 tonnes of ballast, of which 20,000 tonnes was recycled ballast. Laying this track required the removal of 20,000 tonnes of spoil and the provision of 5,000 tonnes of engineering material, along with 27 kilometres of embankment retention. The signalling work also required over 137 kilometres of cables.

Impressive though these statistics are, what counts for passengers is the extra train services, made possible by this project, that ScotRail will introduce during the December timetable change. A total of 20 additional services a day between Aberdeen and Inverurie will provide a minimum of a half-hourly service - every 20-minutes at the peak. ScotRail will also introduce a new Montrose to Aberdeen service that, in most hours, will be extended to provide a Montrose to Inverurie service.

At the other end of the line, an additional six Elgin-Inverness services will add to the nine such services introduced in December 2018, giving Elgin an hourly all-day service. Those who wish to travel longer distances from stations on the route will also benefit in December from the provision of six through services from Inverness to the central belt of Scotland via Aberdeen.

It has taken four years to deliver A2I phase one - one of the UK's longest redoubling projects - as well as a series of enhancements to provide more-efficient loop operation. On a single-track railway, this is perhaps likely to offer greater time savings than line speed enhancements.

As Inverness to Aberdeen is the only UK inter-city rail service operated largely over a single track, it's good to see serious money spent on such targeted enhancements. It will be interesting to see how phase two can bring further improvements.

New shock absorbers.

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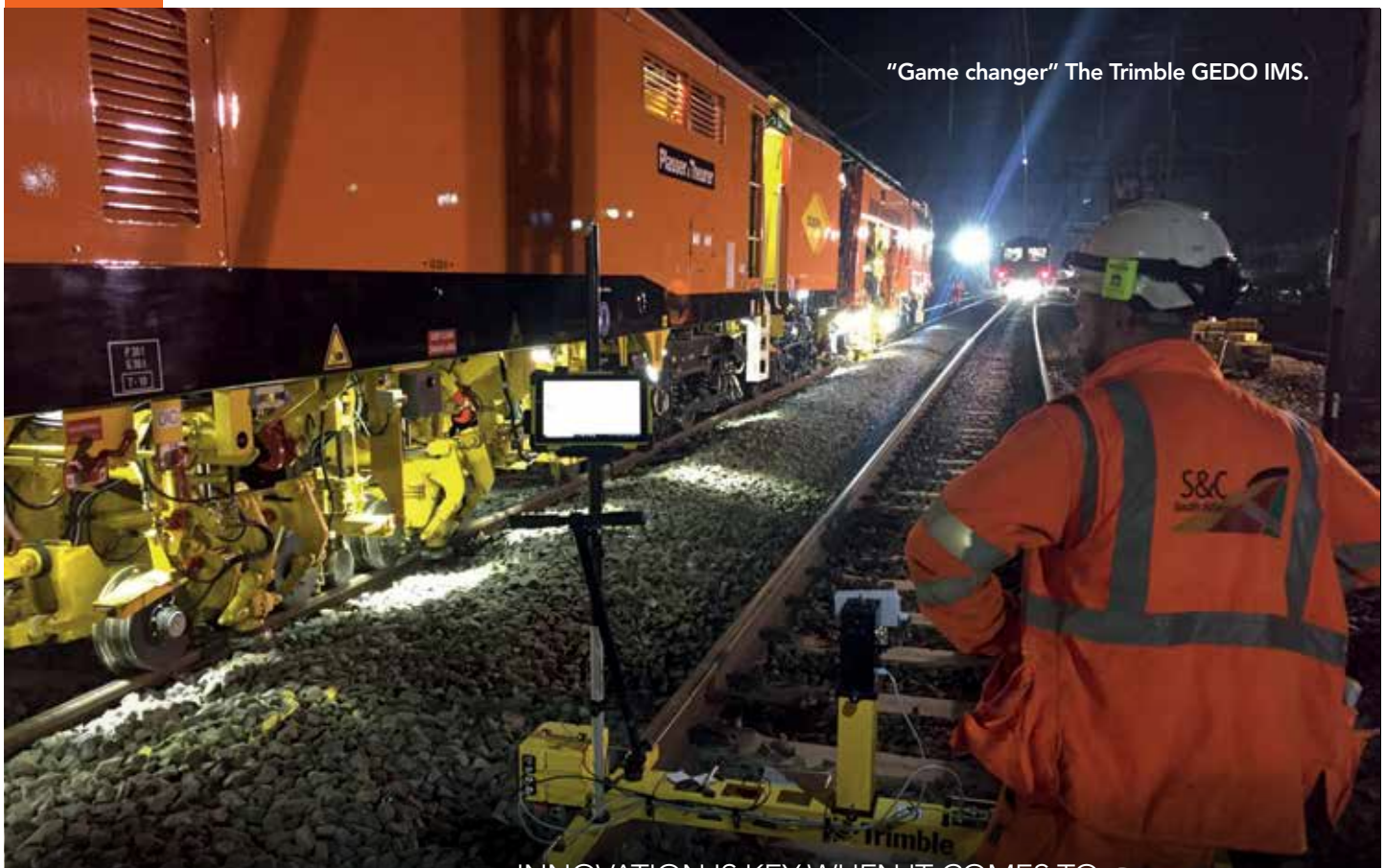

"Game changer" The Trimble GEDO IMS.

INNOVATION IS KEY WHEN IT COMES TO

"Putting the passenger first"

Over the Easter weekend, the West Coast main line was closed over four days during the replacement of Willesden North junction. This included two NR60D crossovers and 400 metres of new line. The aim of the project was to re-open the track on Tuesday morning at 90mph, with no train delays and no evidence of an engineering presence beyond clean ballast and new track.

The West Coast main line is rarely closed, so, when it is, the demands for high productivity, high quality work and a timely job can make for a busy and challenging site. The S&C South Alliance - the partnership between Network Rail, Colas Rail and AECOM that develops, designs and installs major track programmes across the South of the UK - was therefore keen to use a number of innovative approaches. These included the use of the Trimble GEDO IMS Track Measuring Device (a self-contained trolley designed to capture track position, gauge and cant in a single operation) and the Trimble SX10 (high-accuracy total station and 3D laser scanner combined in a single instrument).

In particular, the Trimble GEDO IMS has a highly accurate inertial measurement unit, removing the need for a total station on the track and the attendant challenges this can bring such as line of sight issues, and the possibility of impeding on a site with cherry pickers for OLE, signalling teams and welders. Instead, the GEDO IMS can be easily taken on and off track in the event of obstacles, is easily manageable and has a short initialisation time for rapid use.

Using the Trimble GEDO IMS

Pre-blockade, the team from Colas Rail familiarised itself with both the GEDO IMS and the Trimble SX10. Using the GEDO IMS, a design validation survey was undertaken (DVS) and control was checked. In this case, control was already established every 60 metres on overhead gantries and through the use of chequer boards (70:30), although it could have been easily done using the IMS and GEDO Profiler (used to measure distance and height offsets between the track and any object adjacent to the track).

During the blockade itself, the GEDO IMS was used to survey the track, providing the team with greater accuracy for as-builts behind the tamper, ultimately improving track quality. Downtime was reduced because the IMS was used whilst walking behind the tamper with no line of sight issues leading to enhanced productivity. The

"Day one of 90mph handback running over Willesden North Junction fast lines. As smooth as it gets. Very impressive. Well done to all concerned!" *Peter Bowes, managing director, Virgin Trains West Coast (based on drivers' feedback)*

GEDO IMS proved stable and reliable, performing well despite the vibration and shock from the tamper.

Alignment was measured in relation to tamping on the large clear display of the Trimble T10 tablet running the GEDO IMS field software. This allowed for the detection of the inner and outer track geometry for the immediate spotting of

The Trimble SX10 was used for Progressive Assurance.

error or tamping mistakes. At the end of each chord, readings showed the difference to design for immediate lift and slew.

The team created a front offset file on the tablet and then transferred it to the tamper via a USB after every chord, so that at no point was the tamper waiting for calculations to be made. Previously, this was a time-consuming process that involved a rail shoe and the manual entry of many numbers. Now the process requires just one system and one operator who controls the whole process.

The track was handed back on time at line speed of 90mph, having used Progressive Assurance throughout the weekend. This is a process which ensures that every stage of the process is measured and signed off by a named 'responsible person' for each stage. This creates an evidence file, critical for assessing the line as fit for reopening at a certain speed. In this case it was not possible to open the line at 120mph because the formation stiffeners weren't sufficient to support the high-speed handback.

Following handback, the track was monitored over a period of several weeks using the GEDO IMS and GEDO Office software. A baseline survey was undertaken and then comparison surveys were used to calculate any movement. Further GEDO IMS follow-up tamps were carried out as part of the hand-back procedure.

Trimble SX10 Scanning Total Station

The question that the S&C South Alliance wanted to answer was whether the SX10 could perform in the harsh conditions of a blockade, delivering under the stresses of dust, vibration and restricted access in a decreased working area.

The SX10 would be used both for Progressive Assurance and as an alternative to having a surveyor in the dig capturing data for a 3D model, all whilst setup in a position of safety. With limited windows after the dig and stoning, the SX10 provided a fast alternative to traditional survey methods - a resection to the existing control allowed the scan to be coordinated and using the polygon framing on the SX10 the extents of the dig were scanned.

The data produced by the SX10 could be used immediately in Trimble Business Center (TBC) office software for checking against the 3D model to ensure that everything was correct. In TBC, noise such as machines and people can be removed and the formation/design that goes into the cabs can be laid onto this for checking live in the field.

The SX10 could also be used during the pre-works as a tool to assist site planning and build up area organisation. There is potential for a complete survey of the renewals site from which the safety team can investigate the hazards that could potentially impact on the workforce.

Using the combination of point cloud data and 3D imagery, the engineers and surveyors can overlay the new track designs and organise the site prep works prior to installing new control.

On this project, the SX10 was part of a trial with Network Rail and, in the future, the data can be used to locate previous troublesome areas or soft spots.

Conclusion

Nick Matthews, S&C South Alliance programme engineering manager for transformation, reported that, as a result of being familiar with Trimble's GEDO VORSYS two trolley system, a move to the GEDO IMS was a natural evolution. He said: "The main advantage of GEDO IMS is it is based on a single trolley. This overcomes the line-of-site issues often encountered onsite while using two trolleys. The track position is recorded continually using GEDO. This continuous measurement is far better than the discreet data gathered by using a detail pole and total station every five metres.

"The introduction of GEDO IMS to the S&C South Alliance will be a game changer. It will ensure that continuous data is always captured by the survey and delivery teams rather than discrete data using total stations and detail poles. The KOREC/ Trimble teams were always there during the introduction of the IMS for the Alliance. This included representation at meetings, training and being on site during the works. They provided a world class service to the Alliance."

Throughout the four-day blockade, the Alliance was supported on site by Matt Moss (Trimble Rail applications engineer) and Tom Williamson (KOREC Rail applications engineer). The adoption of the Trimble technology on this site underlines the S&C South Alliance's commitment to continuous improvement and KOREC and Trimble were proud to be a part of this great effort that saw the successful hand back of Willesden Junction, on time, at a line speed of 90mph. ●

"The KOREC/ Trimble teams were always there during the introduction of the Trimble IMS for the Alliance… including being on site during the works. They provided a world class service to the Alliance."
Nick Matthews, programme engineering manager transformation S&C South Alliance.

Passenger Satisfaction - the track was successfully opened, on time, at 90mph.

PAUL DARLINGTON

Making user-worked crossings safer

User-worked crossings (UWC) are intersections where a railway crosses a right of way such as a road on private land, a footpath or a bridleway. Any gates or barriers provided often need to be operated manually, with some crossings requiring users to telephone a signaller to check that it is safe to cross.

The rate of collisions and fatalities at these types of level crossings is higher when compared to other level crossings when the usage rate is taken into account. Often, the only technology to assist the user is a sign informing them how to operate the crossing. However, work is now underway to improve the signs and reduce the risk of such crossings.

When the railway was first built, the former railway companies were required to provide access across the railway for those affected. Where this resulted in the construction of a level crossing, it was operated by the user, and unless the landowner has agreed to give up their rights to use it, it is still the responsibility of Network Rail to maintain the crossing for the safe benefit of all users. The owners of the land and those who also have a legitimate right to use the affected road also have a legal right to use the crossing.

User-worked crossings were also required to maintain access between lands severed by the railway where a roadway or track did not previously exist. The most common being the field-to-field crossing. Along with footpath and bridleway crossings, these types of crossing present one of the greatest safety risks to today's railway, with the user responsible for making sure it is safe to use the crossing and for opening or shutting any barrier or gates provided.

Diverse users

For many years, users of UWCs were generally local and familiar with the operation of the crossing. Trains were also slower and noisier than they are today.

In recent times, the profile of users has diversified significantly. They are no longer just the local landowner, farmer, postman or shopkeeper. Users now include a wide range of couriers, delivery drivers and members of the public, many of whom are unfamiliar with how to use these types of level crossing safely and who may not have English as their first language.

Users are also likely to be 'connected', using headphones or texting on their phones. They may have mobility issues or be riders on horses or bikes. Tractors

are faster and drivers are likely to be in noise-reducing cabs, with the heating or air-conditioning fan running, and be incentivised to move quickly to increase productivity.

On top of all this, trains are now often more frequent and are considerably quieter.

There are around 2,500 such private crossings in Great Britain, representing more than a third of all level crossings on the network. The Rail Accident Investigation Branch (RAIB) published a report on its investigation into a fatal collision in October 2017 involving a high-speed train and a delivery van at a private crossing at a farm in Teynham, Kent. This recommended that the government, in conjunction with the Office of Rail and Road and Network Rail, should review and revise signs at private crossings so that they clearly and unambiguously convey information and instructions on how to use the crossings correctly.

The technology available to the rail industry to manage level crossings and enhance protection has also developed in recent years, such as through technical advances in miniature stop lights (MSLs). However, the signage at crossings has not developed at the same rate, and this presents a potential safety risk to members of the public. To improve safety at these crossings, Network Rail is now working closely with the Department for Transport (DfT) and the Office of Rail and Road (ORR) to revise and make improvements to the signage provided at UWCs.

RSSB report T983

The work started with the production of T983 - Research into signs at private level crossings - by RSSB. This considered, from first principles, the types of signs that should be presented to users at UWCs, including those at field-to-field farm crossings. The project explored which signs and signals best convey the particular points of information that users need when approaching these crossings.

It made use of the methods and findings of a recently completed project examining signs and signals at public road crossings, and drew on good practice in signage in general and in the railway environment in particular. Existing signs at level crossings were compared with good practice and, where it was judged that they were not the best solutions, other signs were considered.

The project focused on proposed improvements to signs and markings, and carried out an initial evaluation of the proposed improvements and identified barriers to implementation. It was identified that users did not always associate the existing user-worked crossing sign with the crossing being approached. The sign was too 'wordy' and did not use a pictorial representation of a crossing.

As a result of the research three types of draft signage were proposed with simple, clear and unambiguous instructions, and making good use of pictorial icons:

1. Universal user-worked crossing 'triangle' sign. The proposed sign, unlike the existing signs, shows the three separate crossing elements as icons: a train, a gate and a railway track.
2. High level instruction 'blue' signs to inform users to 'Stop look and listen' or to 'Stop and telephone'.
3. Detailed instruction signs. These would have a mixture of illustrations and text to clearly instruct users. »

T983 identified that it was important that the proposed signs were legible and well understood, or it could make matters worse instead of better. It recognised that, while the proposals may be clear when viewed on the desk or on a computer screen, trials were recommended to compare the legibility of the designs with the current instruction signs.

Trial evaluation

Network Rail is now involved with all stakeholders to take forward the benefits of the T983 report and to implement a 'root and branch' review of the UWC signs proposals in a systematic way, to establish where and how the improvements can be made. The three proposed signs produced by RSSB were reviewed in workshops at which specialists, including route level crossing managers, representatives from DfT and ORR and with signage experts, discussed everything from level crossing risk to ergonomics.

The proposed signs were produced by Royal British Legion Industries (RBLI), then installed and trialled at a user-worked level crossing 'mock up' site which had already been established by the ORR and Network Rail at Cannock Chase, Staffordshire. This is a facility used as a training resource for those organisations who regularly come into contact with user-worked level crossings.

Five different crossing types were evaluated, including common and complex types of UWC. These were non-telephone UWC, telephone UWC, power operated gate opener (POGO), MSL and a POGO MSL crossing.

The site consists of approximately 12 metres of track that leads nowhere and with no trains involved, but it is so realistic many visitors believe it is a real railway. Most of the required infrastructure was already in place, although a POGO had to be installed. The Transport Research Laboratory (TRL) had assisted RSSB in the T983 report with virtual reality modelling, so TRL was also employed by Network Rail to facilitate the trials and to provide continuity with the process.

Initially, 15 different users per day for three days of all ages, gender and abilities were involved with the trials in April, with another similar trial a few weeks later. The users were people who were all unfamiliar with any type of UWC. Some people went over each crossing type as pedestrians and others as car drivers.

One initial finding was that people used the crossings in various ways, even if all of them were safe. Users were fitted with head cameras and asked to complete a questionnaire - all the captured data will be subject to qualitative and quantitative analysis before the recommendations are finalised. This will include the format, the size of the signs, font and icons, together with a Welsh version. One change to the T983 report proposals already identified is that the icons on the signs will be at the top and read left to right, rather than vertically on the left.

Further trials are planned with users who are familiar with the operations of UWCs.

Implementation

The first operational installation trial is planned for Jacky Duffin Wood crossing, a UWC POGO MSL on a freight line on the London North East route.

Once all the captured data is analysed and evaluated, the plan is to republish the Network Rail standard for level crossing signage, and any other standards affected, with the new signs available from early 2020. They will be then deployed on the various Network Rail routes, using their local knowledge and crossing risk profiles and liaising with project teams which may be doing work in a particular area.

New legislation will also be required to amend the Private Crossings (Signs and Barriers) Regulations 1996, however Network Rail is working closely with the DfT so that there should be nothing to prevent the new designs being brought onto the network in 2020 via a nationwide trial authorisation process.

The new signs will be enforceable during the nationwide trial period.

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Bearing Up for Reliability

SNCF depot installation.

CLIVE KESSELL

A RailBAM installation in Australia.

With the ever-present focus on putting passengers first, train reliability has to be high up the priority list to achieve this. Modern rolling stock is being equipped with many electronic systems that bring their own maintenance and reliability challenges.

One fundamental element is nonetheless the train wheel and the axle journal bearing upon which it rotates. Should this bearing catastrophically fail, then the train is likely to be declared a failure and to be taken out of service for an expensive repair. At worst case, the train could derail, with the risk of this being a major accident.

The monitoring of axle journal bearings is therefore an important safety precaution. Equipment to detect hot axle boxes (HABD) has been available since the 1960s and has been refined in subsequent decades. This technology, whilst effective, has reliability issues and offers only reactive alarms when a failure has occurred. HABD systems are not compatible with third-rail electrification infrastructure and mainly target the major freight routes, where derailment is known to be a higher risk.

