LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
4. SPAGNOLETTI AGAIN

THE CITY & SOUTH LONDON RAILWAY

The City & South London Railway (C&SLR) was opened for passenger traffic in December 1890 between King William Street in the City of London and the suburb of Stockwell, a little over three miles south. It was the first electrically operated underground railway in Britain and it was heralded world-wide at the time as a leader in modern urban transport technology. There were some drawbacks with being a pioneer, with the power supply being under-specified, the rolling stock being way over the specified weight, the electric locomotives being under-powered, the terminal design being too restrictive and the signalling not being really suited to the frequent train service planned.

The C&SLR's problems were largely due to its intended design as a cable-hauled system. When the cable company supplying the system went bankrupt, the C&SLR board quickly decided to use electric traction instead but this did leave them suddenly in need of, amongst a host of other things, some sort of signalling system. As a result, they prevailed upon Charles Spagnoletti to design one. He had been appointed originally to advise on the conversion to electric traction but he was better known professionally for his expertise in signal engineering. Not unnaturally, he produced a revamped version of the design he'd used on the Metropolitan and Great Western Railways. The equipment was installed by Dutton & Co[1] to his specification.

The system as originally installed used a simple arrangement of a home signal and starting signal at each station, with the space between stations forming the block section. Because the original stations were constructed in separate tunnels, there had to be a separate box for each direction, although Elephant & Castle station uniquely had a single box controlling both directions. Trains were handed from section to section using Spagnoletti's new lock and block system. It was rather different from his design for the Metropolitan Railway.

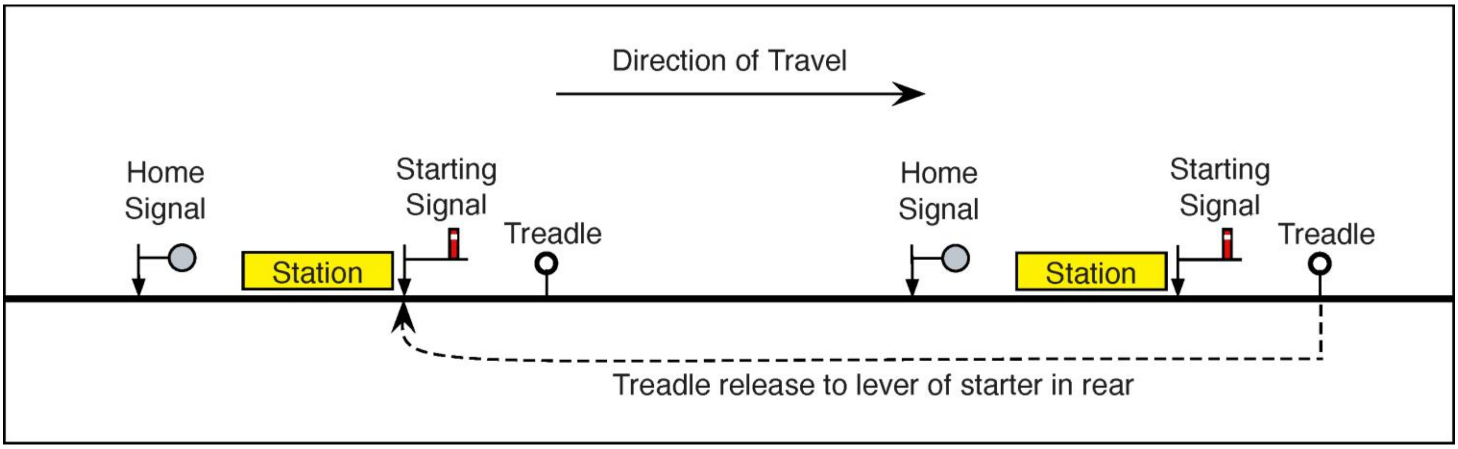

Figure 1: A schematic of the signalling as installed on the C&SLR for the opening in 1890. The starting signals were miniature semaphores but the home signals were in the running tunnels, where there was insufficient space for semaphores, so rotating, spindle-mounted colour lamp signals were used instead. At each station, a treadle, positioned a train's length beyond the starting signal, was used to detect the passage of a departing train so as to release the lock on lever of the starting signal in rear. The signalman couldn't reverse the lever to lower this signal until this release was obtained. Drawing: P. Connor.

BLOCK SYSTEM DEVELOPMENT

For his original Metropolitan Railway installation, Spagnoletti used three wires for the block instruments and bell but, from 1880, he added wires to operate electric locks on the starting signal in rear of each box to provide full lock and block. Normally, no train was allowed to be offered forward until it had arrived at a station. When it arrived, the signalman unpegged the white key showing "LINE CLEAR", causing the discs of the instruments to show "LINE BLOCKED" and then, using the bell code, offered

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1 Samuel Telford Dutton was a former employee of the McKenzie & Holland signalling company who set up his own company in 1888. The business was sold to J. F. Pease & Co in 1899 who were, in a perverse turn of fortune, taken over by McKenzie & Holland in 1901.

the train to the man in advance, who would then peg "TRAIN ON LINE" with his red key. This released the lock on the lever of the starter in rear to allow it to be lowered and the train to proceed. When the train operated the treadle at the starter of the station in advance, the discs on the instruments swung to neutral. "LINE CLEAR" was then rung back and acknowledged and the white key re-pegged at the box in rear.

