LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
6. THE CENTRAL LONDON RAILWAY

MORE SPAGNOLETTI

The Central London Railway (CLR) was officially opened by the Prince of Wales (later King Edward VII) on 27 June 1900. After three weeks of running a full service without passengers so that staff could get used to the new systems and to iron out the inevitable teething troubles, the line was opened to the public on 30 July. The new line ran from west to east across the centre of London, much of it in twin tube tunnels under the straight alignment of the old Roman road that became Oxford Street.

The railway had to spoil the Roman legacy of the straight route at each end because of the need to follow the line of the streets above to reach the City terminus at the Bank and to access the depot beyond the western terminus at Shepherd's Bush. Both locations had severe curves, the one at Bank (the present westbound platform) having a radius of 89 metres, while west of Shepherd's Bush, the single track from the station up into the depot on the surface at Wood Lane (today's westbound track) squeezes round a 60m radius curve. At Notting Hill Gate, Chancery Lane and St. Pauls, because of site constraints, they had to place the platforms at different levels.

The CLR was bigger in many respects that either of the two tube lines already opened in London. It was almost six miles long and it had longer trains that could be made up to a 7-car formation, with large, 4-motor electric locomotives to haul them. Locomotive changes took place at each terminus in much the same way as on the City & South London Railway (C&SLR). The signalling was also much the same as that provided on the C&SLR, being designed by Charles Spagnoletti using his lock and block system. The block instruments and electrical signalling parts were provided by the company known as Spagnoletti and Crookes. The principal partners were J.E. Spagnoletti, son of Charles, and Joseph Crookes, son of Sir William Crookes, the eminent physicist. When Joseph Crookes died in 1902, the business was continued for a while as Spagnoletti & Co. The mechanical parts of the CLR system were installed by Evans, O'Donnell & Co. who were also providing the equipment on the C&SLR extensions at this time.

ORIGINAL SYSTEM

The original block sections ran from station to station with a signal box at each station controlling both roads, except at the three stations with platforms on different levels, where a separate box was provided for each direction. There was also a signal box at the depot entrance at Wood Lane (Figure 1).

Each station had an outer home, an inner home and a starting signal for each road[1]. A signal box had up to three Spagnoletti instruments for each direction, one for the inner home, one for the outer home and one for the starting signal of the station in rear. It is likely, initially at least, that only two instruments were provided at some locations, one for the starter and one operating for both homes.

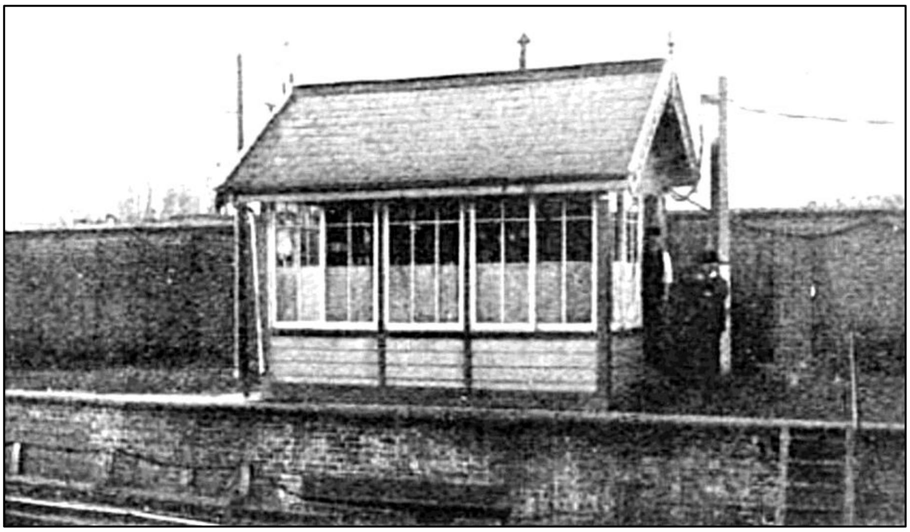

Figure 1: The original signal box at the Central London Railway depot at Wood Lane. This was the only signal box on the line that was in the open. It controlled the movement of trains in and out of the depot and the line to and from Shepherd's Bush. It was later moved as part of the project for the building of the new station at Wood Lane in 1908. Apparently, it was provided with a 30 lever frame, with 9 levers spare at the time of the opening of the new station. Photo from 'The Sketch', 28 May 1902.