Alternative acoustic technology, originating from Australia in the late 1990s and trialled in the UK in 2007, is now universally available. RailBAM (Rail Bearing Acoustic Monitor), produced by Track IQ, a Wabtec company, is well established in this technology, as well as providing other trackside monitoring systems in the UK. At a recent meeting of the London & SE section of the IRSE, the RailBAM system was explained, just proving that signal engineers are eager to learn about technology in all rail disciplines!

Origins

An introductory article on the RailBAM system appeared in issue 151 (May 2017), written by Stuart Marsh. This explained how the technology was developed by the Australian company Trackside Intelligence, which subsequently became branded Track IQ and was taken over by Wabtec in 2015, enabling a larger penetration into worldwide rail markets.

All bearings emit noise and that noise will vary according to the condition of the rolling surfaces within it. The RailBAM system captures the sound emitted from every axle journal passing a trackside monitoring site to check for defects developing on the rolling surfaces. In the event of a defect detection, an alert is sent to the rolling-stock maintainer, thus allowing remedial work to be planned without impacting on the day-to-day train service.

Such predictive advice allows defects to be fixed long before anything more serious happens whilst in traffic.

System components

The principal units are two acoustic cabinets mounted trackside and a third enclosure away from the track that houses all the necessary electronics, communications and power equipment for operation of the system. Wabtec's

FleetOne web-based server allows the rolling-stock maintainer to access its own fleet data and create email alarms and alerts to suit its business.

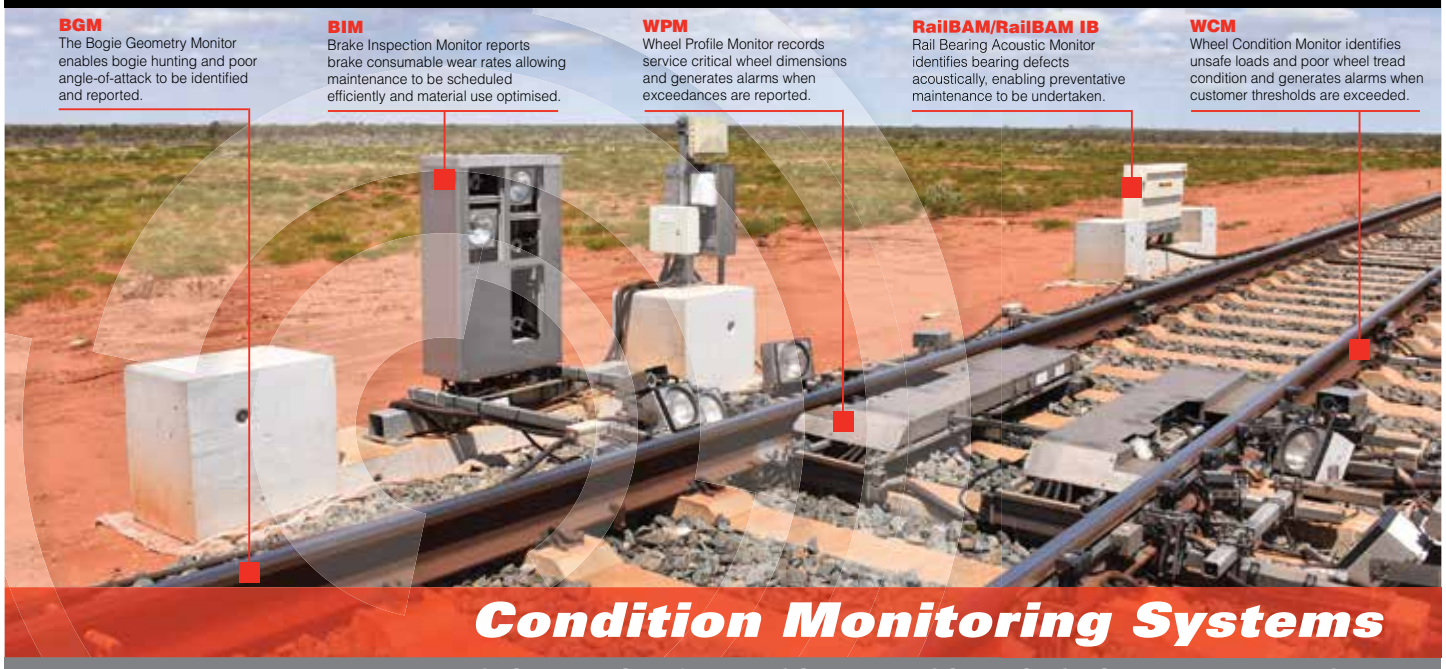
The acoustic cabinets incorporate a motorised shutter that opens upon detecting the approach of a train, thus exposing the array of microphones to the side of the train. Ideally, a cabinet will be placed on either side of the track so as to collect sound from bearings on both sides of an axle in one pass, and this is typically the arrangement on single-track lines. On double or multiple-track railways, there is limited space between the running lines, so the system is split across adjacent tracks, allowing complete coverage to be achieved over a return trip.

Identifying the train is vitally important, which is achieved by fitting the train with RFID (Radio Frequency Identification) tags. Just how many tags are required for each train or vehicle needs a pragmatic consideration. A fixed-formation diesel or electric multiple unit will probably only require two tags, one associated with each cab end. On a passenger train, where coaches may be swapped around, a tag is needed on every vehicle. This includes the high-speed train (HST) fleet. On freight trains, a tag is needed on the locomotive(s) and every wagon (or fixed wagon pair or triple) if robust bearing monitoring is to be achieved. Tags are passive units programmed with the identity of that particular piece of rolling stock and are powered by the trackside reader as the train passes.

The RailBAM system has been successfully operating for over 20 years. Its flexible and robust design enables installations in the extreme heat of the UAE and the icy cold of North America. Power can be taken from the local electricity provider or solar battery supplies. Connection to the internet is either via wired networks (often the railway internal network), cellular radio, or even satellite communications in extremely remote locations. »

RailBAM and wheel condition monitor at Skatval, Norway.

Reduce the cost of rolling stock maintenance



Condition Monitoring Systems

GLOBAL PRODUCT AND SOFTWARE SOLUTIONS FOR THE RAIL INDUSTRY

Track IQ has a global reputation for being specialist manufacturers, suppliers and maintainers of wayside condition monitoring equipment and data management systems to the rail industry. Track IQ's complimentary systems provide a holistic view of rolling stock and their relative health and safety. The powerful and customisable FleetONE database and visualisation tool presents, prioritises, alarms and reports to meet each customer's specific requirements, driving down the cost of rolling stock maintenance, whilst increasing safety.

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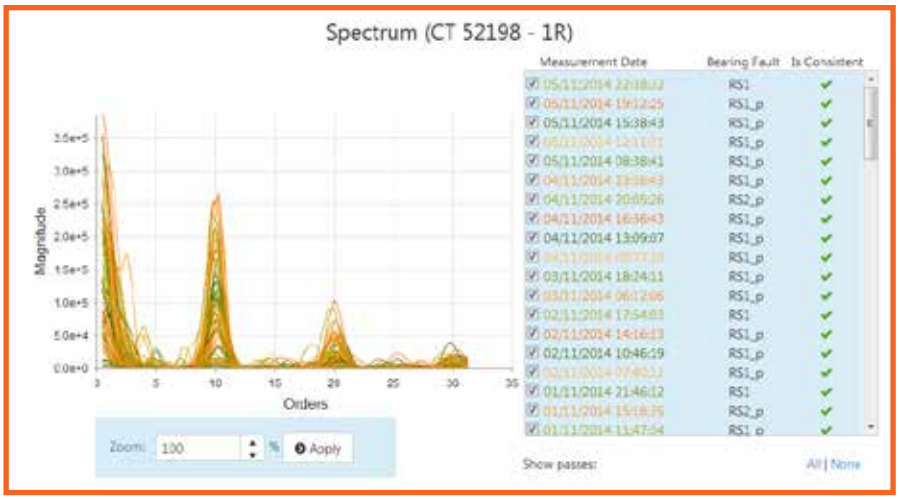
Operation

The principle of operation is that, as a train passes the acoustics sensors, the sound profile of each axle journal bearing is captured and stored. The acoustic reading is then linked to the train tag data, the pass-by date and the time. Knowing the train identity allows the FleetOne system to compile the train consist and associate each dataset with the correct wheel position and axle journal bearing. Repeat pass-bys are recorded to provide updated data for each bearing, thus allowing the data to be used to observe any worsening condition and trigger alerts while also enabling analysis of behaviour trends and patterns.

With the acoustic system being sensitive enough to detect even small defects in the bearing, it is then typically over 100,000km before the defect would mature into a service-affecting failure. This means that, generally, no action need be taken until the next routine maintenance visit.

There are some constraints as to where and how the trackside sensor units should be positioned. For optimum results, they should be on straight track which is in good condition - if any 'sleeper pumping' is happening, this can cause noise and confuse the readings. The site also needs to be where normal train speeds are between 13 and 80mph. This does not present a challenge on high-speed lines, as even the fastest trains have to slow as they approach stations or junctions, which are usually ideal locations for the trackside readers.

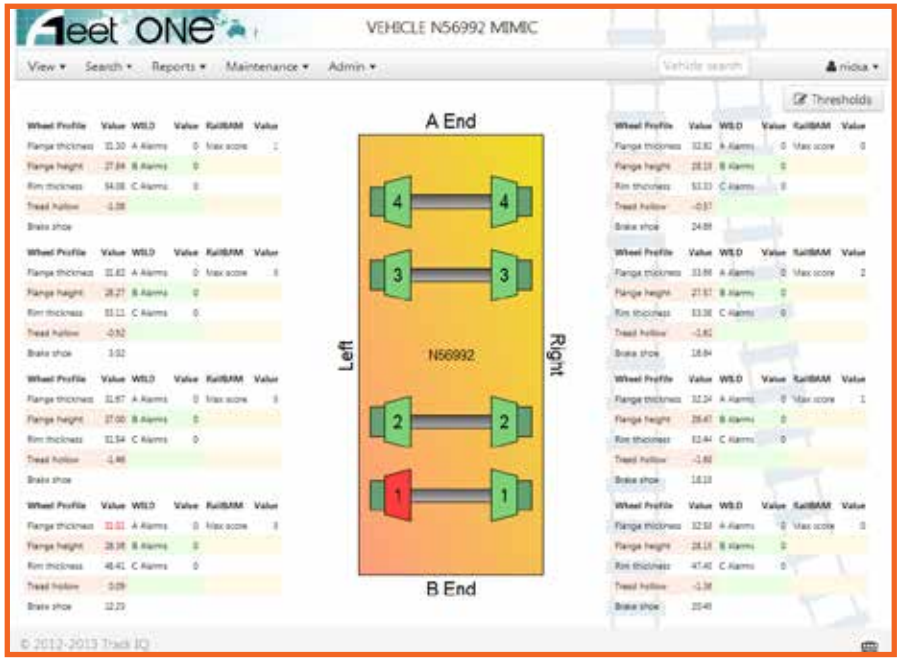
The types of defect that are detected include:



- Rolling surface defects, including wheel flats and wheel roughness;
- Roller bearing wear, including for an individual roller;
- Cup/cone spalls (flakes of metal broken off from the bearing components);
- Multiple spalls;
- Extended spalls.

Since the RailBAM system is aimed at discovering developing defects rather than catastrophically damaged components, a root-cause history can be investigated and built up, which in turn will lead to the implementation of bearing improvements and a reduction in the bearing attrition rate.

As would be expected, the RailBAM system is continually evolving and improving. The data from over 100 RailBAM systems worldwide is hosted on Track IQ's own data server in Adelaide (Australia), allowing the performance to be monitored daily and improvements deployed globally.



UK performance and statistics

Whilst the majority of systems have been installed overseas, the first UK application was a limited trial in 2007 on Southern at Three Bridges, targeting the Class 377 fleet. Although successful, the trial was not expanded.

In 2009, Siemens installed the first RailBAM system in the UK and the first globally to target only passenger stock. This was on the South West Trains network and monitored Class 444 and 450 units with the trackside unit installed at Swaythling, between Southampton and Eastleigh. The system captures data for the whole Siemens fleet as well as other trains using the route.

A second trackside unit was later installed at Mortlake with the fitting of tags to more of the SWT fleets, thus enabling all units on what is now South Western Railway to be monitored.

Noting the results, First Great Western installed a trackside unit at Kensal Green, near to North Pole depot, and began equipping its HST fleet with tags. This was then expanded to take in other classes of FGW trains.

As one would expect, the number of axles monitored by the three RailBAM installations is counted in the millions as the statistics show:

- More than 265 million bearing data sets reads in total;
- Equates to an average of 35 million bearing data sets/year;
- 8,600 collective days of operation across the three sites;
- Monitoring of approximately 5,000 tagged assets;
- Successful identification of several hundred defective bearings.

The overall system has achieved 99.99 per cent reliability and more fleets are being tagged as franchises are renewed.

The business case

The whole justification for this technology is to allow predictive rather than reactive maintenance. This yields huge savings, in the order of millions of pounds when taking into account the material optimisation as well as the penalties imposed when rolling stock failures occur.

The main beneficiary is the train maintenance provider, be this a train operator (TOC) or a leasing company (ROSCO). In most cases, the upfront investment is borne by the maintaining organisation, which seeks the approval of Network Rail to allow Track IQ to install the lineside units. With a typical system installation costing less than £300,000, the benefit for the rolling stock maintainer and the infrastructure provider is extremely strong, whilst also improving safety.

One question is whether the RailBAM system can replace HABDs, of which there are 228 on Network Rail. Whilst the acoustic equipment can detect defects well in advance of hot axle box systems, thus redefining what is ALARP (as low as reasonably possible) for bearing monitoring, it is primarily designed for trains with the more common roller bearings. The effectiveness of acoustic monitoring on shell bearings, of which there are a number remaining in service, is still being evaluated.

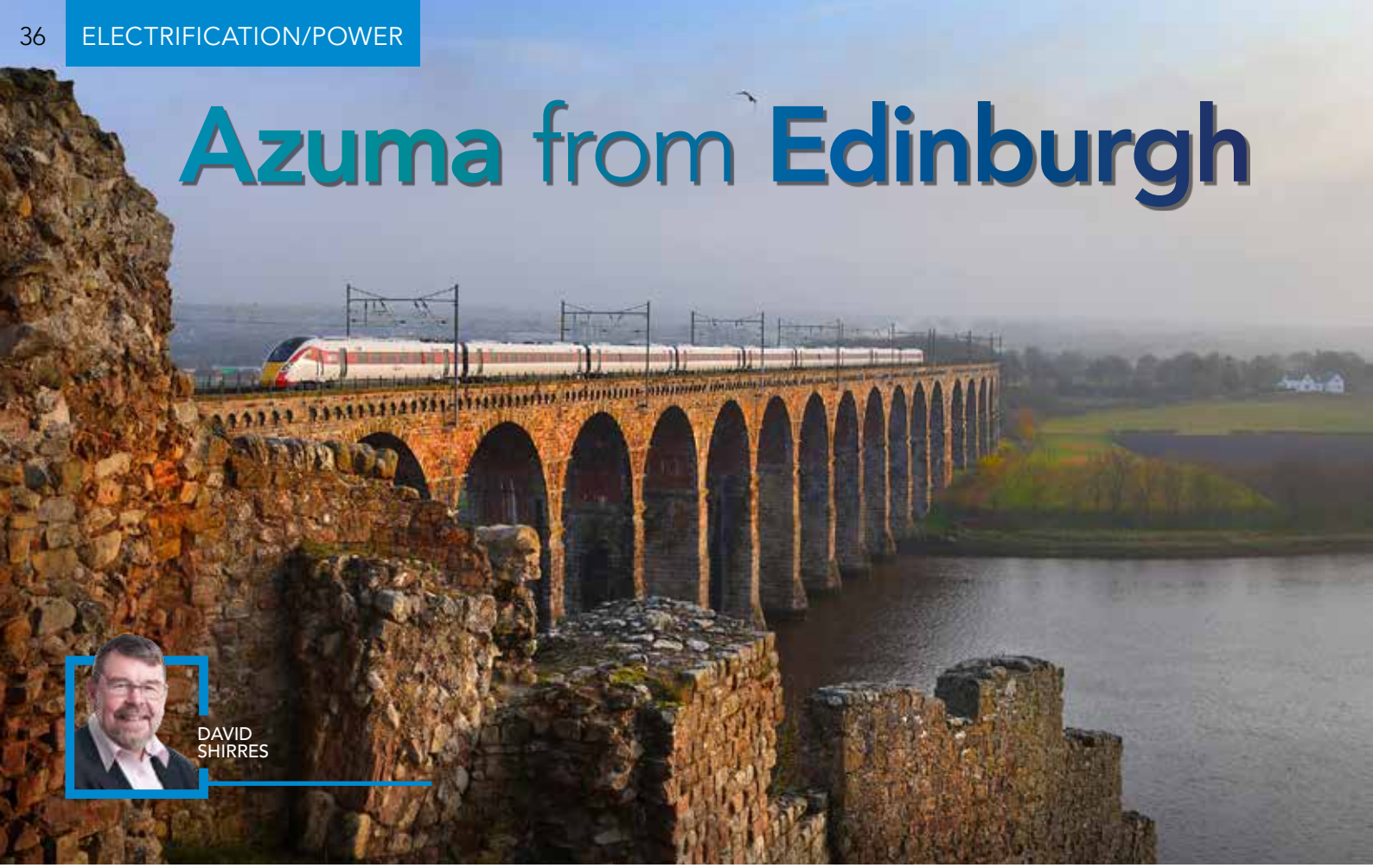
So, for the present, there are no plans to remove the HABDs. However, since the detection of axle journal bearing problems is made much earlier and more reliably, it is estimated by the RSSB and Network Rail that as few as 35 trackside acoustic sites are needed to provide national coverage.

With all elements of rolling stock monitoring now becoming the norm, a holistic approach to link RailBAM into other systems, such as FleetOne, is under consideration and is all part of the goal to improve overall train and infrastructure reliability.

Thanks to Nicholas Kay of Track IQ and Paul Baker of Bakerail Services for taking time to explain the system to a bunch of signal engineers!

RailBAM in the UK at (above) Mortlake and (below) Swaythling.

Azuma from Edinburgh



DAVID SHIRRES

It can take a long time to introduce a new train. In 2007, the Department for Transport (DfT) issued its invitation to tender for its Intercity Express Programme (IEP), for trains to replace the ageing Inter City 125 fleets on the Great Western and East Coast main lines. Five years later, after various contract negotiations, the train chosen by the DfT was the Hitachi AT300 product family which was to be built at a new plant in Newton Aycliffe, County Durham. Production commenced in 2015.

These trains were the subject of a £5.7 billion contract to supply and maintain 866 vehicles. 497 of these were for East Coast services, consisting of Class 800 bi-mode trains (13 nine-car and 10 five-car) and class 801 electric trains (30 nine-car and 12 five-car). The London North East Railway (LNER) has branded its new trains 'Azuma', which means 'East' in Japanese.