The setup devised by Spagnoletti for the C&SLR was rather different[2]. This was a two-wire system[3], with the bell codes sent over the wire on one polarity and the instrument release on the other, for each direction. The instruments were of two types, each with a circular dial opening, showing the words "TRAIN ARRIVED" on a green background. The telegraph instrument had a bell key and two tapper keys, marked "TRAIN ON LINE GOING" and "TRAIN ARRIVED". If the first key was used, a red disc showing ''TRAIN ON LINE COMING'' appeared at the box in advance. When the train arrived there, pressing the "TRAIN ARRIVED" key would cause the "TRAIN ON LINE COMING" display to be replaced by "TRAIN ARRIVED". This setup was just for the block telegraph. The backlock circuit for the lever operating the starter was separate. It was set up using a plunger on the second instrument. When this was pressed momentarily and then released (known as being 'plunged') at the box in advance to accept a train, it locked itself, energising the lever releasing circuit to the box in rear and causing "TRAIN ON LINE COMING" to appear on the instrument. The backlock of the lever for the starting signal in rear was only released by a rail deflection treadle[4] placed in advance of the starter at the station ahead.

If we take an example of how this might work, we can consider the down (Southbound) signal box at Kennington, which has a train arriving that has to go on to the next station at Oval. The signalman at Kennington offers it to Oval. If the line is clear, the Oval signalman plunges on his accepting instrument. The plunger locks in place and the instrument displays the indication showing "LINE CLEAR SENT". This action releases the lock on the starter lever at Kennington and indicates "LOCK OFF" and "LINE CLEAR" on the instrument there. The signalman can now reverse the lever to lower the starter and the train can pass into the section on its way to Oval. The signalman will operate the key "TRAIN ON LINE GOING". After passing the signal, the departing train actuates the treadle, which indicates on Kennington's instrument "TRAIN ARRIVED", unlocks the plunger for the section in rear (at Elephant) and shows "TRAIN ON LINE COMING" at Oval.

In addition to all this, levers in areas where there were points were mechanically locked of course, to prevent conflicting routes being set up in accordance with the requirements of the recently introduced Regulation of Railways Act 1889.

SIGNALS

Station starting signals were semaphores, specially designed with very short arms, but the tunnel signals were housed in a rotating cast iron box with a light inside it. Two sides of the box at a 90 degree angle had stepped lenses to give either a stop or proceed indication. It is likely that initially the signals had a white light for proceed and red for stop. The whole apparatus, including the balance weight, was mounted on the tunnel wall.

At the terminals, calling on or shunt signals were added to allow locomotives to shunt in and out of the platforms when being detached or added to trains. At the southern terminus at Stockwell, additional signals were installed to permit access to the depot siding. A bridge over the platform end carried six semaphore signals, three for each platform – a starter and two shunt signals. The box here had 24 levers, more being added later when extra siding tunnels were built. The lever frame was of a unique type on the line. It was designed by W. Buck for Dutton's., according to a patent No. 11,741 of 1889, the special feature being that there was no separate catch handle (Figure 2, right). All the other frames on the line had conventional catch handles (Figure 2, left). Apparently, the Buck design was chosen for the Stockwell terminus because it was considered to be fast in operation. The design found its way on to a few other railways, but it didn't catch on[5].

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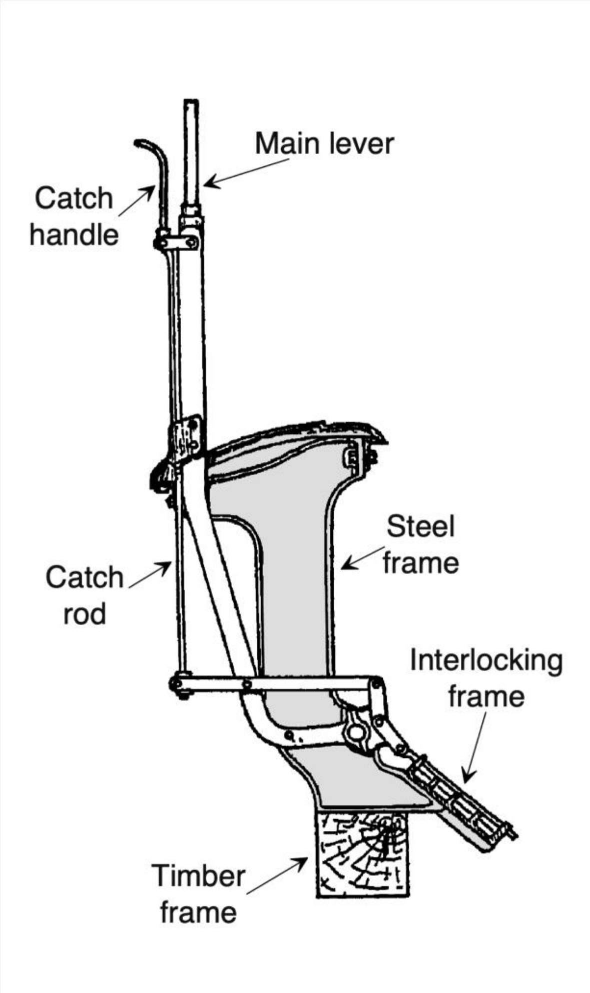
2 The system was described by Lascelles, T.S. (1941), "Early Tube Railway Signalling", *Proceedings of the Institution of Railway Signal Engineers*, 1941, pp.45-49.