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1 Lascelles, T.S. (1950), "Jubilee of the Twopenny Tube", *Railway Pictorial and Locomotive Review*, Vol.3, No.15, August 1950.

The levers for the home signals had electrically operated locks which prevented the lever being reversed to clear the signal before contact with an end of train brush on a 'treadle' released the lock in the instrument. Then, the signalman could press the plunger on the instrument to complete the release of the lock on the lever and reverse it. Another instrument permitted the signalman to plunge to release the starter of the station in rear provided the treadle in advance of the outer home signal had been operated. The treadle was normally positioned at least 300 feet (91.5m) in advance of a signal to provide an overlap as an overrun space. As was usual with Spagnoletti equipment, the lock acted on the trigger rod of the signal lever, not the lever itself.

The station starting signals were short arm semaphores but tunnel signals had vertically moving spectacles showing red or green in front of an electrically powered lamp as used on the C&SLR extensions (see box). There weren't any distant signals, so stop signals were positioned carefully to provide adequate sighting for the driver, who was always located on the north side of the locomotives. Shunting movements were, if we assume they were the same as on the C&SLR, signalled by small semaphores.

C&SLR IMPROVEMENTS

The signals originally supplied for the City & South London Railway (C&SLR) were of the rotating type, where a lens was mounted on two sides of a square iron box on a vertical spindle that rotated through 90 degrees. These signals had backlights. They were provided so that the signalman could see that the lamp illuminating the signal was working. A green backlight was provided for the stop position and a white one for the proceed position. The green was later changed to a violet light, following the adoption of green as the standard light for proceed. When the extensions were added in 1900, Evans O'Donnell & Co. of Chippenham supplied the signalling equipment. The new signals had vertically moving spectacle plates in front of the signal lamp and these became the new standard design.

The Spagnoletti block instruments gave two indications, "train arrived" displayed on a green disc and "train on line coming" or "going" on a red disc. On most main line railways, the block telegraph was used to communicate with signalboxes on both sides, using the same bell for accepting and sending trains. On the Spagnoletti system, the instruments were separate for each line, which meant that each signal box had four block bells instead of the usual two.