The Azumas will replace the current East Coast fleet of 30 IC225 nine-coach sets powered by a Class 91 electric locomotive and 15 Inter City 125 trains, which provide diesel trains from London to Aberdeen, Inverness, Lincoln, Hull, Sunderland, Harrogate and Stirling. When the bi-mode Class 800 Azumas are used for these services, they will only operate under diesel power for the smaller part of the journey, where there is no electrification.

Newton Aycliffe rolled out its first Class 800 in December 2016. In October 2017, these units were introduced on Great Western services. It had originally been intended that the East Coast Azumas would start running in September 2018, however, as with many new trains, delays postponed their launch to May when Azumas were introduced on services between London, Hull and Leeds.

Hitachi's design philosophy

Rail Engineer recently gained insights about the Azuma's design from a wide-ranging interview with Hitachi Rail Europe's head of engineering Koji Agatsuma, who observed that the Japanese custom is to take a long time considering what a customer needs and developing a product before offering it to the customer. As an example, he cites the development of the Class 395 Javelin trains, which were delivered in 2009 after the contract was let in 2005.

The IEP trains were developed to meet the DfT's capacity and performance requirements, which include the requirement for bi-mode trains to run beyond the electrified network. After Great Western electrification was cut short, there was a greater requirement for diesel running which resulted in the Class 800 diesel engines being uprated from 560kW to 700kW. Koji advised that this wasn't a problem as Hitachi had anticipated this customer requirement and allowed for it.

The extra capacity of the IEP trains comes from the use of 26-metre-long coaches, three metres longer than the present vehicles, which results in passenger space forming a greater proportion of the train. Furthermore, unlike the current trains, the electric and diesel traction equipment is above and below the passenger space. The result is that the Azumas have about a hundred seats more than the Class 91 trainsets they will replace, with seven centimetres more legroom in standard class.

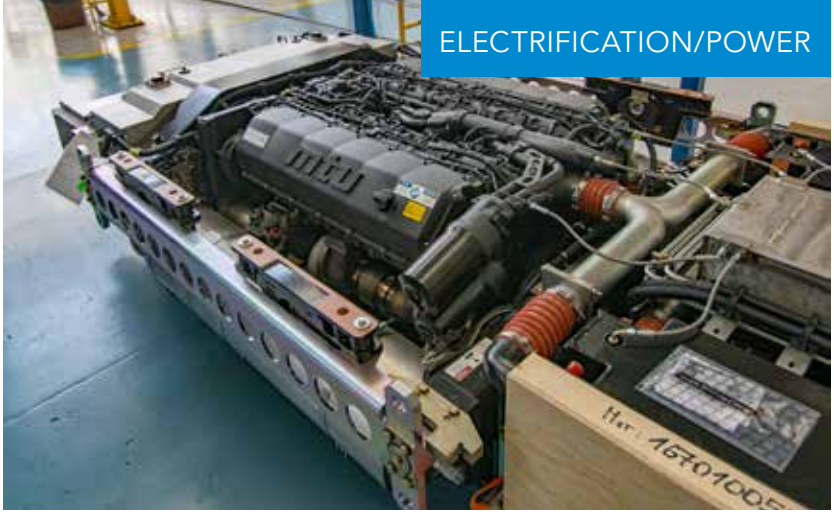
The first Newton Aycliffe-built IEP is rolled out on 9 December 2016.

The nine and five-coach IEP units have, respectively, five and three motor coaches each, with all axles powered and a power output of one megawatt under electrical power. Thus, over half of the axles on the train are motored. Koji mentions that the train is geared to have high acceleration from low speed in order to reduce journey times.

As previously mentioned, all equipment is carefully packaged to maximise passenger space. Koji mentions an example, for which Hitachi has a patent, of the use of a common supply converter designed to be fed from either the secondary winding of a 25kV AC transformer or the diesel generator unit. He also stresses the Hitachi philosophy of reducing weight wherever possible, of which the trailer bogies' inner frame structure is an example.

Electromagnetic compatibility between the IEP trains and the legacy solid-state interlockings had delayed their service introduction north of Doncaster. Koji explained that this was due to the higher frequency harmonics from modern traction control for which the solution was passive filters. In addition, Network Rail had improved cable screening.

Finally, Koji reflected on the use of battery and hydrogen rail traction. He considered that it was perfectly feasible to fit batteries to the company's Class 385 units to give them a last-mile capability. However, he felt that hydrogen power is not yet of age as it would seem to be costly and its equipment takes up too much space.



Diesel generator unit on bi-mode class 800.

Pre-service celebrations

The first Azuma passenger services from both Edinburgh and York to London ran on 1 August, for which there were suitable celebrations in the two cities beforehand. On 30 July, an Azuma had a photo call with Mallard, the world's fastest steam engine, at York station. The next day Edinburgh greeted the train's arrival with bagpipes and a new tartan.

At the Edinburgh launch event, LNER's managing director David Horne explained how the Azumas will bring a real revolution of rail travel to the East Coast route, which has a proud history of pioneering express trains. Over the past five years, the East Coast route had seen a 25 per cent increase in patronage for which the Azumas would provide much needed extra capacity.

David also emphasised the importance of sustainability, noting that an Edinburgh to London rail journey has one sixth of the CO_2 »

Class 800/1 800 104 at Edinburgh Waverley on 31 July about to leave for special trip to Berwick.

emissions of the plane journey. The Azumas will further improve rail's sustainability benefits as their bi-mode operation will ensure that all East Coast services under overhead lines will be electrically powered.

On a special Azuma run from Edinburgh to Berwick and back for press and stakeholders, Rail Engineer had the opportunity to talk to LNER's engineering director, John Doughty, who explained that the original launch date had been delayed due to a combination of infrastructure compatibility, teething problems and LNER taking delivery of its first Azuma in March 2019 instead of the original date of August 2018.

Getting trains operational

John stressed that LNER had been "very careful not to run risks" whilst introducing these new trains, the priority was to ensure that everything was right before the launch. One issue that had to be addressed was the hazard of someone contacting the overhead line equipment after using the sets of jumper cables between coaches as a ladder. Following discussion with the ORR, LNER's mitigation of this risk has been approved pending the development of a permanent design solution.

Another issue is that feeder stations at Doncaster and Marshall Meadows at the Scottish Border need to be upgraded to provide enough power to supply LNER's full electric train service. Whilst the feeder station at Doncaster is to be upgraded in October 2019, it is expected that Marshall Meadows won't be upgraded until at least 2021. Until then, to limit the load on the feeder station, a few Azumas will have to operate on diesel power for approximately 30 miles on either side of the Scottish border.

John advised that there are now seven of the nine-car Azuma trains in passenger service and that LNER has been working with Hitachi to ensure the trains are perfect. He emphasised that a key reason for this is to ensure that staff have full confidence in their new trains - the Azumas are currently achieving 9,735 miles per technical incident which he considered was "not bad for a brand-new train".

He explained that he has a project team of eight people accepting the new Azumas, with three needed for each nine-car train. Before LNER accepts a train, it must pass a static acceptance test and accumulate 2,000 miles of fault-free running, during which the mileage is reset if any faults occur. It typically takes a week to accumulate this mileage as it is difficult to get diagrams for it on the crowded East Coast route.

When asked about the five-car Azuma sets, John pointed out that the split of five and nine-car sets was decided by the DfT,

Azuma first class coach.


Azuma standard class coach.

which also specified the seating configuration. On most routes, the five-car sets will run coupled together as 10-coach trains. The five-car bi-mode Azumas will enable LNER to introduce a new regular service to Lincoln later this year, as well as more frequent services to Harrogate, and, in future timetable changes, direct services from London to Huddersfield and Middlesbrough. LNER's website shows the planned introductions.

During September, it is planned to introduce Azumas on four more East Coast Scottish trains, including, from 23 September, LNER's sole London-Glasgow service. Between October and December, more Anglo-Scottish services will transfer to Azuma operation.

The December timetable change will see the introduction of LNER's half hourly daytime service between London and Edinburgh - by next May, all these trains will be Azumas. To manage seat reservations as the Azumas are fed into the service pattern, the plan for each service is fixed eight weeks in advance so that tickets can then go on sale.

By December, bi-mode Azumas will operate LNER's Aberdeen and Inverness services. The latter service will be particularly demanding, as it includes a 16-mile climb up a 1 in 70 gradient to the 1,484ft Drumochter pass, the highest point on the UK rail network. It will be interesting to see how Azumas in diesel mode compared with the more powerful Inter City 125s that they will replace. John has no doubt that Drumochter won't be a problem for the Azumas, which have more than half their axles motored and so are less prone to adhesion problems. He also pointed out that, unlike the trains they replace, Azumas have self-closing doors, which will reduce station dwell times on these routes.

Experiencing the Azuma

Having had the opportunity for a short trip from Edinburgh over the border to Berwick and back, your writer was keen to experience the Azuma on a longer journey so joined the 05:40 inaugural service from Edinburgh on 1 August. With long stretches of 125mph running, this was an opportunity to experience the Azuma at speed, when the ride was lively on occasions. However, catering staff considered that it was better than they were used to, so they didn't expect to bruise their legs on the tables.

The longer journey also provided an opportunity for a closer look at the train which has 101 first-class and 510 standard-class seats, all of which have their own power sockets. There is a traffic light seat reservation system above each seat which turns to green after the portion of the reserved journey has been completed. Amber denotes that a seat has been reserved later in the journey.

Bike compartments and café bar.

The coaches on the nine-car Azuma are lettered A to C and G to M (with no coach I). Coaches A to J are standard. A has two wheelchair spaces, B has two bike compartments, each holding two bikes, G has the café bar, K has two bike compartments and is half standard, half first class, L and M, which has two wheelchair spaces, are first class coaches. There are ten toilets on the train, including two universally accessible toilets.

As the average passenger journey on East Coast services is typically twice the average on Great Western, LNER's passengers expect more in the way of catering. Hence, the only difference between the coach layout on these two routes is that LNER Azumas have a café bar in coach G (for grub), on Great Western the only catering offered to standard class passengers is from a trolley.

The extra three metres gives the Azuma coaches a spacious feeling, although, in standard class, seats are not lined up with the windows. Standard class seats are firm, but I did not find them uncomfortable. The first-class seats are lined up with the windows. They are less firm than standard, though perhaps not as comfortable as the plush seating of current trains, that three years ago, were refurbished to LNER rather than DfT standards.

Each coach has two luggage racks, with toughened glass used for luggage shelves to enable passengers to see what they have put there without standing on the seats. When walking through the train, the five coaches with generator sets underneath were evident by the slight ramp from the vestibule due to their raised floor, which was otherwise not noticeable.

Newcastle to London – average 105mph

The 05:40 Edinburgh to London train is LNER's Flying Scotsman, taking exactly four hours to reach London. Its only stop is at Newcastle, after which it offers the UK's longest non-stop run - over the 268 miles between Newcastle and London - although it is the only train of the day to do this in either direction. On 1 August, the train left Newcastle at 07:05 and arrived at Kings Cross at 09:39, a minute early, having averaged 104.8 mph.

The high average speed of this non-stop run is not new, as class 91 electric locomotives have been operating this service for some years. »

Three generations of East Coast Traction at Kings Cross (LtoR) Azumas, Inter City 125 and Class 91 electric locomotive.

David Horne, managing director of LNER, with Azuma and Mallard at York.

An indication of what is new occurred when the train almost wasn't a non-stop run. Just before Grantham, it slowed down to 19mph to enable a preceding train to be looped ahead of it. The Azuma then demonstrated the high acceleration that Koji Agatsuma had referred to by taking only 2 minutes 5 seconds to accelerate from 29 to 100 mph up the 1 in 200 gradient south of Grantham.

Combined with infrastructure improvements, it is this power which will provide the required acceleration for a regular four-hour London to Edinburgh journey with the current stopping pattern, which is expected to be introduced in December 2021.

To mark the occasion, souvenir inaugural run Azuma key rings and miniatures of Tomatin malt whisky (distilled next to the Azuma's route to Inverness) were handed out. As the Azuma approached Kings Cross after its flawless inaugural run, LNER's managing director, David Horne, thanked those on board for joining LNER on this memorable occasion. On arrival, the train was greeted by a single piper and Azuma shopping bags were handed out.

Before the inaugural return Azuma service left Kings Cross at 17:30, its passengers were offered more shopping bags and treated to a performance from the Red Hot Chilli pipers. Although Tomatin miniatures and key rings were again handed out on board, there wasn't quite the buzz about this return working, which took 4 hours 40 minutes to get to Edinburgh having stopped at Peterborough, Newark, York, Darlington, Durham, Newcastle, Alnmouth and Dunbar along the way.

This time there was no piper to greet the train at its final destination, although LNER staff, clearly proud of their new train, were taking selfies to mark the occasion. Over the past three days, the Azuma had been given a special launch, now it was time for the train to start routinely offering a high-class service on the East Coast route.

Log of inaugural Azuma Edinburgh to London service 1st August 2019

miles		time	passing speed	pass to pass average speed	start to pass average speed	Notes
0	Edinburgh	05:40:10				
29.25	Dunbar	05:59:34	84.9	90.5	90.5	
57.5	Berwick	06:19:00	55.6	87.2	88.8	
89.75	Alnmouth	06:36:39	84.5	109.6	95.3	
108	Morpeth	06:48:15	48.6	94.4	95.2	
124.5	Newcastle	07:00:04	0.0	83.8	93.5	
		07:05:15				
132.75	Chester-le Street	07:13:05	112.5	63.2	63.2	
138.5	Durham	07:16:19	72.1	106.7	75.9	
160.5	Darlington	07:30:07	90.2	95.7	86.9	
174.5	Northallerton	07:37:24	125.3	115.3	93.3	
182.25	Thirsk	07:41:09	127.8	124.0	96.5	
204.5	York	07:53:59	20.6	104.0	98.5	
237	Doncaster	08:11:10	98.2	113.5	102.4	
254.5	Retford	08:19:58	120.1	119.3	104.4	
273	Newark North Gate	08:29:21	105.6	118.3	105.9	
287.5	Grantham	08:38:38	72.3	93.7	104.7	1
316.75	Peterborough	08:53:23	105.1	119.0	106.7	
365.5	Stevenage	09:19:02	125.1	114.0	108.1	
380.25	Potters Bar	09:27:10	105.3	108.8	108.1	
390.5	Finsbury Park	09:33:58	39.8	90.4	107.3	
393	London Kings Cross	09:38:56		30.2	104.8	
1. Checked to down to 19 mph, one mile before Grantham						
Average Edinburgh to London Kings Cross - exc Newcastle stop time					100.9	
Average Edinburgh to London Kings Cross - inc Newcastle stop time					98.8	

Red Hot Chilli pipers play out the inaugural 1730 Kings Cross to Edinburgh Azuma.

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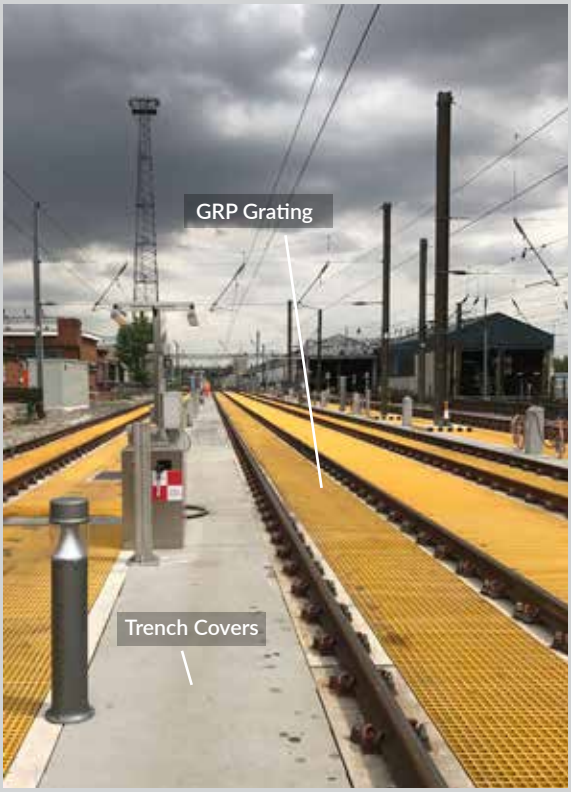

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Proposed new Transport for Wales (TfW) Tri-mode Vehicle.

Much has been discussed recently about the state of electrification in the UK, and how it is being delivered at a much higher cost than on the continent.

The article in Rail Engineer titled 'Getting electrification right' (issue 164, June 2018) demonstrated the all or nothing method the UK Government has taken in its approach to electrification and the resulting move towards diesel-powered, bi-mode vehicles; an unsustainable option in the pursuit of reducing the nation's carbon footprint.

North of the border, Transport Scotland has taken a somewhat different approach, and one which seems to have been more successful. Over 25 per cent of the Scottish network is now electrified, and a steady programme of electrification seems to have had results.

In Wales, the Welsh Government took over the franchising of the railway and appointed KeolisAmey to operate and develop the Wales and Borders rail service and South Wales Metro, working in partnership with Transport for Wales, on a 15-year contract from 2018 until 2033.

This lengthy contract term has encouraged both Transport for Wales and KeolisAmey to take a long-term view, which they have already done with the announcement of new rolling stock purchases and a new approach to electrification that taps into hybrid technology already in use in road vehicles.

Balancing the budget

The key challenge of electrification schemes to date has been the ever-rising cost and time to complete the works. Overspend, programme delays and scope reduction of schemes are all reoccurring themes across the board on electrification programmes, largely due to the complexity and extent of the work needed to fully electrify a whole line.

A significant proportion of the cost of any electrification scheme is made up of the track and civils works needed to provide the necessary safety clearances. All overhead line equipment (OLE) has minimum distances to be applied to keep the public safe, such as at any public standing surface (station platforms) and at level crossings.

In addition, many historic bridges and other structures over the railway, built over 100 years ago to much smaller gauge clearances, require considerable alteration work to accommodate the overhead catenary.

These factors mean that a great deal of investment is needed, either to lower the track or raise bridges, to allow for compliant clearances prior to the electrification works. This costly work must be avoided to make electrification a more cost-effective solution.

A different approach to rolling stock

Bi-mode trains are being introduced on several of the UK routes to overcome the limitations of the reduced electrification scope. These trains operate on electric power when under wires but switch to diesel where overhead power is not available.

It's a simple solution. However, trains must therefore carry pantographs and transformers as well as heavy diesel engines and fuel tanks, all of which need to be carried throughout the journey.

Hybrid technology, now firmly established within the domestic car market, seamlessly blends power from the combustion engine with power from an on-board battery pack. Energy is recovered and stored in the battery through regenerative braking, dramatically improving fuel economy. The latest 'plug-in hybrid' cars (PHEV) use the battery pack as the primary power source, with the combustion »

Proposed new Transport for Wales (TfW) Metro Vehicle.

engine providing an increase in the mileage range and a back-up in the event of an empty battery.

KeolisAmey has come up with a solution for the new Central Metro in Wales that will make use of this state of the art yet well-established hybrid technology in its new train fleets; both tri-mode and metro vehicles.