3 Plus a circuit return wire.

4 Described in Article 3 in this series, see *Underground News*, No.702, June 2020.

5 Lascelles, T.S. (1941), "Early Tube Railway Signalling", *Proceedings of the Institution of Railway Signal Engineers*, 1941, p.40. MRFS mentions that the most famous and still-surviving example is at Douglas on the Isle of Man.

It is worth mentioning here that the signal lever catch was originally introduced by Saxby in 1856. In his and Dutton's installations, amongst others, the catch rod also operates the interlocking tappets. This was another Saxby idea. However, many lever frames were designed with the interlocking tappets linked to the main levers rather than the catch rods. There were debates in the industry during the 1890s about the benefits and drawbacks of both systems and the application around the country was about evenly divided between the two options.



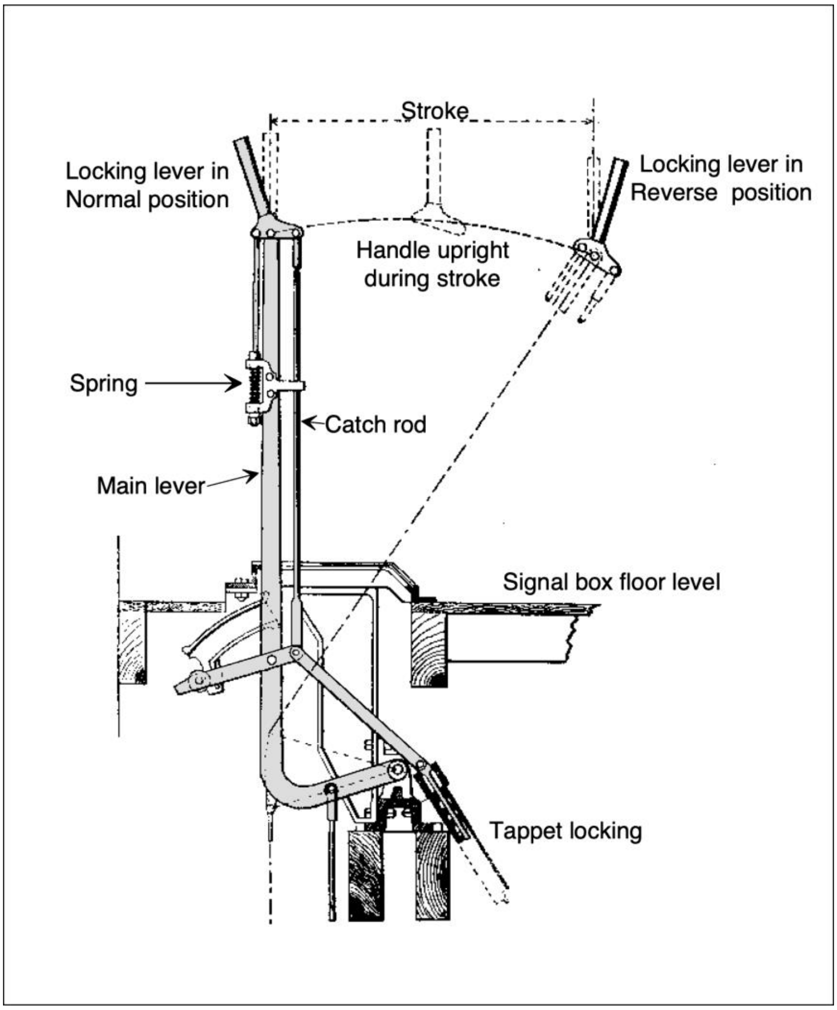


Figure 2: Two types of signal levers used on the C&SLR. On the left, a Dutton designed signal lever from the 1890s, similar to those used on the C&SLR. The main lever has a catch handle – the small additional lever attached to the top of the main lever and connected to a rod with a catch at the base where it sits on the slot in the lever frame. Its purpose is to lock the lever in the normal or reverse position so that it can't be moved other than by a positive action. On the right, is a drawing of the lever designed by W. Buck, although it was installed by Dutton's. Buck's lever had the catch rod and main levers operated by the same handle. The lever handle was held at an angle by a spring in the normal position. It was pulled forward to a vertical position to release the catch, retained in that position throughout the stroke of the lever and then pulled further over when the lever reached the reverse position. The geometry was interesting in that the spring actually forced the handle to the correct position when it was released in either reverse or normal. Drawings modified by P. Connor from (left) an original in "Modern Railway Signalling" by Tweedie and Lascelles, Blackie & Son, 1925, p.8 and (right) from Lascelles (1941) "Early Tube Railway Signalling" IRSE Proceedings 1941, p.45.

