MEETING REVIEW
AUTOMATIC TRAIN OPERATION ON LONDON UNDERGROUND
by Piers Connor
A report of the LURS meeting at All Souls Club House on 8 January 2008

Piers introduced himself and stated that his talk was designed as a prelude to what he expected a future speaker to cover in a talk on ATO on the Northern Line, a talk postponed till a later date, and that this evening's talk was to cover how Automatic Train operation began on London Underground, the current situation, and what future developments may bring.

Basic Signalling: Piers explained that signalling was needed to protect the route ahead of the train and to prevent conflicts at junctions. The route in front of a train must be at least the stopping distance, because a train must be slowed down and stopped before it reaches whatever is in front of it, to avoid collisions. With the aid of a diagram, the audience was shown that the braking or stopping distance ends with the signal – as Piers was once told when being taught to drive trains: 'the signal is the border between your territory and that of the company, and the company doesn't like trespassers'. Before the train reaches the signal there must be enough distance in which to stop, and the length of this can be affected by the low rail adhesion, which gives about 10% of the adhesion enjoyed by a vehicle on a road surface. Low adhesion causes a long stopping distance, and the driver MUST stop because if not, 'all sorts of stuff comes flying off the fan'. Additionally, drivers need to be able to see the signal in order to stop at it if it is at danger and on London Underground a driver has 6 seconds to react to put the brakes on so that the train can stop in a reasonable time. Therefore the sighting point is 6 seconds x the speed of the train + the braking distance at least, in order to stop before reaching the signal.

Overlaps: Piers stated that it is necessary to force drivers to comply with signals showing a stop aspect. On London Underground, the tripcock and trainstop system is used. Coming into contact with the trainstop will cause a train to 'come up in a heap' with an emergency brake application. The position of the signal has to be at least an emergency braking distance behind the train you are protecting with that signal, so in calculations you must now add to the sighting point, braking distance and signal position, a space ahead, or in advance of the signal, where the train still has room to stop having passed the signal at danger. Track circuits need to include this emergency braking distance in what we class as 'our territory', and this protected section beyond the signal is called the overlap. Every signal on LU has this, and this is what has given LU its safety record over many years. The audience were shown pictures of a trainstop and tripcocks.

ATO: Piers asked the question: 'Why spend all this money on ATO if we have a safety system which works well already?'. He explained that Trainstops rely on mechanical contact at speeds of up to 60 miles per hour. If the train goes above 60, it could exert forces on the trip arm and trainstop which will either damage the equipment or compromise the integrity of the system. It was for this reason that main line rail never widely adopted the tripcock system, since maximum speeds must be limited to avoid excessive contact forces. Another problem is that trainstops are held down by 60psi of compressed air, and when the train goes over a lowered trainstop under a proceed aspect, the air then releases and a spring pushes the trainstop head into the upright position. This system requires a continuous air main throughout the network and the longer the distances between the compressors at substations, the greater the difficulty of maintaining continuous pressure and the higher the risk of occasional failures such as air leaks causing signal failures and water ingress causing an air main to freeze up. Plus there is the need for the system to be tested.

Trainstops can only operate when a train goes past a signal so there is no warning, no pre-emptive strike – it is always after the fact. The train is already trespassing when it gets its emergency stop. The system also needs long calculated overlaps between signals, so you are effectively increasing the distance between trains, causing you to run fewer trains, thus decreasing line capacity. Trainstops only protect against overruns of the limit of authority, not against overspeed unless you design them to do so – a trainstop's purpose is not to regulate speed, only to regulate stopping at a signal.

Another reason to go into ATO is that colour light signals require clear sighting and can be missed by drivers or misread. Drivers can reset and proceed after a trip – you don't want them to sit there forever, but incorrect use of the reset has led to accidents as we know to our cost, such as Kilburn and Leyton in the 1980s. As a result of such accidents SCAT was introduced. Speed Control After Tripping means that train speed is limited to 10mph for at least three minutes after the tripcock arm has been operated by a trainstop, for whatever reason. This gives rise to the question: If something fails, signalling stops the trains; is that safe? Initially yes, but with heavily loaded trains and passengers overheating in hot tunnels between stations, it may not be. Other issues which make conventional trainstop systems less attractive include the fact that varying driver performance affects line capacity.

Elements of automatic train operation have been round since before the 1960s. These include automatic acceleration plus retarder controlled braking, which regulates the train's braking, and programme machines, which dispense with the need for signal operators, replacing them with automatically operated route setting.

Victoria Line ATO: This line has the first fully automated system in the world (New York had a one train shuttle which ran for two years then mysteriously caught fire soon after it was announced that the system was to be rolled out over the New York network. As a result that scheme was abandoned).

On the Victoria Line system there are two elements: A safety box which preserves the signalling status, or, if you like, looks after the train, and an auto driver box (ADB) which stops the train at the stations. Traditionally signalling engineers were in charge of the safety box, the only piece of train equipment that the Rolling Stock Engineers could not touch. Both elements use track to train transmission, via coded track circuits for safe speed instructions, and command spots for braking at signals and stations. Piers described the system as published in his *Underground News* articles "The Underground Electric Train" Nos. 34 and 35.