This change from the existing diesel multiple units (DMUs) on the network to hybrids will lead to a profound reduction in carbon footprint and the on-board batteries will significantly reduce the cost of electrification.

On the Core Valley Lines (CVL), which is everything north of Cardiff Central, tri-mode vehicles will be used from Rhymney and Coryton to Grangetown, powered by OLE and battery only. The addition of the diesel engine adds flexibility to the vehicles to continue on to Penarth, Barry and Bridgend, and elsewhere on the network if future needs demand. (See map, page 38).

Queen Street to Rhymney will operate on OLE and battery power, including an unwired section between Caerphilly and Lisvane & Thornhill, where battery-only operation will be used to avoid costly waterproofing works in Caerphilly tunnel.

Metro vehicles from the three remaining valley heads (Treherbert, Aberdare and Merthyr Tydfil) through to Cardiff Bay will be OLE/battery hybrids only, with no diesel engine. These trains will run wire-free to the new station at the bottom of the Cardiff Bay branch, which will lay the foundations for future 'on street' extensions into the city centre.

Permanently earthed sections for cost efficiency

This proposal for the electrification of the Valleys will significantly reduce the number of track and civils interventions. Why? Because the use of permanently earthed sections (PES) will allow the OLE clearances at structures to be significantly reduced, removing the need for many alterations.

These permanently earthed sections of OLE, similar to extended neutral sections, are not a new solution and are already used on conventional electrical schemes for some low structures where track or civils works are not feasible. However, their use is usually only possible in locations where a train has sufficient momentum to 'coast' through a non-electrified section - a risk assessment is needed to make sure that a conventional electric train will never stop and become stranded in this area.

The hybrid capability of both new train types means that they can accommodate the use of a PES wherever electrical clearances cannot be achieved, including in station areas. The new rolling stock will switch to battery power through these sections, with the pantograph remaining raised, and switch back to overhead power when live OLE is detected.

The widespread use of PES for the South Wales Metro transformation will avoid up to 55 track or civils interventions across the Valleys. Complex station canopy alterations and the provision of protective screening are also avoided, with track lowering expected to be needed at just 17 sites and only one bridge needing to be lifted.

The cost savings from the use of battery power and PES to overcome areas that are difficult to electrify are evident and, unlike diesel, achieve the zero-carbon operation that is expected of a modern rail network.

This approach to electrification by the Transport for Wales Rail Services, operated by KeolisAmey, may well pave the way for similar methods to be adopted for other networks in the future and, with battery technology ever improving, it is clear that the rail industry must not be left behind.

Graeme Brindle is technical director and Nathan Sealy is regional engineering director, both with Amey Consulting.

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BRINGING MORE POWER to Merseyrail

Merseyrail will be introducing new trains to its network around the Liverpool City Region from next year, replacing the current fleet of electric multiple units which are now approaching 40 years old.

Built and maintained by Swiss manufacturer, Stadler, the trains will be modern, fast and comfortable. They will also be able to carry more people, more quickly, helping support the growth of the City Region with the potential to run beyond the current 'third rail' to places like Wrexham, Skelmersdale and Warrington in the future.

To improve passenger safety, and make the network more accessible to all, the new trains will have a sliding step that will allow level access.

Merseytravel, which oversees the operation of the Merseyrail network, will own the new trains on behalf of the Liverpool City Region Combined Authority, which has set aside a reserve to help fund the project. Merseytravel will then lease the trains to Merseyrail.

Of course, there is more to the project than simply buying a fleet of new trains. The £460 million project includes provision for power upgrades to the network and work on platforms and track to help manage the gap between the train and platform. There will also be major refurbishment of the depots in Kirkdale and Birkenhead, so they can be adapted to maintain modern trains, moving to more computer-based diagnostics.

More power

Although modern trains are more efficient than those built 40 years ago, they also have additional electrical requirements.

For example, they demand more electrical power for traction and auxiliaries, such as air conditioning. Regenerative braking pushes power back into the 750V DC supply network, which has to be capable of accepting it (for example by having another train in section which is demanding power). If the system is not receptive, then the train's onboard batteries will be charged.

The power supply network therefore had to be upgraded. This was required to meet the demands of the new fleet but will also eradicate existing DC issues at the fringes of the network, which had often caused delays on the Southport service.

Contractually, the situation is somewhat complex. Network Rail is undertaking the work, funded by Merseytravel. VolkerRail is the delivery contractor, employing AECOM as the lead designer.

The substation work needed was almost equally complex. Seven were to be upgraded (three on the Wirral lines and four on the Northern lines) by the provision of high-voltage (HV) switchgear modules, auxiliary transformers and isolation transformers.

One track paralleling hut (TPH) would be converted to become a full DC substation by the provision of an HV switchgear module, a DC rectifier module, a transformer rectifier, an auxiliary transformer and an isolation transformer.

In addition, three completely new HV / DC substations would be built, each including HV switchgear modules, DC switchgear modules, DC rectifier modules, transformer rectifiers, auxiliary transformers and isolation transformers.

All this would draw down more power from the distribution network operator (DNO), so three new substation buildings would be required, constructed in accordance with Scottish Power Energy Networks' specification, to accommodate a 33kV power supply and a 33kV/11kV transformer to suit the demands of Network Rail's upgraded substations and equipment.

HV feeders

Modelling of the existing Network Rail distribution system identified several areas of weakness within its existing HV feeder network. Based on these findings, AECOM recommended the introduction of new HV supplies to the proposed new substation sites at Long Lane and Aughton as well as HV cable modifications at Aintree.

These HV feeder enhancements included the provision of three new HV feeders. One will be between Walton and Long Lane, another at a site still to be determined between Maghull North and Town Green stations. There will also be one between the new DNO substation building at Birkenhead North and the upgraded substation at Bidston.

Modifications to the existing High Voltage (HV) route at Aintree substation required the existing HV cable to be cut and redirected into the existing substation to create two separate HV feeders.

In addition, electrical traction equipment (ETE) enhancements include upgrades to the existing along-track continuity bonding, impedance bonds, negative DC track feeder cables and track isolation switches.

Ongoing design

AECOM has now completed outline designs (GRIP 3) for the HV feeders and ETE works and is carrying out the detailed design (GRIP 4/5) for the HV, ETE and substation works.

It's a complex job, requiring both preparatory work and the interfacing of several different design disciplines.

Before design could commence, topographical surveys were undertaken on all of the substation, under-track crossing (UTX) and under-road crossing (URX) sites. In addition, ground investigation works, including soakaway testing, were undertaken for all substations, UTX and URX sites.

The design itself brought in the skills of AECOM's experts in:

- Civil and structural engineering (foundation designs, ancillary civils works, cable management / containment systems, UTXs, URXs, brickwork and DNO buildings);
- Telecoms (SCADA connections for new substations);
- Geotechnical (ground investigation factual and interpretive reporting, slope stability analysis, slope remedial works and retention structures);
- Highways (road access for new substation sites, including road safety audits); »

» Drainage (flood risk assessments, SuDS (sustainable drainage systems) suitability assessments);
» Environmental and ecological surveys and management.

In addition, consideration had to be given to the key external interfaces with both Scottish Power Energy Networks and Siemens Switchgear.

Smooth progress?

In the main, the design process went smoothly. AECOM principal engineer Azadeh Ghadamgahi, who has over 12 years of experience in the design and management of power systems and electrification projects, commented: "The design submission was comprehensive and received only minor comments back from the client. The team was aware of the programme and deadlines by having effective/good communication.

"While going through the technical quality review process, everyone, whether they are a designer, checker, CRE or lead verifier, was accountable for their own work, which helped us to have a successful submission.

"As there are several sites within this project, with a multitude of designers, our aim was to maintain consistency of approach in order to produce a standardised product.

"As with any major project, there have been requested changes to the design from the client later in the process, which we have integrated faultlessly."

One of the features of this project was the number of young designers working on the team. One such was Luke Thurgood, who started his career as a rail design engineering apprentice and has learnt his trade through the support of senior engineers around him. He now has a strong knowledge of the design of heavy-rail electrification systems, mainly focused around third-rail contact systems, negative bonding and points heating supply and distribution.

In the past year, Luke has obtained Engineering Technician (EngTech) status with the IET and continues to develop his academic knowledge while working by undertaking further studies (HND) at London South Bank University. All his studies have been funded through the government's apprenticeship scheme - AECOM is a keen supporter of this initiative.

The AECOM E&P team

The AECOM E&P team consists of 125 engineers spread over nine offices in the UK, Madrid and Bangalore.

All of AECOM's rail disciplines feature a very comprehensive competency process. In addition, there is an independent process for internal assessment of CRE and CEM competency. This ensures that, at all levels, engineers are assigned to projects matched appropriately to their skills. For E&P, this is especially important as there are a large number of sub-discipline specialisms to cover, for example earthing and bonding in electrified areas.

This competency process is also used for staff training and development to guide on appropriate mentoring as required.

AECOM's teams are competent in all elements of trackside LV design, including points heating, signalling power (there is in-house competency to undertake testing and inspection); station and trackside building M&E design (supported by the buildings division with 350 M&E engineers) to have the capability and competence to undertake any size rail station scheme; OLE design with demonstrable competence in all series with recent Series 2 experience on GOBE (Gospal Oak to Barking Electrification); traction power (including traction simulation), substation (750V DC (Wessex Capacity Alliance PSU) through to auto transformer feeder station (Boreham feeder station design)) and HV design up to and including 66kV (the industrial power division covers design up to and including 400kV); all elements of ETE design (S&C Alliance and Wessex Capacity Alliance) including protection studies and stray current mitigation design; and full depot systems design capability in the South West, which can be demonstrated with recent commissions with Southwestern Railway at its Fratton, Farnham and Basingstoke depot enhancements for new rolling stock.

In addition, AECOM operates Bentley's ProjectWise, which supports a common data environment (CDE), for all its projects, which allows for unrivalled workshare ability across all offices and geographies. This, coupled with AECOMs desktop Jabber system (calls and screen sharing) and office-wide video-conferencing facilities, enables virtual side-by-side working and meetings globally.

AECOM's UK design teams are able to interact with our systems modelling team in Madrid as a single delivery unit to provide for the complete electrification solution:

» Electrification system studies and modelling;
» Overhead line design;
» Third and fourth-rail design;
» Traction power substation (11, 22, 25, 33 and 66kV) modification/replacement;
» HV feeders 11, 22, 33 and 66kV (replacement or diversion);
» Earthing and bonding and stray-current mitigation;
» Points heating;
» Lightning protection;
» EMC/EMI management;
» ECR modifications including SCADA.

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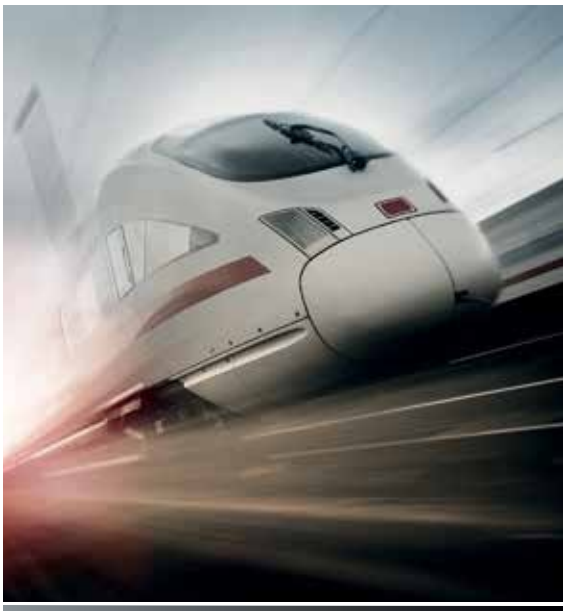

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DANNY AISTHORPE

Sicat joins Network Rail's UK Master Series

With the need to electrify significant parts of Great Britain's rail network to meet rail decarbonisation targets, the industry continues to design and develop innovative solutions that will deliver improved value over the life cycle of an asset.

One such solution, Siemens Mobility's Sicat SA cantilever, has received acceptance from Network Rail's Contact Systems Group and so is now included in Network Rail's UK Master Series (UKMS). UKMS is a standard set of Overhead Line Equipment (OLE) design ranges for use on new and refurbishment schemes on Britain's rail network.

The light-weight, aluminium Sicat SA platform offers cost, installation and maintenance advantages, having been designed with a focus on 'value creation' to address the challenge that the industry has been given to reduce the cost of electrification schemes and optimise their efficiency through the adoption of alternative technologies and processes.

Demonstrating the advantages

Siemens was able to demonstrate the benefits of Sicat SA through its work on the TransPennine Route Upgrade (TRU) project through evalutaion and dynamic testing processes. Working alongside design consultancy TSP Projects and key alliance partners to deliver a number of value-engineering work streams to demonstrate the benefits of including elements of the Sicat SA design range solution into the UKMS.

One of the main perceived advantages of the traditional UKMS equipment (which covers line speeds up to 125mph) is its modular construction. However, system procurement is often left until the later stages of the design process - thereby restricting the opportunity for any design flexibility. In contrast, the Sicat cantilever arrangement can be designed and readily fabricated specifically to suit the requirements of each site and so optimise performance.

The components for each style of cantilever are largely common throughout the Sicat range and can therefore be bulk ordered, even at outline design development phase. This not only gives greater assurance in achieving programme delivery targets, but also provides the flexibility to meet any programme changes. As the Sicat cantilever assembly is fabricated from lightweight aluminium tubing and aluminium components, the system offers an effective balance between adjustability, ease of fabrication, and ease of installation.

Using like-for-like system parameters, most UKMS cantilevers require a top mast bracket to be positioned 1.1 metres higher than is required for a Sicat SA cantilever, generating a saving in material cost. As a result, initial estimates show that the required section of steelwork can be reduced,

representing a 25 per cent reduction in cross-sectional areas, and therefore further saving in material costs.

One of the key differences between the Sicat SA and UKMS OLE equipment is the weight of the support assemblies, with Sicat's cantilever and brackets being 28 per cent lighter and the under-portal cantilever 35 per cent lighter.

At portal locations, there is also a significant difference in weight associated with steelwork to support the assemblies, such that an additional machine with a crane arm is required to install UKMS safely and efficiently - whereas Sicat SA support steelwork can be safely installed from the basket of a mobile elevated work platform (MEWP).

These savings in plant and installation time, together with safer manhandling at height (compared to that of heavier cantilevers), provide significant cost savings. The system may also be constructed either on or off-site, offering further potential cost, operational and safety benefits.

As well as new 'green field' electrification schemes, the Sicat SA cantilever can be used as a direct replacement for life expired or damaged equipment on existing routes and is compatible with existing MkI, MkII and MkIII overhead line systems cantilever assemblies. Therefore, when used in areas of existing electrification, the reduced load of the Sicat cantilever increases the probability that existing masts may be re-used, with resultant cost savings.

Dynamic modelling

To identify the optimum solution for each individual project, Siemens is able to carry out dynamic modelling of the interaction between the overhead line contact system and different rolling-stock pantographs. This allows OLE designs to be fully optimised; for example, using parameters derived from both UKMS and Sicat for open route and discreet features, with various pantograph and speed combinations.

The TRU project has focused on value-engineering workstreams in support of the Railway Industry Association's Cost of Electrification challenge. The project team utilised Siemens' OLE dynamic software modelling tool to optimise overhead line parameters. Using this approach, the project identified that TSI dynamic performance criteria could be met with increased span lengths and is in the process of updating the Master Series to allow spans of up to 74 metres.

Longer span lengths can significantly reduce the number of foundations, structures and cantilevers required, as well as the associated equipment, resulting in significant cost reductions due to reduced infrastructure, faster installation, reduced overall time on site and significantly reduced waste and materials surplus.

An early incarnation of the Sicat SA overhead line system has been in operation in Scotland for more than 10 years, having replaced the life expired OLE equipment on the 6.5-mile Glasgow Shields junction to Paisley Gilmour Street line. More than ten years on, the equipment continues to deliver outstanding service, with exceptional reliability, availability and maintainability (RAM) scores achieved on this suburban route.

Catering for a large number of multiple pantographs, the route called for high availability and robust, long-life performance. Sicat SA has delivered this, providing assurance that, over the system's life, it can meet both operational and environmental requirements, delivering reliability and therefore high availability.

Clearances and surge arrestors

Digitalisation enables transport operators worldwide to increase value sustainably over the entire lifecycle, with one such solution being Siemens 25kV surge arrestor.

The cost of electrification programmes is often adversely affected by the inevitable proximity between live overhead-line conductors and trackside structures. As the overhead line system is energised at 25 thousand volts, compliant electrical clearance must be allowed at both design and installation stages to ensure the electrification infrastructure doesn't suffer unnecessary flashovers between live conductors and lineside structures.

The required electrical clearances are defined within legislation and standards. These control the design and installation requirements and allow for a number of 'worst case' conditions, including, for example, environmental conditions and pantograph uplift.

Clearances are an essential factor in the planning phase of overhead line system design. If a conflict of electrical clearances occurs, then considerations have to be made to either modify the relevant structure (bridge, tunnel or building) or lower the tracks, both of which require complicated, extensive and expensive design and construction works to achieve the required electrical clearance.

To address this issue, and so to reduce or eliminate the costs of either having to make modifications to the structure or to lower the track, Siemens has developed an alternative solution which uses a surge arrester in circuit with the overhead line system. This offers significant benefits both in terms of the cost and speed of electrification works, particularly compared to any requirement for reconstructing or modifying buildings, bridges or tunnels, or for lowering existing tracks.

By introducing a surge arrester in this way, if over-voltages do occur (potentially as a result of lightning strikes), then these are limited by the surge arrester to a magnitude of voltage which complies with the available electrical clearance values between the overhead line and structure.

Depending on the required protection level, surge arresters can be applied to the overhead line equipment on both sides of the structure - for each contact system running through the structure requiring a reduced electrical clearance.

Surge arresters have now been specified by Network Rail for a structure in Cardiff, where restrictions caused by the proximity of a canal, combined with a rail intersection bridge, mean that the track simply can't be raised or lowered to accommodate compliant electrification clearances.

The Sicat system has already been installed on nine routes across the Danish railway network, covering a total of 1,300 kilometres of new electrified line.

Danny Aisthorpe is engineering director, rail electrification with Siemens Mobility.

STEVE COX

Electrifying Innovation

The need for electrification

The UK has a clear target to reach net zero emissions by 2050. Rail is already a naturally low-carbon means of transport, responsible for less than 2.5 per cent of total transport emissions and about 0.6 per cent of the UK's total emissions. But in a world where electric cars are becoming quickly commonplace, to remain competitive, rail's emissions can and must be reduced even further.

Industry must play its part, not least by meeting the Government's challenge to remove all diesel-only trains by 2040. As the Committee on Climate Change's report in June outlined, decarbonisation by 2050 is achievable and affordable but it means every sector, not just some, need to act.

At Alstom, we believe a two-pronged approach is essential here. Electrification is the only viable technology that can be deployed for high-speed and very long-distance passenger parts of the network, and it will have a crucial role in the coming years as the network winds down its usage of diesel trains.