In a footnote to his description of the C&SLR signalling, T.S. Lascelles[6] records that the old signal frame and five of the semaphore signals remained on the site of the King William Street station as late as 1939. I doubt that they survived the war.

Stockwell also had a special arrangement for the current conductor rails over the scissors crossover installed there (Figure 3). The surface of the conductor rails on the C&SLR was lower than the running rails because of the very tight clearances under the electric locomotives. Wooden ramps had to be installed at crossings to allow the collector shoes to clear the crossings. At Stockwell, the crossing was rather acute and to enable the locomotives to negotiate it satisfactorily without shorting the system or getting gapped, movable bridges were fitted, operated from the signal box and appropriately interlocked, so providing a safe path for the shoes (Figure 4).

[6] Ibid

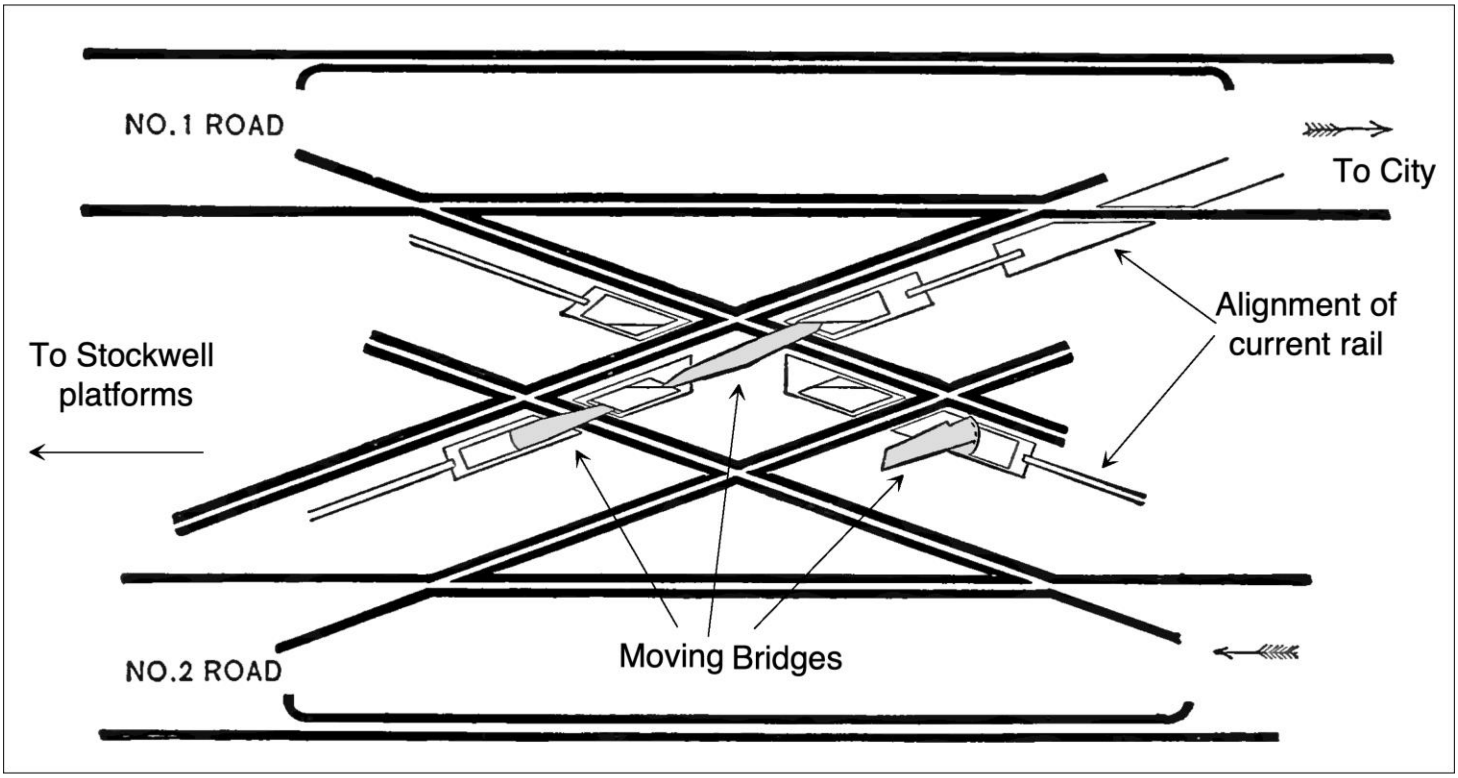


Figure 3: A diagram of the conductor rail bridges for the diamond crossing installed at Stockwell in 1890. The mechanism was needed to prevent the up and down lines being connected electrically as a locomotive crossed from one line to another, whilst allowing the collector shoes to be kept clear of the running rails. The detail of the operating mechanism isn't entirely clear but I have highlighted the obvious moving parts. These must have been insulated. The system was interlocked with the signalling. Drawing adapted by P. Connor from an original in Cassier's Magazine, May 1899, p.539.