Piers showed slides of the layout of the various command spots on a typical journey between two stations and into the platform, pointing out that at the inception of the system, the tolerance for stopping was +/- 6ft because the driver had a CCTV monitor for the back four cars and could see the first four from his position. When newer type monitors were installed close to the train, positioning became more critical, and now a train has to stop within +/- 250mm. The train wasn't designed to stop so precisely, so the next generation of auto driver, the Replacement Auto Driver

Box was added in 1988 to aim for greater accuracy, and because spares for ADBs were scarce. But as any regular traveller knows, Victoria Line ATO is still pretty crude and the driver often has to operate a brake handle because he thinks the train may overrun the monitors. A better and more accurate new Auto Driver Box (NADB) is progressively being fitted to the fleet.

Central Line ATO: This was implemented between 1993 and 1996 based on the Victoria Line but also with experience gained in Singapore and Madrid. All the equipment was provided by Westinghouse. The description appears in Piers' article No.36.

Developments: So far we have seen what is there now; next Piers mentioned the kind of developments the future may bring in automatic train operation.

The Jubilee Line Extension was originally specified with moving block signalling to achieve a 36 train per hour capacity according to the original signalling contract – before the equipment had been installed this was rationalised to 33tph. The original specification also included a fall back fixed block system of 17tph. Because of the pressures surrounding the opening being wanted in time for the celebrations of the millennium, LU decided to abandon the untried and untested moving block technology and chose the fallback system which was modified and tweaked to achieve 22tph. More recent modifications have shortened some block sections and got to 24tph, but only if everything runs exactly to time and there are no disruptions. As part of the upgrade, all the JNP lines will be resignalled with an Alcatel updated Seltrac system. BCV and SSL lines will be signalled by Westinghouse Distance to Go (DTG). No one yet knows quite how two overlaid systems will interact on shared tracks. Piers then gave a description of the two systems, details of which were published in *Underground News* as parts of his series on "The London Underground Electric Train" Nos. 37 and 39.

Moving Block: Piers went on to explain that moving block works like cars on a motorway in that you do not travel a complete emergency braking distance behind the car in front because you know it will take time to stop so you have time to stop too, and you brake as soon as you see its brake lights come on. Moving block is very flexible and has no fixed sections and thus no apparent restrictions on capacity. Trains send their positions to the control centre by radio. Train 1 says 'I am travelling at 60kph and not in a braking mode' so train 2 behind it is told 'you can travel at 60kph also, and get up as close as 50m behind the train ahead' (the safety margin distance). Balizes every 200m allow the train to check its position.

The pros for the system are that it is flexible, reducing lineside equipment and could theoretically increase capacity over fixed block. Cons are that you need a vitally secure radio system (no one has a reliable one yet). How do you make sure all trains know by radio where they are? Will they pick up the signal? The radio system has to be safety secure because it is passing vital information about train locations and speeds. Failures would take a long time to recover. If you lose the radio signal you don't know where any of the trains are and must manually contact each one and they must vitally reply with information about their position, speed, or whether they are stopped. That would take a long time with, for example, 67 trains on the District. Then there is the question of headways. LUL headways depend on terminal throughput and dwell times. Terminals are the pinch points. You can only get a 126 second headway through Brixton and thus the train service on the Victoria line only works with 28.5 trains. You cannot get 30tph on the Victoria Line because of Brixton.

Piers then summarised with the aid of diagrams the relative performance of each system. If, for example, conventional signalling can provide a 28tph service on a line, then coded track circuits might give you 33tph. It is also true to say that reducing the train speed in steps to reduce the length of the emergency braking arc helps to give more trains. ‘Theoretically’ said Piers, ‘you could get 33tph on the Central Line if we could do something about Bank’. Continuous monitoring systems such as Seltrac, with much closer train headways and much shorter block sections could deliver 36tph. You could get 36tph assuming you could get 36tph in and out of Morden, which you can’t. ‘It’s a push to get thirty even with three platforms and stepping back in operation’ observed Piers.

‘What next? You have to agree the operational rules for new signalling, such as they are doing on the Victoria and Jubilee lines, and you have to sort out terminal protection and the compatibility issues on jointly operated lines’ said Piers. He then invited questions from the audience.

Questions covered included the consequences of a derailment in a moving block system, and would this cause multiple pile ups? The necessity of having stronger ventilation systems to cope with higher density of trains in tunnels; and the relative under-performance of ATO during low rail adhesion conditions such as snow. (Piers remarked that in Singapore drivers are ordered to drive manually in the rainy season).

One questioner pointed to a conflict between the position of balizes in station platform areas and the position of suicide pits. Another asked why LUL had got itself into a position where two mutually incompatible signalling systems will be installed? Piers replied that as PPP had split the railway up in a different form to the privatisation of BR, the signalling systems had been imposed on LUL as a result of political decisions. One questioner asked why Brixton was a pinch point but not Walthamstow? Piers replied that not all trains went to Walthamstow. Another asked would higher speed under moving block decrease capacity? Piers replied that you can get 11% more people through in the same time by running fewer trains at higher speed. It’s the escalator conundrum, you get more people on by making them stand rather than walk.

At this point the talk concluded and the Society Chairman then invited the audience to show their appreciation in the usual way.

Donald McGarr