For other parts of the network, where electrification is not feasible due to costs or practicalities, hydrogen is the most viable answer. It is proven to work by Alstom in Germany, and ready to enter the UK network soon through Alstom and Eversholt Rail's 'Breeze' project to convert Class 321s to hydrogen-powered at Alstom's train modernisation centre in Widnes.

As a global leader in electrification, Alstom also has the proven and innovative solutions to ensure electrification of the network can play its part in taking polluting diesel trains off the rails. This innovation brings a wider range of benefits too, from a reduction in construction risk, improved health and safety during the works, and the need for less kit that, in turn, improves the public realm.

Alstom's electrification pedigree

Nestled in the foothills of the Italian Alps lies the beautiful Italian city of Lecco, situated on the edge of Lake Como and the home to Alstom's in-house centre for excellence for electrification components. It is here that Alstom's high-speed electrification systems, which are installed throughout Europe, are manufactured and supplied.

In the UK, this has meant that the Lecco factory has also supplied much of the electrification equipment for the railway systems being installed by Alstom's joint venture with TSO and Costain in the Crossrail tunnels. This electrification system is based on Alstom's OCS3 range of equipment, with Alstom S&I Lecco rigid overhead conductor beams being used throughout the tunnels.

Having complete ranges of electrification equipment suitable for mainline, high-speed and urban schemes has been a critical factor in Alstom achieving its global leading position in electrification. As part of this, Lecco has produced the Clever Cantilever, or »

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CLever, developed specifically for use in the UK and now fully part of the Network Rail Master Series range of equipment. This innovative electrification support system has now been in operation on the UK network since 2016.

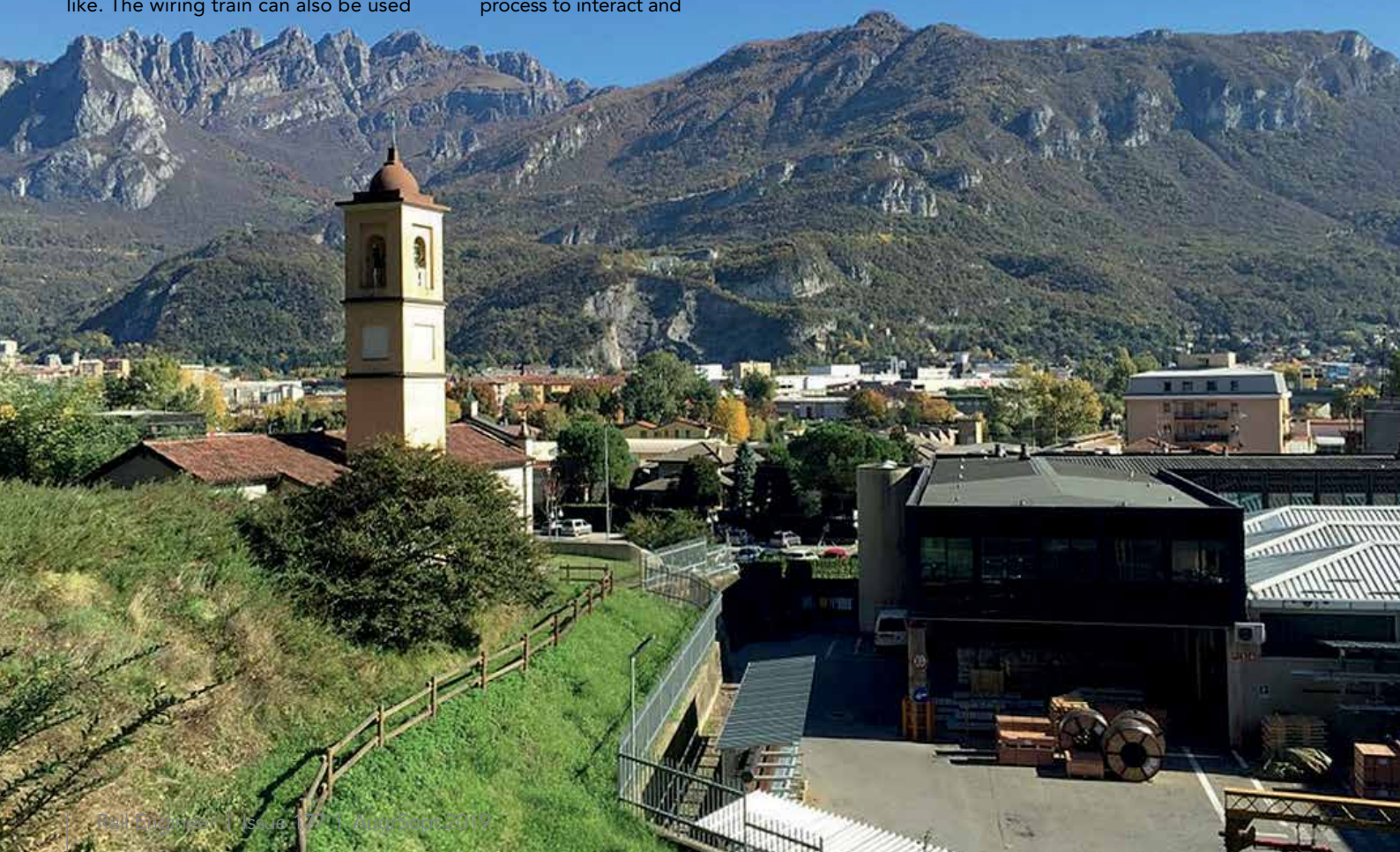
High-output delivery in the construction phase is something that Alstom has developed over a number of years in specialist wiring techniques. In October 2015, Alstom introduced its wiring train in the UK. Modified specifically for use on the British network, this was successfully deployed on the Edinburgh Glasgow Improvement Programme then subsequently on Stirling, Dunblane, Alloa and Shotts. The train consists of seven vehicles, each of which has a specific purpose - a traction crane and MEWP (mobile elevating work platform) unit, drum carrier, wire tensioner, manipulator and MEWP, two independent MEWPs and a traction unit with MEWP and pantograph.

The wiring train has the advantage of being classed as an OTM (on-track machine) and, as such, can travel loco-hauled. Once the train gets to the work site and into the possession, it can run out catenary and contact wire together at full line tension. The individual units that comprise the train can split, allowing registration activities to be undertaken and the fitment of any in-line items such as section insulators and the like. The wiring train can also be used to run ancillary wires such as earth wires and feeder wires, providing a complete electrification delivery solution.

The advantage of the Alstom electrification installation system is that three wire runs can be completed in one shift, compared with four shifts conventionally for one typical wire run. A higher quality installed tension length is achieved due to the mechanisation and, as with all Alstom innovations, the focus is on safety as the number of trackside workers is reduced. This innovative and unique electrification delivery system was highly commended in the 2019 Rail Partnership Awards for driving efficiency.

With any infrastructure project, successful delivery and commissioning frequently requires long, costly possessions. When combined with the safety risk element of having multiple workforces on track, any innovative development that improves safety while reducing the commissioning period, saving time and money, is valuable. In this regard, Alstom's industry-leading signalling business has developed its SMARTCert tool suite to eliminate the need to use spreadsheet trackers and paper-based reporting - this tool can also be applied to electrification projects to provide efficiency benefits.

The SMARTCert system allows all stakeholders within the commissioning process to interact and obtain all the information they require from one single source of truth. SMARTCert allows for multi-user access, a single source of information and process improvements to the paper and spreadsheet-based process whilst still complying with the Network Rail test and commissioning standards. »



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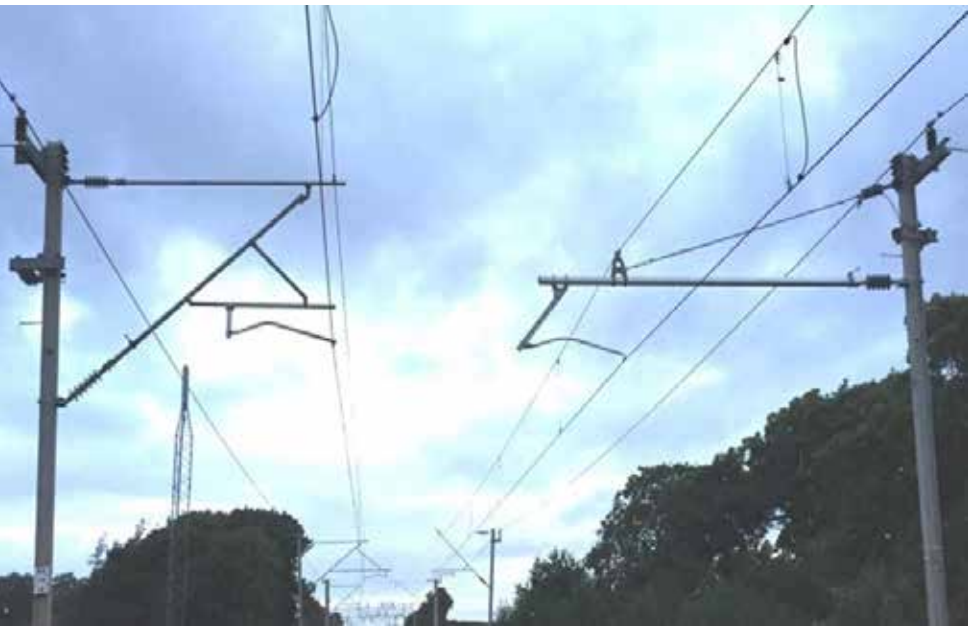


The electrification process

Alstom, as a global leader in electrification, has developed a complete, efficient delivery process built on four pillars: BIM (Building Information Modelling), automation, complete capability and experienced people. Alstom is one of the few businesses that has a complete electrification offering covering design, manufacture, installation and maintenance.

The Alstom electrification process is centred around BIM, using automatic design tools to develop the model out of which schematics, bills of material and cross sections can all be developed. These tools provide the maximum advantage when deployed early in the scheme development, at GRIP 3 or 4 (option selection and single option development).

At this stage of the design process, accurate scheme layouts and BOMs can be developed that help with both costing and planning for later GRIP stages of detailed design and delivery. The Alstom BIM process allows for asset information to be collected throughout delivery, providing the maintainer with a high level of information on the delivered electrified asset.

Technical excellence and competence are key pillars in Alstom's delivery process, in this regard a World Class Engineering (WCE) structure has been developed. WCE is Alstom's way of identifying technical expertise within the business globally and providing a platform to sustain and develop the technical expert community. It means Alstom can measure experts and competence in a consistent way across the business and ensure the best people are selected to deliver the clients project.

Innovative systems

Not only is Alstom a leader in overhead electrification, its innovative reversible power-supply substation (issue 140, June 2016) optimises the power required for light rail and metro traction systems and can capture up to 99 per cent of recoverable energy from regenerative braking. Hesop, of which there are units on London's Victoria line, the Paris T1 tramway and Riyadh Metro, increases the energy efficiency of the electrical system, resulting in a decrease in carbon emissions. This is achieved by converting the energy emitted by trains during braking into usable electrical power that can be used by station services such as lighting and elevators.

As the energy is reused, it removes a source of heat. This, when deployed in tunnels, will have the effect of reducing temperature - important in hot summer months or for railway systems installed in the UK and even hotter climates.

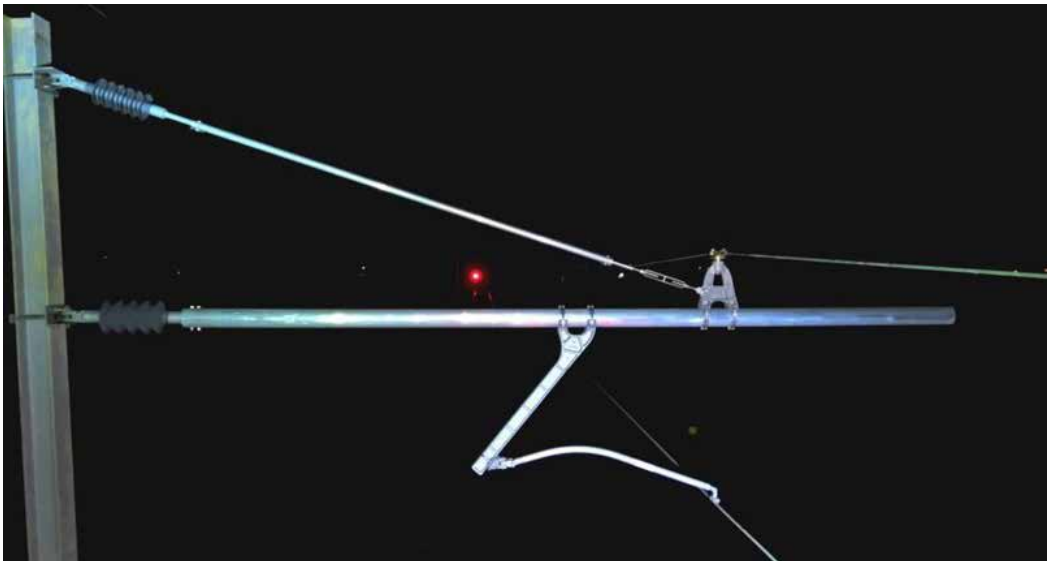
The additional benefit gained from Hesop is that, by optimising the electrical power system, the distance between traction substations can be increased and, potentially, their number reduced by 20 per cent. This reduces the amount of infrastructure and hence construction required, providing a capital and lifecycle cost advantage as well as a safety benefit as less construction eliminates the associated health and safety risks.

For the urban environment another form of innovative electrification is the SRS system. Building on 15 years of expertise acquired developing APS 'third rail style' technology, Alstom extends its feeding systems portfolio with SRS, a conductive ground-based static charging system for trams or electric buses equipped with on-board energy storage.

SRS is a technological breakthrough in electric public transport, enabling city authorities to operate clean, quiet electric fleets eliminating the need for catenary masts and overhead lines. This is an added advantage for cities with exceptional architectural heritage or constraints such as narrow streets or bridges, where overhead infrastructure is unsuitable or unfeasible. The charging system can be used at stops while passengers board and leave the train and also at line terminuses, in particular for electric buses which can fully recharge in the space of a few minutes.

Alstom is a company that truly delivers 'mobility by nature', a leading global player in sustainable and smart mobility. Alstom is investing in the UK, and through its electrification products and new traction systems like hydrogen, it stands ready to play its part in decarbonising Britain.

Steve Cox is Engineering & Technical Director SS&I at Alstom.

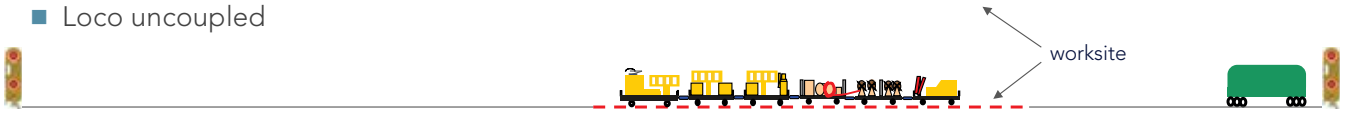


Wiring Train Methodology

ALSTOM

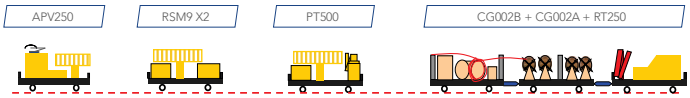
- Arrival into possession

- Loco uncoupled



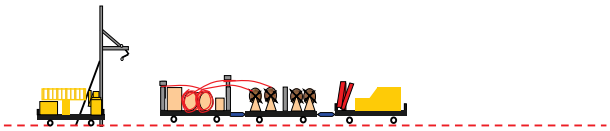
- Wiring train self propels to worksite

- Wiring train uncouples into sub systems and individual vehicles

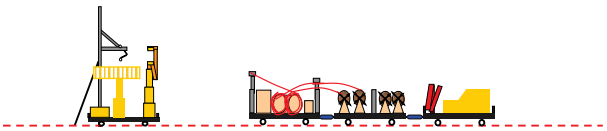


- Arrival at the anchor mast

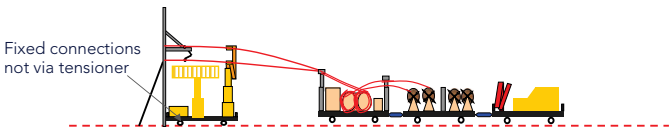
- Preparation to anchor



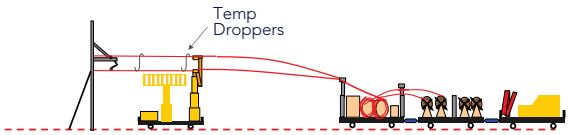
- Vehicle Setup at anchor mast



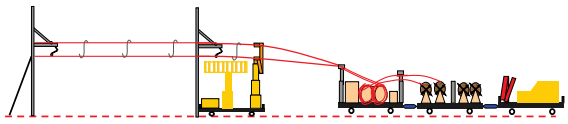
- Anchoring



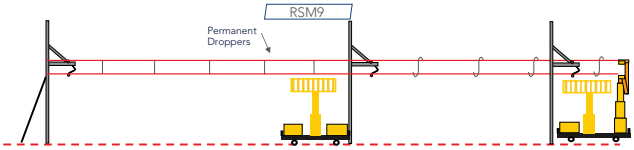
- Commence running wire



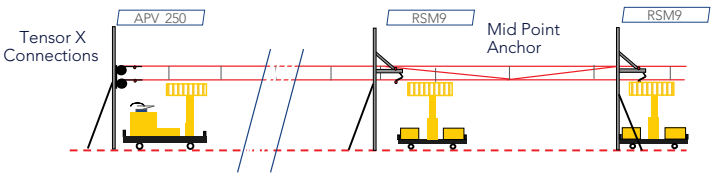
- Continuous Production



- Droppering activity



- Final Connection



Mid Point Installation

Anglia OLE renewals:
SUCCESS THROUGH COLLABORATION

CAROLINE BACHER

Since 2007, Network Rail has steadily been replacing the overhead line equipment (OLE) on the Great Eastern line from London Liverpool Street, first to Chelmsford and then on to Southend Victoria. The old system had reached the end of its lifespan was increasingly becoming a reliability issue.

A key goal for the project team was to reuse as much of the existing infrastructure as possible.

Working with OLE specialist Furrer+Frey, Network Rail developed a new, auto-tensioned, modern 25kV AC system that retained a vast number of existing steelwork structures in order to save costs, reduce risks and minimise disruption and impact on service. It also aimed to address known reliability and performance issues, and in such was tailored to the region and its specific challenges.

Upon completion of the new system's development, a rolling programme of electrification renewal was undertaken on this route and, after 10 years, is due to finish. Once some initial teething issues were ironed out on the first few sections, both design and installation went smoothly and without major drawbacks as the teams grew closer together and the supply chain worked well on all levels. Furrer+Frey and the Network Rail in-house installation team OCR were working hand-in-hand to deliver the renewals without major impact on the service.

Moving on to Thameside

With the Great Eastern largely complete, Network Rail has now started to plan the next phase of this programme, renewing the OLE on the Thameside route out of London Fenchurch Street, the line that was previously known as LTS (London - Tilbury - Southend).