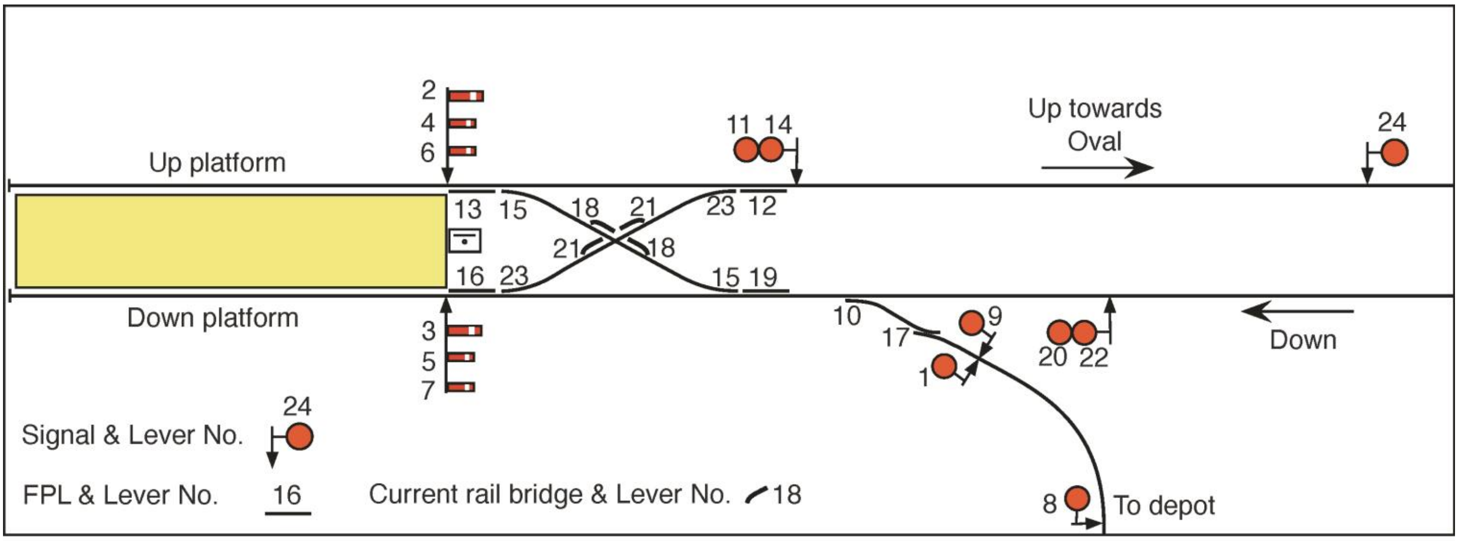


Figure 4: A schematic of the Stockwell terminus in 1892 after the installation of the advance starter (Signal No.24). The crossover shows the levers operating the current rail bridges, Nos.18 and 21. It also shows the Facing Point Lock (FPL) levers and the depot exit signals Nos.1 and 8. Signal No.8 appears to have been positioned at the bottom of the ramp from the depot. This suggests that it might have been linked to the control of the haulage chain that lowered trains down the ramp. The advance starter was installed to reduce the length of the section between Stockwell and Oval and the lever could only be reversed when the treadle in advance of the starter at Oval had been activated by the passage of a train. Lever No. 17 operates the catch points on the depot exit road. Drawing by P. Connor from an original prepared by John Hinson of ***www.signalbox.org***

C&SLR IMPROVEMENTS

Traffic increased rapidly on the C&SLR and it soon became apparent that the signalling arrangements restricted the throughput of trains, particularly at the two terminals, King William Street and Stockwell. Under the lock and block arrangements, a train waiting to depart the terminal platform had to wait until the line was clear all the way to the next station, including the platform of that station. In the case of the King William Street terminus, the previous train had to be clear of the southbound platform at Borough, on the other side of the river. In effect, the block section was too long, so it was divided by installing an additional signal on the approach to Borough. This was about 600 yards (549m) in rear of the original home signal. It was known as the "Outer Home" signal. It allowed an earlier release for the starter at the terminus. It was installed in February 1892. A similar setup was put in between Stockwell and Oval shortly afterwards.