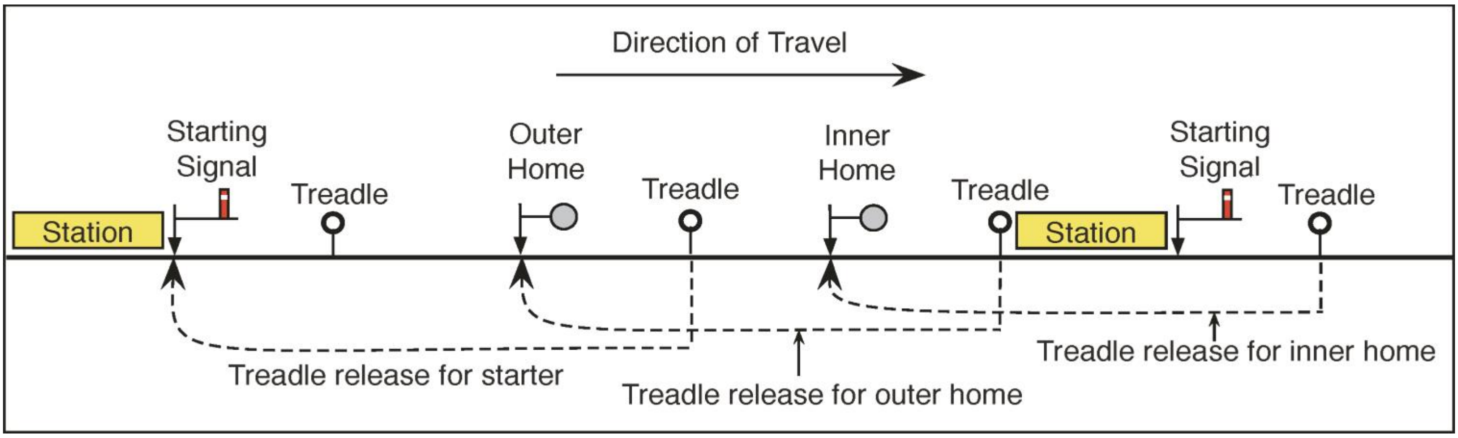

Figure 2: Schematic of CLR mechanical signalling to the design of C.E. Spagnoletti showing how both inner and outer home signals could be used as section signals. Each signal had a brush activated treadle about a train's length ahead of it that was used to detect the passing of the rear of the train in order to release the instrument locking the signal in rear. Drawing by P. Connor.

There is some doubt about how the home signal controls were originally used. It isn't clear from the available literature whether all the inner home signals were initially used as section signals in their own right to create additional blocks or whether they simply provided platform protection[2]. If the inner home was not being used as a section signal, both homes would have been released through the same treadle in advance of the starting signal. Certainly, some inner homes were used later as section signals, e.g. approaching Shepherd's Bush from Wood Lane (after the latter station was opened in 1908) and between Lancaster Gate and Marble Arch. Figure 2 shows the layout with both inner and outer homes used as section signals.

2 T.S. Lascelles, who is said to have written over 3,500 articles, papers and books on railways, had a particular interest in the London Underground and he is the source for much of what we have on the original CLR signalling. However, in his two published descriptions of the signalling, one for the Institute of Railway Signal Engineers in 1941 and one for the Railway Pictorial in 1950, he isn't entirely consistent in his descriptions and some of his wording is contradictory. Much of what Lascelles wrote appears to be based on personal visits, memory or from his employment with W.R. Sykes & Co.

TREADLES

As we have seen in earlier articles in this series, the term “treadle” has been used to describe a variety of train detection systems used for mechanical signalling installations and the Central London was no exception. Treadles were used on the CLR as end of train detectors. They were similar to the later type used on the C&SLR, where a copper brush on the end bogie of the train passed over a contact plate fixed next to the track and thus activated the release instrument in the signal box. This allowed the signalman to get a release on the signal lever lock when he plunged the button on the instrument.

The treadle was usually mounted a train’s length in advance of a signal to release the lock on the signal in rear protecting the entrance to the block. Like all the treadles used on the railways at this time, it wasn’t a fail-safe system. It required a positive action to detect the passage of a train and it was possible for a train to pass without the activation of the treadle. Such failures were not uncommon and, when it happened, it left the instrument locked and the signalman unable to clear the signal for the next train. This was the time when you had to ‘take a release’.

We’ve seen in earlier articles in this series that experience had shown that train positioning devices provided for electrical lever locking systems could go wrong and that it was wise to install some form of release mechanism if long delays were to be avoided. These devices usually took the form of keys or push buttons and were usually mounted in a separate, sealed box. On the CLR, release plungers were provided, protected by a paper seal. We know this because of a good description of the operation of CLR signalling provided in the Board of Trade accident report into a collision that took place at Shepherd’s Bush (eastbound road) on 30 September 1913[3]. I go into more detail on this below.

TRAINSTOPS

About 1907, it was decided to equip the CLR with trainstops as part of a scheme to dispense with the assistant drivers provided on each train[4]. By this time, trainstops were already provided on the District, and London Electric Railways’ electrified lines and on parts of the Metropolitan Railway and they were now regarded by the inspectors at the Board of Trade as essential on any railway running in tunnels with only one man in the cab. Central London management, looking for ways to cut costs, took the option to fit trainstops to all running signals so they could single-man the driving cabs. Of course, the trains had to be equipped with tripcocks as well. These were connected to the brake pipe so as to bring the train to a stand if the driver passed a signal at danger[5].