Like the Great Eastern, the first sections of Thameside were initially electrified with DC equipment in the 1940s. This was further extended in the 1960s at 6.25kV, before finally being converted to the more common 25kV AC in the 1980s. As with Great Eastern, the initial DC sections were installed using fixed tension equipment, meaning that there are no balance weights or tensioning devices to keep overhead wires taught and instead wires are fixed at a specific tension. This means that, on hot days, wires can sag requiring speed restrictions to be put in place.

Since the Thameside system was mainly installed in the 1960s, reliability had fallen over time and service disruptions had become more common. The route has been installed primarily with Mk1 equipment, which is an early UK electrification system, thus the current project has become known as the Mk1 Renewals project. Due to the age of this Mk1 equipment and its inherent reliability issues, there is an increased maintenance cost associated with this life-expired equipment.

Once again, Network Rail decided to renew the electrification equipment but retain the structures wherever possible, to minimise costs and possession requirements.

At the end of 2018, Furrer+Frey won the contract to be the lead designer on this project. This move makes it possible to replicate the success of the Great Eastern project, continuing the successful and collaborative working relationship between Network Rail and Furrer+Frey and bringing all their relevant experience and expertise forward to the new project.

This consistency is also maintained on an individual level, as many staff members from the Great Eastern project teams have now moved across to the Mk1 Renewals project, both within Furrer+Frey and Network Rail, as well as Network Rail's long-term partner CPMS, project manager for the works, and the in-house installation team OCR. Finally, Furrer+Frey is once again supported by OLE Ltd, another carry-over from the Great Eastern.

The collaborative spirit of the teams working together to deliver the project is ensured by a number of contractual elements to which all parties are committed. These include progressive design reviews, as an informal means to align and manage expectations, and a series of collaboration workshops to define behaviour and communication rules and address any issues outside the technical core of the project.

Caroline Bacher is head of UK projects with Furrer+Frey.

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Safer, quicker and sustainable CABLE PROTECTION

As the world, and the railway, goes more and more digital, the big growth industry seems to have been in the production of cable. Offices are festooned with cables linking computers, servers, storage devices, alarms, CCTV cameras, printers, scanners and a host of other devices. Every desk has the potential to have a 'rat's nest' of cables lurking underneath it.

Homes are no different. To the cables linking computers, routers, printers and scanners can be added the ones to TV sets, control boxes, recorders, speakers, CD players and satellite dishes.

One solution to this is, of course, to make as much as possible wireless. Many devices now use Wi-Fi, Bluetooth or infra-red technology to get rid of those annoying cables.

Cable protection

The railway has the same problem. Some wireless technology is creeping in, but there is no solution to the need for power cables - both traction and signalling power - as they cannot be replaced. Communications cables, for signalling control and other functions, are often also needed for security and reliability reasons.

So, the side of the railway starts to look like the side of an office desk - cables, cables and yet more cables.

These cables need protecting. Traditional methods see ground-based cable troughing used. However, where there isn't a clear walkway alongside, the trough lids are often walked upon. If the route is not of designated walkway width, this practice can be rather unsafe and, with slips, trips and falls maintaining their number-one spot in workplace incidents, it's a risk that needs to be reduced.

And, of course, the manual handling of cable troughing has to be carried out safely and within prescribed weight limits. Solutions to improve this element of the project are very welcome.

There are two solutions to these problems. The first is to make the troughs from lightweight polymer materials - several different solutions now available.

The second is to elevate the trough above the ground on posts. Then, no matter the angle of the side of the embankment or cutting, the trough is safely above it all. It also can't be walked on - another plus - and

presents cables for maintenance at waist height, making things simpler for the maintainer.

Network Rail prohibited the manual handling of metre-length C/1/43 ground-based concrete troughing units in 2014. Since then, the industry has kept a very strict eye on the installation of cable troughing and any methods introduced to reduce the risk to workforces were, and still are, very welcome. With this in mind, Scott Parnell worked in partnership with Complete Composite Solutions to introduce the UK to a revolutionary product which was already leading the way across Europe with full approval by Deutsche Bahn.

Innovative system

ArcoSystem is the only elevated troughing system in the UK which can span six metres between post centres. Already fully approved by Network Rail, the product offers a reduction in hole centres (versus traditional elevated systems) of up to 75 per cent. This saves workforces from the process of digging out foundations, mixing postmix and water, and installing the posts every 1.5 to 2 metres, as is the case with traditional systems. With this reduction in post centres, there is also a decrease in the risk of cable strike, which can occur during any ground penetrating installation.

The ArcoSystem troughs are made from a lightweight, pultruded, twin wall fibre-reinforced polymer (FRP), which provides the strength to support each length over six metres. In addition to this, it means the overall weight of each six-metre length is under 36kg, making them safe for two people to lift easily.

The reduction in post centres not only protects workforces, but also decreases installation time by up to 60 per cent. As possession times get more and more congested, with more contractors having to share track time, this saving is invaluable.

ArcoSystem not only works well as a foundation-installed elevated route, it also interfaces seamlessly with the complicated rail infrastructure. Transitioning from ground-based troughing up to an elevated route then back to a wall mounted system is easy. Alternatively, it also works perfectly for a suspended route by utilising handrails on one of the many walkway systems. The system should be hung on the outer edge of the handrail to prevent the safe walking area being reduced in size.

Should the standard range of ArcoSystem not be suitable for certain areas, Scott Parnell will work closely with project designers, engineers and construction teams to develop bespoke units to fit, no matter what the infrastructure is that's presented to them - versatility at its best!

ArcoSystem has now been present in the UK's rail sector for three and a half years and has been used on some major schemes, from Crossrail Anglia and Weaver Wavertree resignalling to, more recently, HS2 enabling works at Euston. In such a short space of time, it has become a popular choice amongst contractors with over 125km of route now installed on the UK's railway network.

Safer installation

Although Scott Parnell has seen ArcoSystem go from strength to strength, the company has certainly not just sat back and rested on its laurels. It has also worked on creating an installation technique which was even safer for workforces to implement. Following an overview of the entire installation process, Scott Parnell identified areas for improvement and enhanced these accordingly.

ArcoSystem offers a vast reduction in manual handling by reducing the number of holes installers need to dig into the ground for post foundations. As the six-metre distance between post centres cannot be expanded, the maximum saving in manual handling is achieved. Furthermore, it is not possible to reduce the weight in the system components without affecting the integrity of the product. Scott Parnell will never compromise on quality, and therefore it was realised that improvements were possible and would be made. Stand by for the innovation of the year... »

For each post foundation which is embedded into the ground, approximately 60kg of postmix is used, along with around 20 litres of water to mix it. This process, which has not changed since elevated troughing was first introduced into the rail sector, is one which is almost always done manually, without the aid of machinery. It therefore has a considerable musculoskeletal impact on the installation teams, especially those gangs installing troughing systems shift after shift, project after project.

Introducing Techno-Crete

To combat this problem, Scott Parnell has introduced Techno-Crete, a new product that provides an innovative solution by replacing the need for both postmix and the associated water, around 80kg of product, with just 1.6kg!

To put this into perspective:

» 1km of traditional two-metre span troughing requires 30 tonnes of postmix;
» 1km of ArcoSystem six-metre span troughing, with only one third the number of posts, takes 10 tonnes of postmix;
» 1km of ArcoSystem six-metre span troughing, installed with Techno-Crete, needs just 267kg of Techno-Crete.

Techno-Crete is revolutionary in the reduction of manual handling, but the benefits of this innovative product do not end there. With a curing time of just 20 minutes, Techno-Crete can decrease the installation time of ArcoSystem even further.

Where postmix has traditionally had a curing time of 24 hours, this has meant installation teams have had to plan work carefully and revisit site again to install the trough route onto the posts once the postmix has set. However, one recent installation using ArcoSystem with Techno-Crete resulted in 22 metres of route being installed within just four hours - all while workers were being suspended from ropes down a steep embankment!

Techno-Crete also has sustainable benefits. It is manufactured using 85 per cent recycled and sustainably sourced vegetable and rapeseed oils. This is a key advantage as CP6 begins, which has the toughest sustainability targets the sector has ever seen.

The CO_2 saving compared to postmix is over 70 per cent - approximately 10kg of CO_2 per post foundation. Just 100 foundations using traditional postmix would require six tonnes of concrete to be used. Also, at the end of its life, Techno-Crete can be crushed and fully recycled into products such as precast concrete.

Techno-Crete is delivered to site in a two-part set - 'Bag A' and 'Bag B'. When the foundation is ready, the two bags are opened and one poured into the other. A vigorous shake will mix the two components together and then the mixture is poured into the ground. Within 10 minutes, the product will expand to twenty times its original size and within twenty minutes the mix will have set. Health and Safety protocols are no different to that for the application of postmix, and transportation and storage costs are both dramatically reduced.

Scott Parnell's new Techno-Crete is also ideal when used as a foundation for a variety of railway systems, from handrails to fencing and DIS boxes. Anywhere postmix can be applied, Techno-Crete can be used as an alternative.

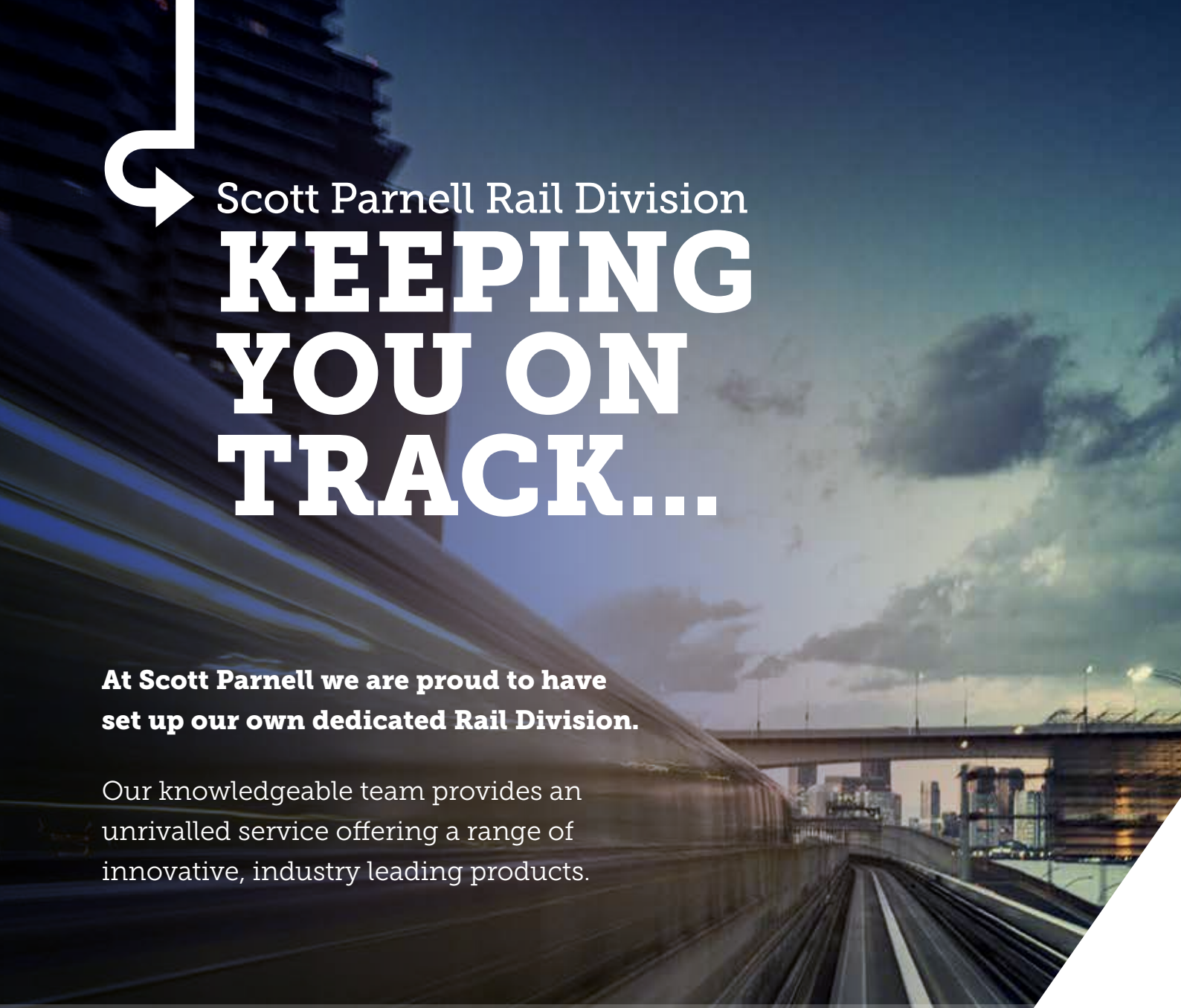
Innovative supply

Sharon Rice, national rail manager at Scott Parnell, said: "The UK's rail industry has been aware of the implications that manual handling has on its troughing installation teams for some time and huge progress has been made to improve this. At Scott Parnell, we have worked tirelessly to make sure we do our best to support this movement. For example, we were one of the first to provide six-metre length GRP troughs which sit comfortably within safe weight limits for two people, reducing not only the weight, but number of lifts required during installation.

"With the introduction of Techno-Crete, we are taking things one step further by eliminating the need for three 20kg bags of postmix, which are currently required to install each individual post. Posts are often positioned in difficult to reach locations meaning that postmix, and the large water quantities needed to mix it, causes a huge manual strain on workforces and often requires a costly RRV to get it to the installation point. One box of Techno-Crete weighs far less than a single bag of postmix, meaning that one person can easily carry the material for up to 12 foundations in a single lift.

"With all this in mind, Techno-Crete has the potential to make a real difference to the rail sector and the way construction and improvements are carried out. In particular, the reduction in time to complete projects and the resulting safety benefits of quicker installation and manual handling makes it ideal for possessions".

With innovations such as this, it is clear to see why Scott Parnell is the supplier of choice for the rail industry.



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GRAEME BICKERDIKE

Better by design

Major projects, new trains, bewildering technology: these are the big-ticket items that command everyone's attention these days. And why wouldn't they? Who cares about the high-volume, low-cost bits and pieces that literally hold the railway together? Nuts, bolts, pins, clips, arms, brackets…

Politicians don't cut ribbons at the installation of a cable cleat, but they might - conceivably - have to explain the havoc wreaked by one failing following an electrical big bang. A single dodgy component can inflict disruption and embarrassment that's wholly disproportionate to its size and cost, by a very significant factor.

With this in mind - as the magazine's unofficial Analogue Correspondent (my heart was hewn from the earth by Victorian navvies) - I was despatched to Rillington in North Yorkshire to visit a company that's been keeping cables in check for almost 60 years. In parts, the experience proved surprisingly digital.

Basic principles

In case you're unfamiliar with the term, a 'cleat' is used to secure electrical cables to a structure by installing them at intervals along the cables' length. What could be simpler? But there are a number of factors affecting its ability to fulfil that role safely and effectively, including environmental conditions, the materials used, performance in the case of fire or impact, resistance to corrosion and the cleat's strength.

The latter is often determined using a mechanical tensile test; however, the results can

Ellis cleats in the London Power Tunnels.

Installing Ellis brackets in the Severn Tunnel.

prove misleading as the force is applied in a slow, controlled manner. The electromagnetic forces in short-circuit conditions act almost instantaneously and oscillate in every direction, sometimes with destructive consequences. A cleat is most likely to fail at peak current, about 0.01 seconds after the event starts; a breaker won't have woken up by then.

So, the only reliable way of demonstrating that a cleat will withstand the resulting forces is to also conduct a short-circuit test - International Standard IEC 61914 provides a formula for calculating those forces between two conductors in a three-phase supply. Potentially, they can amount to several tonnes.

Restraining cables during a fault is a fundamental role of the cleat; it's a means of protection as well as support. In order to withstand the applied forces, the optimum spacing between each cleat can be determined using a formula which takes account of the required loop strength and peak short-circuit current.

Potted history

None of this is news to the specialist team at Ellis - formerly Ellis Patents - which boasts a skilled workforce of around 60, mostly residing in the towns and villages around Rillington. The firm was founded by Arthur Ellis, who piloted more than 90 bombing missions for the RAF during the Second World War.

Back on civvy street, he trained as a plumber and set about manufacturing plastic pipe clips and cable clamps, with electricity boards as his major customers. That was 1962; today the firm has an annual turnover of around £7 million.

The operation moved to its current site in 1974, about a mile from the York-Scarborough line. Unfortunately, the village station had closed 44 years earlier. Following Arthur's retirement in 1987, the company was acquired by Chris Calvert - its current chairman - and fellow investors from Walkern Victoria Industries. It acquired EDL Cable Supports in 2002 and has since become a global force, offering one of the most comprehensive catalogues of cleats, clamps, hangers and associated peripherals to international clients and projects.

As you walk around, you get the sense of an open, collaborative culture and an engaged workforce. Innovation is encouraged and facilitated through ongoing - and sometimes speculative - investment in new kit. This is not a company that's resting on its laurels, but neither are staff being driven to distraction. Managing director Richard Shaw tells me they are encouraged to go home at the appointed time and not check their emails. One culprit habitually ignores the edict whilst another recycles redundant equipment to assist with his construction of a traction engine! This seems a happy place.

Vertical integration

Unlike many competitors, Ellis is fully resourced in-house - not only designing its own products, but also building CAD models and subjecting them to finite element analysis. "This tells us where a component will break and under what force", says Richard. "Then we can 3D-print it.

"We know the printed model is about 40 per cent of the strength of the real thing due to the difference in plastics so - when we test it - if it comes out at 40 per cent of the figure we were expecting, we know we're on the right track. We can do all that work without ever »

Production of Centaur cleats.

(Above) Emperor cleats.

(Right) Production tooling manufactured by Ellis.

making anything, but it gives us the exact volume of materials needed, how long it will take to manufacture and the price."

Beyond that, Ellis' capabilities extend to prototyping and tooling for die-cast and injection moulding. This creates enormous flexibility and an inventive mindset: when a client comes with a problem, ways and means are readily available to develop custom-made solutions.

Through the 37 miles of tunnel on High Speed 1, there's an Ellis cable cleat every 600mm. When the consulting engineer first approached the company during construction, he told them he needed 70,000 bespoke aluminium cleats in 12 weeks. They were designed, tested and delivered on time.

Ellis products are deeply embedded on the London Underground and Hong Kong Metro; they also formed part of the design for the recent installation of overhead line equipment through the Severn Tunnel. Thousands of its Centaur cleats can be found in the London Power Tunnels - extending for 20 miles under the capital - as part of the firm's biggest ever order, worth £1.5 million. And the UK's Astute-class nuclear-powered submarines also feature its products.

Attention to detail

As we know, though, the railway is different; visit most of our classic tunnels and you're unlikely to see many cleats. Instead, the approach taken since the advent of power, telecoms and signalling was to place the associated cables on hangers, fixed to the sidewall. It's quick and makes life easy. But even here, there's scope for improvement.