The release was initiated by a treadle installed in advance of the outer home, which sent an electrical signal to the box at the terminus to indicate that a train had passed. This allowed the signalman to send the next train out of the terminus. However, the outer home lever could not be re-stroked[7] to signal the following train into Borough until the previous train had cleared the Elephant starter treadle and the signalman had set his instrument to "TRAIN ARRIVED". It appears that the Board of Trade inspector called in to approve the new setup noticed this and suggested that it could be corrected by allowing the treadle for the Borough starting signal to release the outer home lever (Figure 4). Once this idea had been seen to work at the ends of the line, it was installed between other stations. This work was completed in January 1894.

UPGRADES

In July 1893, the down outer home signal on the approach to Stockwell was fitted with a last vehicle treadle[8]. This was a completely new type. The rail deflection type of treadle installed for the original signalling had proved very unreliable and, in finding a solution, a new safety dimension was added by introducing last vehicle detection capability. The idea was to ensure the whole train was clear of the section by putting the detector on the last car of the train. Previously, detection had been when the first wheelset depressed the rail over the treadle, so the treadle had to be a train's length beyond the signal. Now it could be placed just beyond the signal.

Although they were called treadles, the new devices weren't actually treadles in the accepted sense; they were copper plates attached to the tunnel wall that were activated by a copper brush fixed to the rear bogie on the last car of each train. This provided a positive indication that the whole train was clear of the signal. They worked reasonably well over the years and gradually replaced all the originals.

The new type of treadle wasn't without a rather serious drawback. It couldn't detect lone locomotives. The C&SLR often had to run light engines to take up their duties or to rescue failed trains but the locomotives weren't fitted with "last vehicle" brushes. After all, they weren't normally the last vehicle in a train. To enable a locomotive to run light, they had to clamp a portable brush to it but, whenever possible, they saved themselves the trouble by sending a locomotive coupled to the front of a service train, so a locomotive only ran alone in an absolute emergency.

In later years, some of the stations were provided with block controls on their inner home signals to get a more rapid clearance of the platforms. Some of the sections formed in this way were quite short but even the 5-car C&SLR trains were only around 100 metres long and some signals were moved to even up the distances. This actually produced a form of multi-home operation where the signals protecting a station platform were cleared in sequence as the following train approached. With the signals positioned correctly and the clearances timed accurately, throughput could be improved. Surprisingly, this is a lesson not always appreciated even today, over 120 years later.

LAMPS AND REPEATERS

One problem with the original installation was the oil lamps used to light the signal indications. Apparently, the lamps kept going out because of the draughts caused by passing trains, so it was decided to try gas lighting. This was quickly abandoned, probably because it would have required a gas main to be installed in both tunnels for the full length of the line. Eventually, signals were provided with electric lamps. Lascelles records[9] that the lamps would only light up if the position of the signal arm (or spindle) was in correspondence with the signal lever.

Some signals were provided with repeaters in the signal box controlling them. This had become common on main line installations where the position of the signal arm was not visible from the signal cabin. Both the Metropolitan and District railways had them (see Articles 2 and 3 in this series) and they were provided in electric form on the C&SLR when the electric lamps were installed[10]. Each signal requiring repeating was provided with red/green miniature lights in the signal box to show the aspect on

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7 "Re-stroked" refers to the action of replacing the signal lever to the normal position and returning the signal to danger and then moving the lever back to the reverse position in order to lower the signal again.

8 Lascelles, T. S. (1955), *The City & South London Railway*, The Oakwood Press, Lingfield, Surrey, p. 19.

9 Ibid, p. 19.

10 There is a suggestion in Lascelles work *The City & South London Railway*, p. 16, that repeaters were also provided in the original installation and that these were electric but it is not clear what type they were.

the signal itself. This work was started before 1895 and I suspect that this was when green was adopted for proceed indications in place of the white used previously.

In 1895, when the platform level layout at King William Street was modified to allow two tracks instead of just one, the new signalling required was provided by Evans O'Donnell & Co. of Chippenham and they also supplied the equipment for the extensions. The new tunnel signals were of a different type with vertical sliding spectacles instead of the rotating box. These became standard, but some of the original signals were still in use when the line was resignalled between 1919 and 1921.

With the opening of the extensions south to Clapham and north to Moorgate during 1900, the C&SLR introduced two improvements, both of which were later adopted on all the London tube lines. Electric tunnel lights were fitted at intervals of 50ft. These lights were under control of the signalman, who would turn on the lights when requested, or if he thought a train was an unusually long time in section. The tunnels were also fitted with a pair of bare conducting wires, so that a driver could clip a portable telephone set to the wires and speak to the signalmen in advance or in rear. These tunnel telephone wires were later modified to allow traction current to be switched off in an emergency and they became a standard feature of the Underground.

Further extensions were opened north from Moorgate to Angel in 1901 and to Euston in 1907. These had similar signalling equipment to the 1900 extensions. The section between Angel and King's Cross was considered too long to allow a service of the required 28 trains per hour frequency, so it was divided with a signal box at Weston Street. The layout at the new terminus at Euston in 1907 is as shown in Figure 5. There were sidings on the up side of the approach to the station and two sidings beyond the platform. Apparently a traverser was installed at the end of these sidings but it quickly fell into disuse and it is not shown on the signal diagram. It seems that it was intended to be used without any reference to the signalling controls.