The trainstops provided on the Central London were purely mechanical, being linked by rods and levers to the mechanical parts of the signal operating system. When the signal was lowered, the trainstop was lowered with it and when the signal was restored to danger, the train stop was raised so that it would strike the tripcock mounted on the right hand side of the leading bogie of the train.

SHEPHERD’S BUSH

The only officially investigated train accident on the CLR took place at 07.09 on the morning of 30 September 1913. It was an end on collision, with a train running into the rear of the train ahead, which was standing in the eastbound platform at Shepherd’s Bush. The trains had come from Wood Lane. The line had been extended there in 1908 to cater for the traffic expected for the new White City exhibition site. There were no serious casualties in the accident and there was only minor damage to the two trains involved. The accident was entirely the fault of the signalman, Richard Broom.

Despite his responsibility for the accident, Broom was obviously an honourable man. He had been employed as a signalman for the whole of the 13 years the CLR had been open and he was regarded by his supervisors as a reliable and sober individual. This was proved when he realised he had “blundered” and he freely confessed that he had made the mistakes that had caused the accident. His evidence to the enquiry was clear and, for us looking to see how the CLR signalling worked at that time, detailed and useful.

Broom described that he had seen the release from the treadle of his outer home signal as Train No.17 from Wood Lane approached his station at Shepherd’s Bush so he replaced the signal lever to normal. At the same time, he mistakenly also replaced his inner home signal lever but the train hadn’t actually

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[3] Pringle, Major J.W. (1913), Report into the Accident at Shepherds Bush Station, 30 September 1913, Board of Trade, London.

[4] When the line was opened in 1900, the electric locomotives had a crew of two. Following the problems with vibration caused by the weight and suspension of the locomotives, they were replaced with multiple unit trains from May 1903 but the two crew members were retained for some years.

[5] The CLR trains didn’t have deadman’s handles at this time and, some months after the removal of the assistant drivers, the company received a slap on the wrist in the form of a letter from the Board of Trade advising them that, now there was only one man in the cab, they should fit deadman’s handles. This they promptly did and thus joined the newer tube railways in having both tripcocks and deadman’s handles.

passed it by then and, as the driver approached, he saw the signal "go back in his face", as we used to say. He went into emergency brake to stop but overran the signal and got tripped. He got out of the cab to reset the tripcock and then, seeing the line was clear ahead, cautiously brought his train into Shepherd's Bush. He got out of the cab to advise the signalman what had happened. This was easy as the signal box was at the east end of the platform.

Meanwhile, the next train, No.18, was approaching from Wood Lane. Broom had got himself into a proper muddle by this time and, although Train 17 was still in the platform, he forgot about it. He thought he needed a release on the inner home but he actually used the release for his outer home. When he realised his second mistake, he went on to get a release on the inner home too. The result was that Train 18 ran into Shepherd's Bush under clear signals and struck the rear of Train 17. Fortunately for everyone involved, the speed of Train 18 was low and the damage to both trains was slight.

An interesting feature of the accident report is that Broom told the inspector from the Board of Trade, Major J.W. Pringle, that he had had to use the release system a total of seven times during the previous week. The treadles were obviously not very reliable and signalmen had got used to using the release on a regular basis. This may have contributed to his errors.

Another detail that arises from this report is that at least one of the CLR stop signals had a repeater signal (see box). The report notes the location of the inner home repeater as 452 yards in rear of the Shepherd's Bush signal box. This would place it at the start of the long curve between Wood Lane and Shepherd's Bush, a logical place to site it, bearing in mind the downhill gradient at this point was quite severe at 1 in 28. The driver of Train 17, Ernest Wakeling, reported to the inquiry that he had seen the repeater of the inner home signal showing a green aspect.