Stephen Walton, Ellis' technical director, revealed: "We've reworked the traditional pressed-steel hanger to be stronger and safer by adopting a curved profile; they use less material so the shipping costs are cheaper. We've also developed polymer hangers which are lighter-weight, offer more insulation resistance and will never corrode.

"A lot of what we're doing is about making the products easier to carry and improve speed of install, responding to the needs of the contractors we're increasingly working with."

When legacy hangers become life-expired, Ellis has a modular retrofit system which can be secured in place without disturbing the existing cable system. There's a delightful simplicity and elegance about these products. I spent much of my chat time with Richard and Stephen fiddling with a stackable twist-to-fit no-bolts cleat, a unique device conceived in response to a Network Rail enquiry. The action had something very pleasing about it.

Inevitably, there is a procurement challenge here. Ellis' polymeric products are more expensive than its metal variants, but being less heavy improves installation efficiency - a big issue for the rail industry given the scarcity of possession time - whilst their longevity means that whole-life costs are lower. Cleats can be supplied pre-assembled with the requisite fixings - pushing up the initial purchase price but delivering benefits that reduce costs overall. Until we get our heads around these issues and learn to buy smarter, better products and lower expenditure will elude us.

All that glitters…

2019 represents another busy year for Ellis as it continues to grow the business. It has much to offer the rail sector through a sharp focus on innovation, responsiveness and value. Of course, its competitors would say the same thing - they have similar brochures, product ranges and part numbers. "Their 'innovation' is copying us," Richard reflects ruefully.

It's indicative of the company's position in this market that others closely follow Ellis' lead. However, whilst imitation is often flattering, it rarely compares favourably with the original.

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Sustainability and Decarbonisation

What are transformer losses?

NEVILLE HAIDE

London Bridge REB.

It is a good question, and one that needs to be answered and better understood by a wider audience within the rail industry. The perpetual transformation of electrical energy into thermal energy is seen within a transformer's two main loss components. The off-load standby losses derive from reversing magnetisation and eddy-currents within the core. These losses can be reduced heavily with the quality of core material and designed levels of flux density.

The on-load losses are, in the main, generated from the ohmic resistance of the transformer's nonferrous windings under load and can similarly be reduced with good design practices. A transformer's core loss can be compared to an electric heater, guzzling electrical power continuously and so transforming electrical energy into wasted thermal energy. With a transformer, this also happens in a standby state, with no inductive or resistive loading present. A 60 per cent reduction in standby power losses is easily achievable and has been demonstrated as being commercially viable.

It should be noted this is not a great discovery, nor some revolutionary new technology. Rather, it is the adoption of efficiency-conscious design methodology. In the case of a points drive transformer rectifier, energy is being thrown to the wind even when the points are not moving, so why are we still deploying low-efficiency magnetics into these systems and other power distribution networks?

The UK must hit a CO_2e (carbon dioxide equivalent) reduction target of 38 per cent by 2030. This, in part, can be achieved with the enhancement of standards and legislative requirements to the supply chain and system designers.

Traction power demand annually is around 3,400GWh alone, taking into consideration a highly saturated legacy network of mainly low-efficiency magnetics.

Studies show that at least three per cent of the power generated in the UK is wasted energy from the losses in transformers.

To put this into context, around 102GW of traction power could be attributed to the wasted energy of its associated magnetics. This is the equivalent of unplugging the domestic supply to around 30,000 homes in the UK for a whole year.

Decarbonisation schemes focus heavily on the development of new technology to support a reduction in future carbon emissions. High-efficiency solutions already exist, but they are not being considered by a large majority of regional projects. Why is this? Is there a lack of understanding of the technology, a culture of 'copy and paste' engineering or the age-old commercial driver to satisfy a project at the lowest possible cost?

Either way, selection of the cheapest or oldest products available for an electrical system do so to the detriment of that system's whole life efficiency. Whole life cost assessments favouring high-efficiency equipment demonstrate unarguable carbon reduction and energy savings.

Despite this data, competitive tendering governed by awarding bodies and the flexibility of standards continue to drive the use of high carbon output solutions. Industry leaders who rethink the selection of products for the power networks with an Archimedean point view of a systems efficiency, environmental impact, and whole life cost can make significant changes for the future.

Top-level commitment in CP6 by route asset managers, principal designers and those organisations that demonstrate best practice in the development and/or deployment of low-carbon solutions can align together to deliver a strong, traction-carbon reduction framework for CP6 and beyond. Significant carbon reduction and energy savings over the life of a power distribution system, while safeguarding the environment for future generations, are attainable if we consider the 'low hanging fruit' solutions and technology already available to us.

The world we leave for our future generations must not be one heavily harvested of its depleting earth reserves when widely available alternatives exist. Alternative sustainable solutions for electrical conductors need also be deployed and not just seen to be discussed.

Bauxite, the ore used to produce aluminium, is the most abundant ore on our planet, yet we continue to harvest depleting copper reserves that some environmental analysts predict, with a growth in demand of just two per cent, will be commercially exhausted within the next 25 years.

A coherent policy is needed that considers, where practical, high-efficiency products, and those with advancements in the application of alternative sustainable materials. These should be adopted by all responsible manufacturers, system designers, and project delivery institutions if we collectively are to meet our environmental obligations and targets.

Neville D Haide is managing director of ATL Transformers.

Advanced magnetics supporting industry

GARY TAYLOR

» Siemens adopted the ATL Transformer 'aluminium' range for its new Westlock WESTRACE Trackside System (WTS) as that move aligned with the copper-reduction strategy championed by Network Rail. The aluminium range also provided CDM benefits with significant weight savings and an increase in reliability.

The team at ATL Transformers worked closely with the Siemens WTS team in developing the new range of products, which was first adopted as part of the Thameslink London Bridge Area Partnership Scheme, completed in 2018.

Following the Thameslink scheme, ATL transformers and transformer rectifiers have been adopted on all WTS schemes that Siemens have commissioned, including on Weaver to Wavertree, Liverpool Lime Street, Derby remodelling, Victoria 2B and Huddersfield to Bradford Resignalling.

Following these numerous commissionings, there have been no in-service failures of the ATL transformers, demonstrating how reliable this new product has been.

Gary Taylor CEng MIET, engineering manager - power engineering, Siemens Mobility.

ISTVAN BAZSINKA

» ATL Transformers, as a product and as a company is indeed fantastic. I first came across their low-inrush transformer range during the development phase of 4LM (4 Lines Modernisation - the resignalling of London Underground's sub-surface lines) Wayside LVAC power supply design.

We were in need of finding a working solution to our individual radio power supply inrush-current problem and the inrush limiters on the market just did not do the job - either they were not in range or their RAMS (reliability, availability, maintainability and safety) figures were too low. As hundreds of these are powered from the same network, their x16 inrush has created a rather big problem for protection settings and discrimination.

ATL proposed its unique range of transformers which have helped to eliminate the problem with the excellent 1.96x FLC figure. The company's knowledge and support throughout the project were spot on, its factory testing facility and scheduling flexibility helped save the day and, with our combined effort, we were able to provide a leaner design without the need of any individual inrush limiters.

If a similar situation would occur on any other projects of mine, I would not hesitate to contact them immediately as the very first company in mind.

Istvan Bazsinka CEng MIET, project design authority, Thales.

A KNOWLEDGEABLE AND SUPPORTIVE SUPPLIER

ABDUL REHMAN SAVANT

Throughout the large portfolio of rail engineering projects that we have worked on or are presently working on at Amey Consulting, we have built very good relationships with suppliers and manufacturers that support us in the specification and selection of innovative products and technology.

In the world of electrical power on the UK railway, Amey Consulting has successfully designed and commissioned several signalling power upgrades for reliability, resilience and enhancements. As part of this success, and the present work bank we have, we work very closely with ATL Transformer's rail segment.

ATL has been very supportive in providing Amey Consulting with product solutions to support its energy management targets and global sustainability goals, in particular 'Goal 9' and 'Goal 13', which are 'Industry, Innovation and Infrastructure' and 'Climate Action' respectively. The design work Amey Consulting E&P has produced for signalling power projects include the use of ATL's Rail Signal Transformers and PSP/ASP Transformers.

The new generation of eco-rail® transformers, that have been made available to us from ATL, have characteristics that contribute to the safeguarding of the environment as they are ultra-high efficiency, reducing the carbon emissions and environmental impact. These transformers also present low standby losses which support the reduction in wasted energy.

The latest aluminium range not only supports copper elimination, a major sustainability target, but it also offers a 30 per cent reduction in cost and weight, making the transformers easier to transport and install on projects being designed by Amey Consulting.

As part of our product research and specification of electrical power products, Amey Consulting has attended several CPD (Continuous Professional Development) sessions and exhibitions to support the personal development of staff and the business. ATL's Neville Haide has been a great supporter of this, delivering sessions at our offices and practical sessions on hassle-free installation solutions at exhibitions.

West Hampstead Principal Supply Point.

Amey Consulting has been one of the first E&P design consultants in the UK to design and implement a signalling power distribution system using the new ATL slim, aluminium, lightweight supply transformers located inside principal supply points, resulting in a reduced footprint.

ATL has worked with Amey Consulting, manufacturing bespoke solutions to provide a 'plug and play' system, as required by the client. It has been a pleasure to work with such a knowledgeable supplier that gives the time and effort to ensure they meet their customer's requirements.

As the rail industry has a history of lengthy processes when seeking product approvals for newly innovated solutions, this did not deter the collaboration between Amey Consulting and ATL as both organisations have built a reputation and trust within the industry and approvals was the least of our concerns.

Amey Consulting has several objectives, one of which is a sustainable growth of the business. This objective is related to employee development. In addition to all of the CPD and technical support we have had from ATL, we are also looking at the ATL Training Academy for our apprentices, trainees, graduates and experienced engineers. ⬢

Abdul Rehman Savant CEng MIET is a senior electrical engineer (E&P Design CRE) with Amey Consulting.


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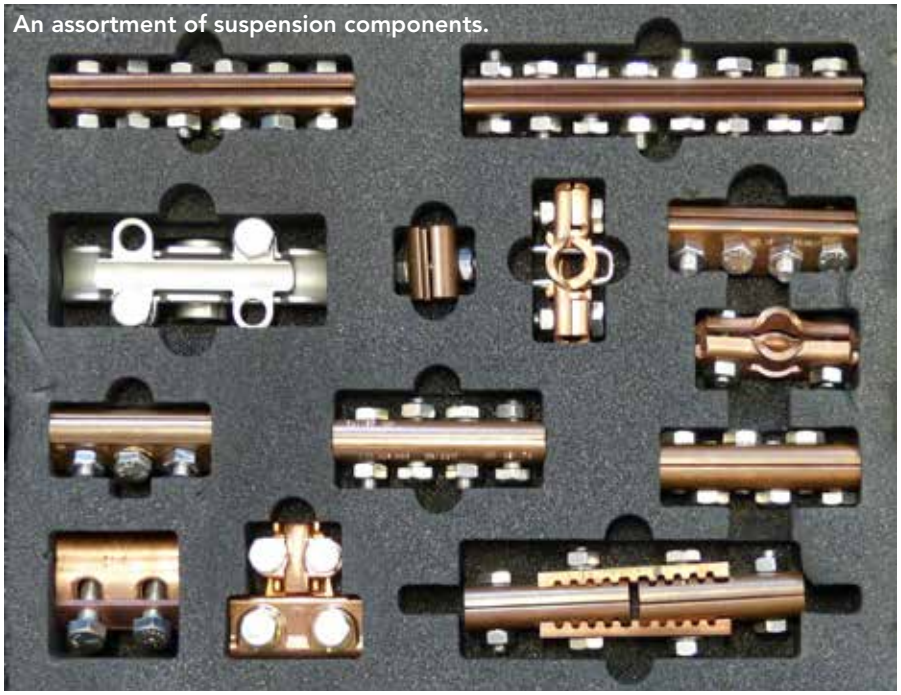

An assortment of suspension components.

MALCOM DOBELL

Take a look at a typical section of overhead line equipment (OLE) and you will see a mass of wires, masts and crossbeams. But, look a little closer, and you will see all the other pieces that actually bind it all together. They reinforce this mechanical engineer's view that electrification is simply mechanical engineering, but with more copper than usual!

What do you do when you need to terminate one end of a 25kV conductor wire? You connect it to conical coupling or a forked collar socket, of course. You want to support the wire? Use cable dropper clamps with one of a variety of cable dropper solutions using straps or wire.

Your writer learned all about this and a lot more when talking to Paul Culnane, who has been managing director of Arthur Flury (UK) for the last nine years.

Arthur Flury AG is a Swiss company that is 99 years old, based in Deitingen, roughly halfway between Bern and Zurich. It manufactures and supplies precision OLE components for railways, metros and trams to over 40 countries around the world. The UK subsidiary is based in Milton Keynes, a convenient location to access the majority of the country; something your writer can confirm.

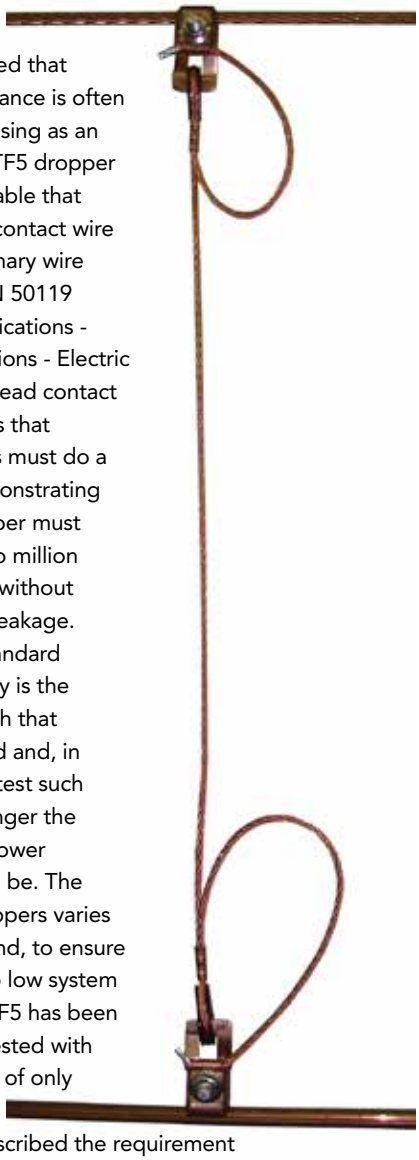
For someone not familiar with the components of OLE, it was a surprise to see how substantial some of the components are. Simple devices such as clamps to splice two wires together can easily weigh over a kilogramme, since the mass of contact wire, catenary wire and all the components to connect and support them is significant.

Paul explained that the component parts his company supplies are, largely, conservatively designed and many customers have been installing the same reliable products on jobs for decades against these trusted specifications; confidence and dependability is everything.

Arthur Flury's main customer in the UK, Network Rail (and contractors working on its behalf) has specified these parts in all the OLE designs it uses, be it from the OLEMI (Overhead Line Equipment Master Index), series 1 or series 2. This involves compliance with international standards and having been through Network Rail's rigorous product acceptance process.

Droppers

Paul explained that simple compliance is often not enough, using as an example the TF5 dropper (the vertical cable that supports the contact wire from the catenary wire (pictured)). EN 50119 - Railway applications - Fixed installations - Electric traction overhead contact lines - requires that manufacturers must do a type test demonstrating that the dropper must survive for two million flexing cycles without damage or breakage.



What the standard doesn't specify is the dropper length that has to be used and, in a mechanical test such as this, the longer the dropper, the lower the strains will be. The length of droppers varies significantly and, to ensure compliance to low system heights, the TF5 has been successfully tested with a short length of only 350mm.

Paul also described the requirement for a pull-off force of the dropper wire from its clamp of 3kN. In the real world, »

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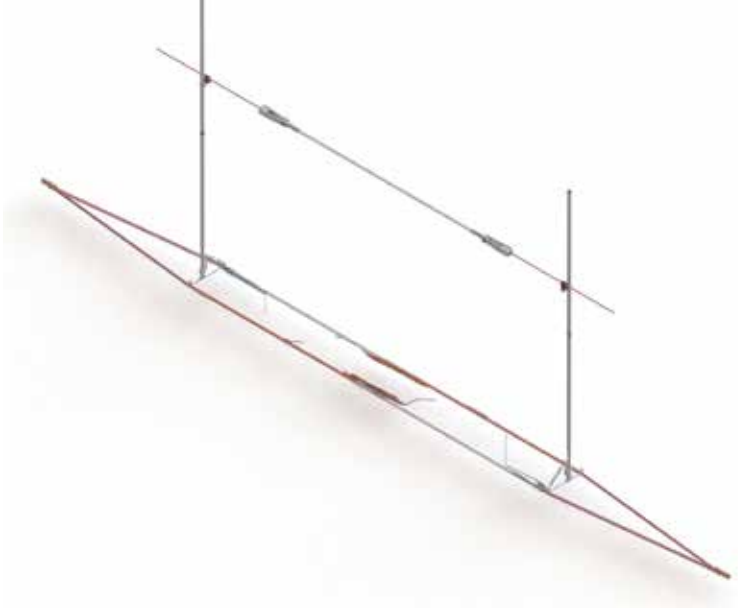


(Right) HI25 section insulator.

however, the vertical force on the clamp is only one of the forces at play, and the design illustrated shows how strain is minimised on the clamps.

Materials

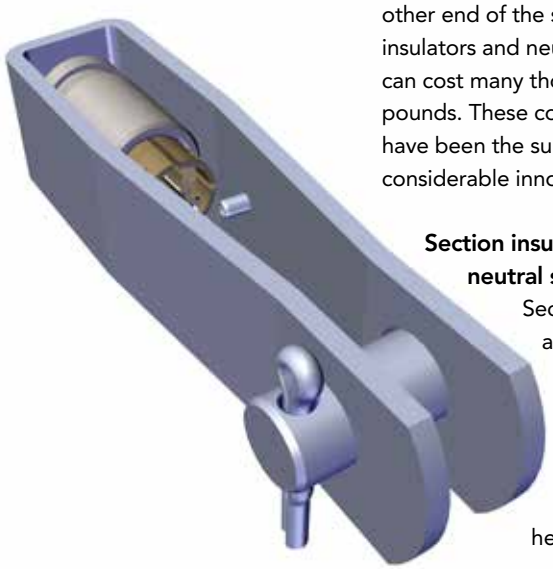
The conversation turned to materials. OLE, couplers and clamps all need to have strength and good electrical conductivity, and Arthur Flury specialises in copper-nickel-silicon (CuNiSi) alloy; the detailed composition and manufacturing process of which is a closely guarded secret. This material allows appropriate clamping forces whilst conductivity is a little different to copper.

Of course, it's not just the manufacture of the alloy that needs to be considered, but the right choice of manufacturing process for the component. For example, components required to have good tensile strength are not good candidates for casting, even though the manufacturing process is fairly inexpensive. Cold forming - as perfected by Arthur Flury - offers much better manufacturing tolerances and product performance, but also requires a greater investment in manufacturing equipment and a more highly skilled workforce.