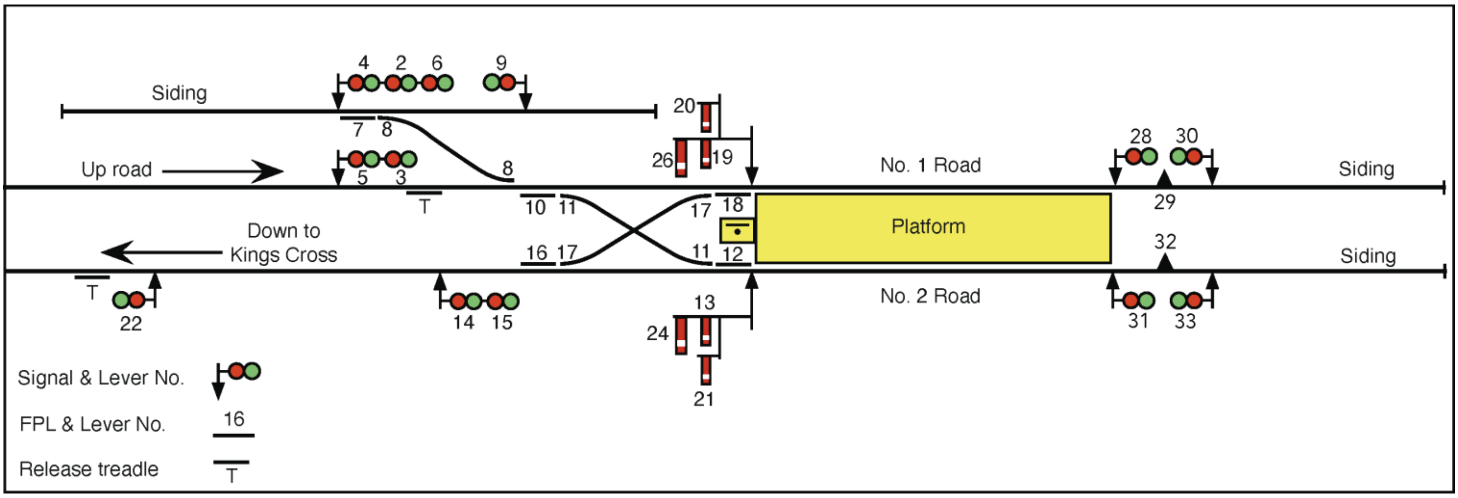

Figure 5: Schematic of the terminus at Euston in 1907. Note that the only semaphore signals were those on the departure end of the two platform roads. The upper signals (Nos.24 and 26) were for the departure route to the down main line, the others were shunt signals. Locomotives always had to run out of a platform behind the departing train on to the Down road. Note that two signals, one above the other (e.g. Nos.3 & 5), were provided for diverging routes, the top signal indicating for the main route, the lower one for the diverging route. This example also has a treadle, which releases the outer home in rear (not shown). The treadle is of the new electric last vehicle brush type so it is close to the signal. Signal No.22 is the advance starter, which required the signalman at King's Cross to release its lever and allow Euston to lower it. It also had a treadle to give a release to the starting signal levers in the two platforms. The levers 29 and 32 operated the derailers at the ends of the siding at the end of the platforms. Drawing by P. Connor from an original prepared by John Hinson of ***www.signalbox.org****.*

After the line was taken over by the Underground group in 1913, a number of adjustments were made to the block sections and positioning of signals in an attempt to improve the throughput further. By 1916, the improvements allowed 26 trains per hour per direction during the peak hours, (amazingly) better that the Piccadilly Line does today and, by 1919 they were getting 28 trains per hour, officially at least. Surprisingly, it seems they actually achieved this on a regular basis.

In 1919, before the start of the work on the tunnel enlargement project, in an attempt to bring the line up to the standards of other tube lines, work started on fitting the C&SLR with track-circuit based automatic signalling, the operation of which I will describe in a future article. This work was completed at the end of December 1921. There was also a brief trial of trainstops but these were found to be unworkable within the very tight dimensions of the tunnels and the restricted envelope of the locomotives and they were not put in until after the enlargement was completed.

In order to reduce the number of signal boxes in use at periods of low traffic, arrangements were made in later years for switching out two boxes, one at Clapham Road (now Clapham North) station and the one at Weston Street. Two special levers were provided, one for each direction of running. The levers were provided so that up and down lines could be switched out independently at a convenient moment. To switch out, the signalman did not replace his signals to danger behind the last train he intended to deal with but reversed the switching out lever for that direction. This action backlocked the levers and lit a white marker light on the starting signal in rear. He then switched out his signal lights. The "TRAIN ARRIVED" indication for each train was transmitted from the box in advance to the box in rear, bypassing the switched out box. The switching in process was also effected separately for each line, immediately after the passing of a train[11].