The signalling along this part of the line, with its repeater, would have been installed when the line was extended from its original terminus at Shepherd's Bush to Wood Lane in 1908. None of the descriptions of the original CLR signalling I have found mention lineside repeater signals and I have not seen any references to them in descriptions of the very similar C&SLR system so, was this the first example? If so, how was it operated? Was it electrical or could it have been linked mechanically to the inner home, using an extension to the cable so that, when the inner home was lowered, the repeater lowered with it. But we might consider that 452 yards was a long way from the lever, especially when the Board of Trade recommended maximum distance was 350 yards. On the other hand, the mechanical movement of the signal lenses was very small, just a few inches, so technically it was possible.

REPEATERS AND DISTANTS

We've seen in previous articles that distant signals were introduced in the late 1840s to give train drivers some advanced warning of the status of home signals. By the time the CLR opened in 1900, it was standard practice on the main line railways but, with the low speeds of the tube railways, they were not considered necessary and they were not provided.

It was also the practice to provide signal position repeaters in signal boxes for some signals. All the Spagnoletti and Sykes installations used on the underground railways in London had them. They were generally referred to as "repeaters". This should not be confused with the lineside advance warning signals introduced later that were also called repeaters. It seems that the Central London introduced them, if not from opening, certainly before 1913, when we first see them mentioned in the Shepherd's Bush accident report.

SYKES PROPOSAL

In 1899, while the line was still under construction, the CLR received an offer from W.R. Sykes to install automatic signalling, using patents issued to Westinghouse. This was the year that Sykes left his long time employers, the London Chatham & Dover Railway (LCDR). In this year, the LCDR joined forces with the South Eastern Railway to become the South Eastern & Chatham Railway so Sykes left and put his own company on a formal footing as the W.R. Sykes Interlocking Signal Co. Ltd. and it seems that the CLR was one of the first places he set out his stall.

Today, we would regard their definition of automatic signalling as rather loose since it wasn't fully safe. There were to be no track circuits. Train position detection was to be by the use of treadles, activated by the passing trains, similar to the Spagnoletti system eventually installed but that's where the similarity stopped. The treadles were to switch the signals behind the train, instead of releasing lever locks.

The system was designed to use colour light signals, controlled by polarised relays (Figure 3). Each signal had to be proved to be on before the one in rear could be cleared. The signal lamps were to be supplied through a special signal main supply. This was a new idea, as far as I am aware, since all previous systems, including the block telegraph, treadles, signal repeaters, signal lamps, signal replacers and anything else electric, relied on batteries.

Trains, however, were to be provided with batteries. They were to be fitted at each end to supply the current to activate the treadles. As the train passed the treadle, its battery would connect to the treadle, through the brush on the last car, to supply a momentary current to the signal relay. The system was designed so that the circuit was completely insulated from earth. It had to be this way because the return circuit of the 500 volt traction supply was through the running rails and, in places, these were bonded to the cast iron tunnel lining.

We should remember that, although track circuits had been around for over 20 years by this time, they were battery fed DC circuits and no one had yet figured out how to make them work on an electric railway with a DC power supply which used the running rails as the return conductor. Also, their application was limited on main line railways for a number of reasons, largely because of the cost but also because of the distance limitations of track circuits and doubts about their reliability.