Clamps, splices, couplers and droppers are comparatively inexpensive components, bought in the hundreds or thousands. However, at the other end of the scale, section insulators and neutral sections can cost many thousands of pounds. These components have been the subject of some considerable innovation.

(Below) A CuNiSi conical coupler used to connect two catenary wires. The wire of the correct size is pushed in from each side and cannot be pulled out.

(Below) A stainless steel forked collar used to connect a contact wire or catenary wire to a structure or insulator.



Section insulators and neutral sections

Section insulators and neutral sections have traditionally been comparatively heavy components and can impede pantograph movement.

Consider a pantograph moving along a plain contact wire. The upward force of the pantograph is balanced by the resisting force of the wire, generated partly by its mass and partly by its tension. A section insulator is many times the mass of plain wire and the pantograph sees this as a significant and sudden increase in resisting force. This is also true of neutral sections.

Arthur Flury has developed solutions that are both lighter and use spring droppers to minimise the impact of these devices on the passage of pantographs. The newest version of a neutral section uses in-line insulators on which the pantograph bears, which are significantly lighter than the more traditional designs.

Paul mentioned that the design of the neutral sections and section isolators was iterative, as accurate vertical forces imparted by the pantographs could only be obtained from prototype trials and were found to be significantly higher than the original estimate.

Logistics

The conversation turned to the process of obtaining the right parts. As a matter of course, Arthur Flury has accreditation to ISO 9001, 14001 and 18001, for quality, environment and occupational safety respectively, and maintains a list of its parts cross referenced to the part numbers for the various OLE series and the Network Rail Product Acceptance Numbers.

As is normal for manufacturers of specialised but standard components, a significant pre-sales task is to advise clients - usually designers - on which of many options is best for a particular application; for example - is a forked collar socket or an eyelet collar socket best for "this" task?

This leads to orders that typically have six to eight week turnaround, although Paul did say that the company will always make its best efforts when faced with a genuine emergency.

There are weekly shipments from Switzerland to the various sites around the country. This prompted the inevitable question about Brexit, even though Switzerland is not in the European Union. Paul explained that there is a bilateral agreement between Switzerland and the UK to maintain tariff free trade and that international freight forwarders have identified the use of alternative ports, to mitigate any possible risk of delays at the France/UK border.

The final word goes to Paul: "From product specification, through component selection and finally to delivery, Arthur Flury is here to support our clients' needs and offer maximum customer satisfaction."

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RailStaff

Transformers
Aluminium or Copper?

PAUL WALKER

There is a drive on the rail infrastructure to reduce the overall cost of signalling power and other installations and increase electrical efficiency. One of the main tenants of this philosophy is the use of aluminium due to its low cost. As such there is also a drive to use transformers with aluminium windings to reduce costs further.

FT Power Transformers have taken on the challenge of producing aluminium transformers for trackside infrastructure in the 500VA to 100kVA range.

But is aluminium (Al) really so much better than the traditional copper (Cu)? Below is a base table of the pro and cons of both aluminium and copper transformers, based on both experience and research.

Issue	Aluminium	Copper
Oxidization	Aluminium oxidizes in air, producing aluminium oxide (Al_2O_3) which has a high electrical contact resistance.	Copper oxidizes in air, producing copper oxide (CuO) which is electrically conductive.
Galvanic action	Aluminium is the most anodic and thus loses material at copper or brass connections. Water condensation makes this worse.	Copper is the most cathodic. No effect due to galvanic action.
Weight	• Total transformer mass is almost the same • Total transformer volume increases slightly for Al. • Mass of core is increased by 5 to 20 per cent for aluminium over copper	
Useable Life	The life of a transformer is the life of its insulation. For Al this is the same as Cu. However, on the rail infrastructure it is dictated by the life of the terminations.	35-year life required by Network Rail Standards
Cost	Aluminium transformers are cheaper weight to weight but less efficient kVA to kVA	Copper prices are comparable to aluminium for trackside transformers
Eddy Currents	Eddy losses are reduced by approximately 38 per cent in the case of aluminium.	
Reliability: Creep Behaviour	Creep rates can be up to 25 times higher for aluminium than for copper under the extreme loading of the transformer	A copper wound distribution transformer has up to 25 times the life of an aluminium wound one in terms of its ability to withstand creep stresses. This is the case for transformers that are close to fully loaded
Inrush Current	Note that Aluminium transformers tend to have lower inrush currents due to their larger winding geometries, higher resistance with more turns and a smaller core for a given kVA. This essentially results in higher leakage impedance. To reduce inrush comparable to copper requires a larger transformer	Low inrush capability but with increased weight

Conclusions

These studies have led FT Transformers to believe that large aluminium power transformers have advantages over similarly sized copper units when it comes to cost and weight. The efficiency of the units is about the same.

However, small trackside units that are rarely maintained will, over the life of the installation, suffer from increasing levels of resistance due to aluminium oxide. This will be a future issue for current trackside transformers, particularly for signalling power units, and will show up as an insulation fault at the permanent insulation monitors (Bender units located with the Principle Power Supply buildings) for the signalling power class II IT feeders.

Regular inspection and maintenance will be required. However, once a signalling power feeder is commissioned, it is often not maintained until there is an issue.

Therefore, it is FT Transformers' opinion that the life of signalling power feeders will be greatly reduced using aluminium, increasing the whole life cost. ●

Paul Walker is a mechanical design engineer with FT Power Transformers.

Further Reading:

Edvard Csanyi - Aluminium vs. Copper: Conductors in Low Voltage Dry Type Transformers (Electrical Engineering Portal, October 2010)

Hans De Keulenaer - Reliability of Terminations: Copper vs Aluminium (Leonardo Energy, August 2018)

Ronaldo Bertoldi - Aluminium vs. copper conductors in transformer manufacture (EE Publishers, March 2017)

Tahir Ayub - Eliminating Copper, the next step (Rail Engineer, July 2017)

Powersmiths International Corp - Transformer Inrush Currents and Protection (Critical Power Group, June 2013)

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PETER STANTON

OLErt

Overhead Line and Pantograph Monitoring

In this digital age, railways are harvesting increasing volumes of data ('Big Data') on the performance of their assets but converting raw data into meaningful information remains a challenge for many organisations in the industry.

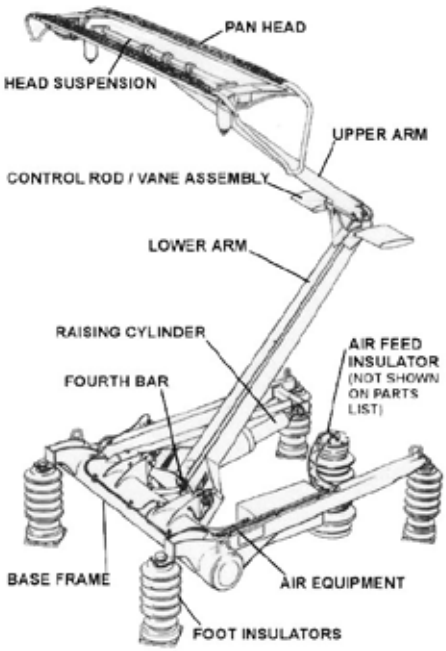
One example of a successful foray into the processing of 'Big Data' is in the area of electrification overhead line contact system performance. The technology application is helped by the introduction of cheap and small sensors, declining computing and data storage costs, new abilities to process and analyse data and ubiquitous connectivity. The coming together of these key enablers is driving the adoption of the Internet of Things in rail and, with it, demands for analytic applications to turn data into operational intelligence.

Rail Engineer was invited to the new traction maintenance depot at Reading to meet the team that has developed the OLErt monitoring system and hear of the advantages it can bring to the railway.

Critical interface

Whilst considerable attention is paid to the interface between wheel and rail, there is another mechanical moving interface between a train and the infrastructure - that between the pantograph and the contact wire. Whilst a failure of the wheel/rail interface can result in a very serious safety incident, a failure to maintain the connection between train and power supply can be operationally disastrous. There are also safety connotations in the case of failure.

For some time, there have been various methods of monitoring the electrification

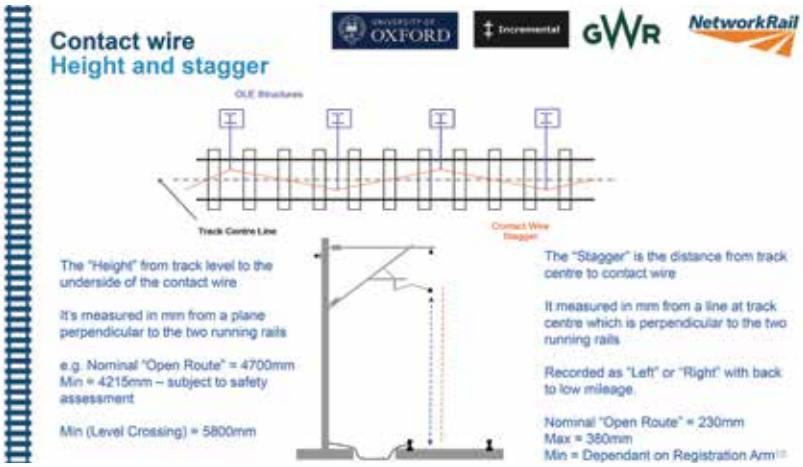


overhead contact system relationship, and processes to avoid that relationship being out of correspondence have been developed.

One major risk emerges if the extremity of the pantograph (the 'horn') becomes separated from the lateral position of the contact wire while that wire is still close to the pantograph. In that case, the contact wire may then get underneath the pantograph horn and either severely damage the pantograph or the contact wire and its associated overhead line equipment (OLE) may be torn down - or both.

Traditionally, stagger (the deliberate deviation of the contact wire from a central position to spread wear on the pantograph contact surface) of the contact wire has been monitored by observation from a train, such as the test car 'Mentor'. Instrumented processes have been used and the height and stagger of the wire may also be checked by patrolling and suitable equipment. Cameras have been mounted on train roofs for some time, but with little recovery of data by technology. More recent developments have involved bespoke equipment to monitor the contact system and the interface - this has not been a low cost or generic option.

The recent development of cameras being fitted to the roofs of modern electric trains has generated an opportunity to develop a more real time and wide-ranging monitoring process.



At present, the cameras provide useful output but, in reality, they only show the circumstances of an incident after it has occurred, such as the contact system/pantograph interface becoming non-compliant with unfortunate results. Using the data to improve performance required a system to identify potential problems and highlight them before an incident occurs.

These events have a high impact, with passenger and electric freight line closure as a minimum. They are also expensive, with each one costing Network Rail time and money for infrastructure repair and compensation to train operators. Despite receiving this compensation, the train operators would prefer better reliability and no disruption for passengers. »

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Understanding the data

So, data was required - Big Data in this modern world - to discover how the pantograph and contact wire interact and to detect any potential faults before they can cause trouble.

Network Rail is already receiving information from in-service trains on the condition of its track, and the wheel/rail interface, but it did not have a system for retrieving contact force data from the pantograph interface at over 100 mph.

Ideally, a pantograph will exert a constant upward force on the contact wire and a good maintenance regime will keep the carbon strip on the top of the pantograph - the point of contact between the train and the wire - in good condition.

With the Great Western electrification programme set to increase markedly both the number of trains running under the wires and the number of pantograph passes, the possibility of increased failures had to be taken seriously.

A consortium of interested parties came together to meet this challenge under the auspices of Network Rail. Software specialist Incremental, communications specialist Icomera, Great Western Railway (GWR) and the University of Oxford began a development project using a modern EMU and capturing data from the monitoring camera. The aim of this 'OLErt' project was to make the camera intelligent.

Team contributions

Incremental Solutions, a high-growth and relatively young company, has been exploiting the concept of 'intelligent mobility' in the rail industry to improve understanding of vehicle movements and to solve critical issues of performance, reliability and journey optimisation.

Its core aims are to assist in the creation of a connected transport network with a proactive approach to predicting and preventing, resulting in improved incident management, more accurate timetabling and, overall, operationally more efficient.

It does this by utilising best-in-class solutions, working with other innovators and liaising with academia. This creates opportunities for SMEs to scale up their ideas, promotes innovation and challenges the status quo.

Of the other contributors, the University of Oxford brought algorithms from its own research groups and Icomera contributed its expertise in wireless connectivity, while Network Rail and Great Western Railway integrated the projects activities. The group has now successfully completed the first phases of the project and, for that, has been voted 'highly commended' at the 2019 Rail Partnership Awards for Driving Efficiencies.

From the group came the inspiration to take the existing camera output from the train and to digitise it, producing a data stream that could continuously monitor the performance of the pantograph and its movement in line with the OLE contact wire. That data stream could then be analysed to extract changes in a normally consistent signature, so identifying potential incident sites.

In order to test the theory, Great Western Railway made available a class 387 electric multiple unit to which was fitted the pantograph monitoring camera. Following a calibration exercise to eliminate any lens distortion and ensure the pantograph was within height range, a network video recorder (NVR) was installed into the train roof-space. This was linked to the Ethernet backbone to enable a secure download of the recorded footage via Wi-Fi, removing risks associated with access to the train roof.

(Left) A Network Video Recorder was installed into the train roof space and was linked to the Ethernet backbone to enable a secure download of the recorded footage via Wi-Fi.
(Right) Two different styles of camera used in the trials.

Processing the data from the camera, utilising algorithms from the Oxford University research, supplied the proof of concept for the project. It was noted that the data from the widely fitted cameras on the fleets was encrypted, so special arrangements had to be made for the OLErt-related measurement camera on the chosen class 387.

In the realm of fixed equipment, a Wi-Fi network was installed in the East yard of Reading Train Care Depot. This included three access points onto the noise abatement wall to cover the stabling locations of the unit - plus the necessary network ancillaries.

A number of test sites were chosen as examples of differing environments, including high-speed running (over 100mph), increased contact-wire height over level crossings, neutral sections, tangential wires crossed at speed and a complex layout.

Results

The series of tests, and monitoring and processing of the outputs, revealed interesting data and proved the concept of the proposals. As stated earlier, the potential is for a mass of data which would not be capable of analysis, but the results passed through the Oxford algorithms allowed the 'signature' of the OLE to be observed and potential problem spots identified. In fact, during the trials, a location with a serious risk of dewirement was picked up and attended to as a matter of urgency.

A conclusion emerged that pantograph stress is more complex than thought - during the trials 51 different signalled patterns were achieved in the five geographical areas. Pantograph force assessment did show that the average pantograph force was compliant with that expected at speed and in service. Interestingly, concerns over dirt on the camera lens, which might have obscured the image, were addressed by application of a special film ensuring that, after four weeks testing, the image obtained was still good.

In summary, the OLErt system has usefully built on existing data acquisition, itself a recent development, and applied advanced methodology to harvest large amounts of data. It has then used algorithms supplied by academia to turn that 'Big Data' into a format that will allow individual sites with potential problems to be identified so they can be investigated before a significant operational or safety incident occurs.

This research will definitely benefit all partners in the operation of the railway and help enhance a continuing good service to customers.

Thanks to the OLErt team for explaining their work and its concepts - Paul Barnes and Dean Shaw (Network Rail), Daniel Lee-Bursnall (Incremental), Stephen Duncan (Oxford University), Rich Fisher and David Eveleigh (Great Western Railway).

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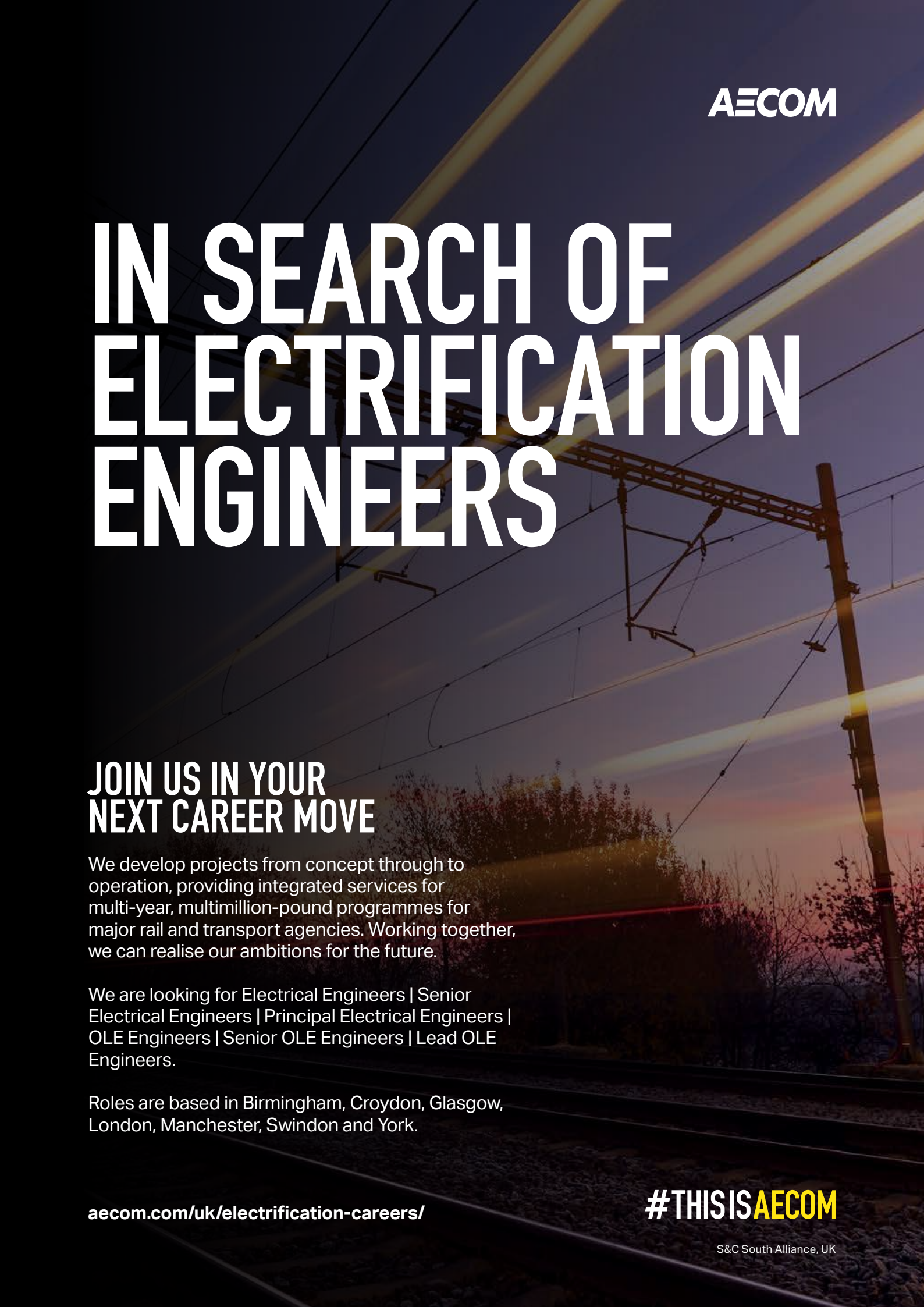
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