IN ADVANCE AND IN REAR

Tom Crame, one of my technical advisors for this series, has suggested there might be some confusion for non-technical readers in my use of the terms "in advance" and "in rear". These expressions appear in a lot or railway literature, particularly in relation to signalling. They are best explained in a diagram (Figure 6), which shows what they mean. Here, Train 2 is standing "at" signal A123. This is how the driver would report his position when contacting the signaller. It's simple and could hardly be misunderstood. However, Train 1 is ahead of it on the line and is stopped between signals A123 and A125. It has passed signal A123 but it hasn't reached A125. Although A125 is ahead of the driver as he sees it, he is said to be "in rear of" the signal. And, as it has gone past signal A123, the train is said to be "in advance of" signal A123.

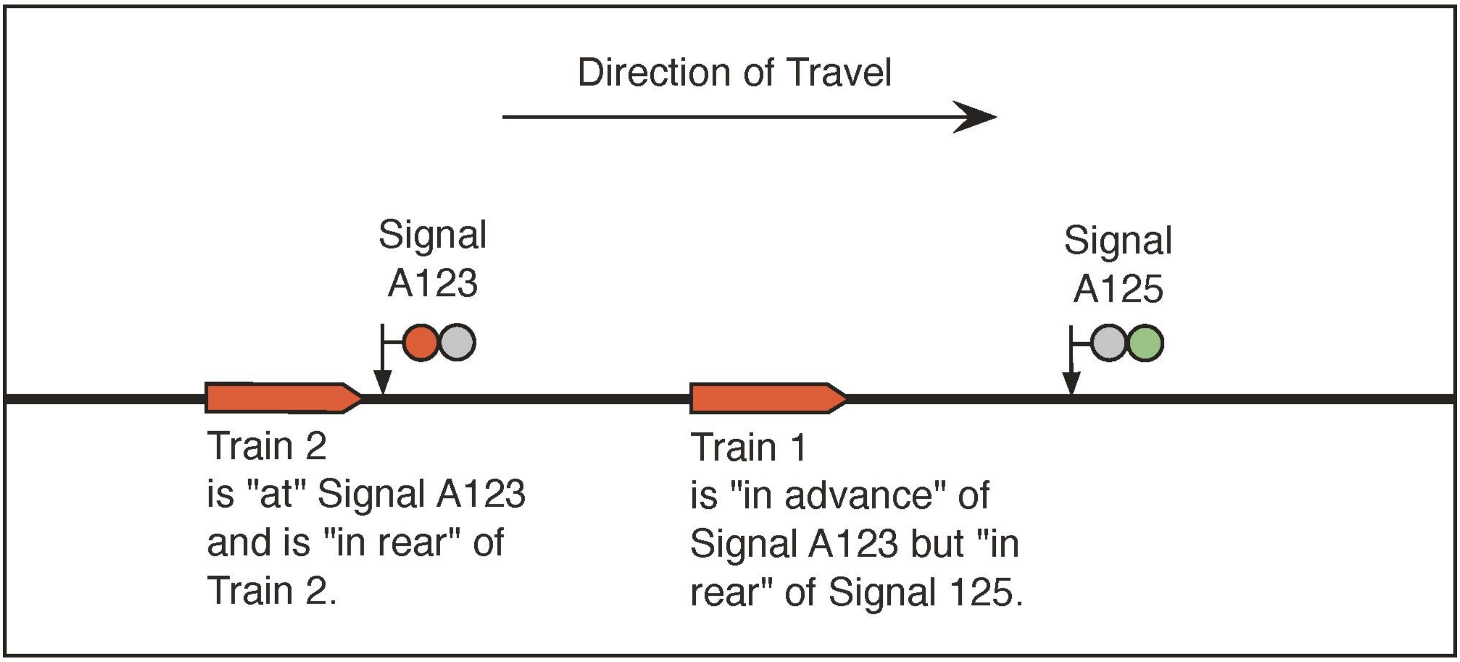

Figure 6: Schematic of section of line showing descriptions of locations relative the positions of trains and signals to demonstrate the use of "in advance" and "in rear". Drawing by P. Connor

If you aren't paying attention, this could get confusing. It is made even more confusing by the appearance in LU Signal Engineering standards of a statement which says that the stopping point for a train "shall normally be 5 metres IN FRONT OF a signal" (my capitals). If this was true, i.e. in advance of the signal, the train would have been tripped! Of course, the signal engineer is looking at the signal the other way round. The back of the signal is where he changes the bulbs and feeds the wires in. The front is where he cleans the lens. The lesson here is that it is essential that these descriptions are standardised, communicated during training and verified as clearly understood when used on the ground. Unfortunately, it isn't always done.

To be continued …

11 Lascelles, T. S. (1941), "Early Tube Railway Signalling", *Proceedings of the Institution of Railway Signal Engineers*, 1941, p. 49.