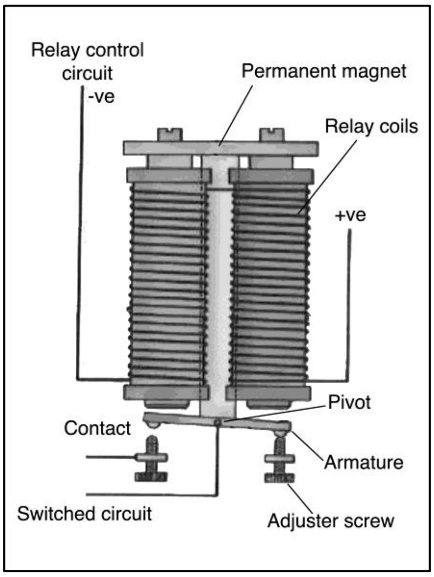

Figure 3: This is a schematic of a Westinghouse designed polarised relay similar to those used in early track circuits. There are two basic electrical forms of relay. There are polarised relays and non-polarised relays. A relay is simply a remote switch operated by a circuit that energises or de-energises the electromagnet in the relay. This opens or closes a switch in a second circuit or circuits. The electro-magnet consists of a soft iron core with a wire wound round it. It operates an armature that is used to open or close a separate circuit, shown here as the switched circuit. The non-polarised type is purely electro-magnetic, so that its iron cores (usually two) with the wire wrapped round them, only operate the armature carrying the relay contacts when a current flows. The polarised relay has a permanent magnet as well as the electromagnet and can be used where it is required that the armature needs to be switched from one position to another if the polarity of the current is reversed. This was useful for preventing a false feed activating a signal to show a false clear aspect. The polarised relay is also able to operate with very low currents, which makes it ideal when dealing with long DC track and signalling circuits. Drawing from PACW.org modified by P. Connor.

Part of Sykes' proposal was that the CLR locomotives were also to be fitted with batteries and treadle brushes but these would only be used if the locomotive was running light. When coupled to a train, the rear car brush would be the one that was operative, not the one on the locomotive. The proposal suggested that the act of coupling the loco to the train would disconnect its brushes so that they would not operate the signals. If I was reviewing this as a proposal, I might consider that it looked like a complicated business, likely to cause trouble in service.

For reasons not known, the Sykes scheme was not accepted. I suspect it was on the grounds of both price and complexity and perhaps because it was completely new to Britain, whereas the Spagnoletti system was mature and the experience with it on the C&SLR was generally positive. Around this time, in 1899, the same equipment was being installed on the C&SLR extensions to Clapham and Moorgate so there was a pool of knowledge already available, allowing a rolling programme to be set up .

J.E. SPAGNOLETTI'S EXPERIMENT

Signal operations were expensive. Every one of the CLR's stations had a signal box. The three stations with separate platforms had two. The line had 17 boxes in all and, for a railway operating 18 hours a day, they would have needed at least 50 people to work them. This was a considerable expense. On top of this, the throughput of trains on the CLR was originally 24 trains per hour per direction at peak times so each signalman was handling up to 96 bell operations and 72 lever and plunger movements an hour for each direction. This amounted to eight movements a minute, plus the writing up of each movement in the signal box register.

After the introduction of multiple unit trains in 1903, the service was increased to 30 trains per hour and this put the Spagnoletti signalling at the limit of its capacity, both technically and operationally. Better signalling was needed but, despite an effort to improve things, it was still some years away.

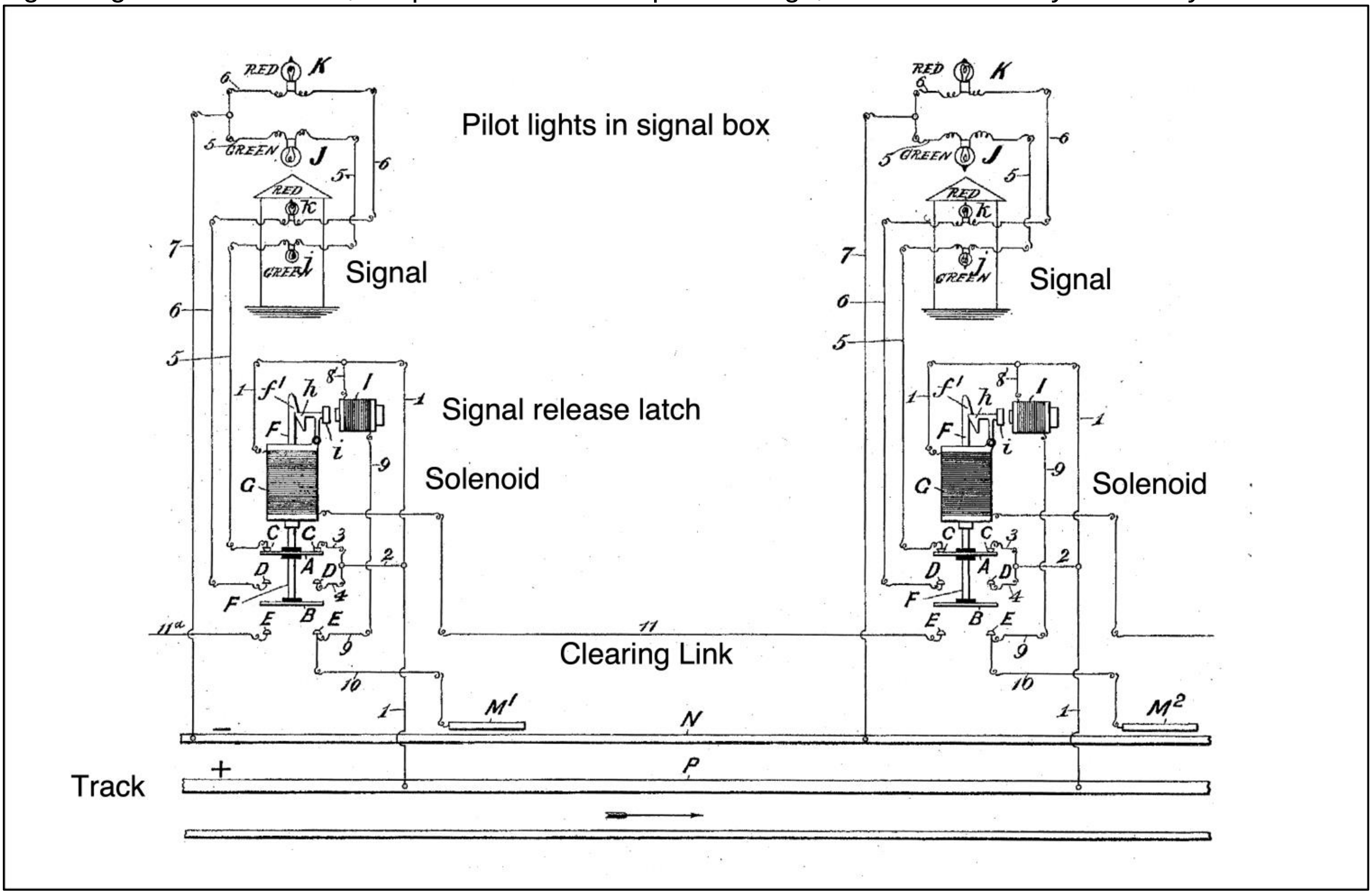

Figure 4: A drawing from J.E. Spagnoletti's US patent application of 1902. It is the same as the one for the British patent but the reproduction is better. It shows the CLR 3-rail track with the centre positive rail (P) as the supply for the signalling and one of the running rails (N) being used as the return. Each signal had red and green aspects lit by lamps in series with pilot lamps (J & K) in the nearest signal box, controlled by the armature of a solenoid relay (G), which was latched up to light the green signal. The catch could be withdrawn by a setting coil (I), connected to a contact plate treadle in advance of the signal. A brush on the last bogie of the train was connected to the traction circuit to release the latch (I) and turn the signal to red. A link to the signal in rear (the clearing wire) restored the signal in rear to green. The treadles M^1 and M^2 were connected to the traction supply when the on-train brush came into contact with them. The contacts on the solenoids (G) fed the 500 volt supply to the signal lamps and the pilot lights (J) installed in each signal cabin to allow them to be monitored . The 500 volts was reduced to 3-7 volts by resistances in series with the signal lamps. The problem with this design was that it required a positive circuit to complete the operation of showing a red signal. It would not satisfy a signal engineer's scrutiny today, since a failure of the latch relay to operate would allow the signal to show a green aspect when it shouldn't. Drawing modified by P. Connor.

The effort to try to improve things came when J.E. Spagnoletti produced a design for an automatic signalling system with train operated signals but still using treadles, and he persuaded the Central London to try it. It was described in a paper by T.S. Lascelles published in the IRSE proceedings of 1941. Spagnoletti was granted a British patent for the system in June 1902. He describes it as suitable for use on electric railways in tunnels. It was unusual in that it used the traction current supply to operate the system[6]. The patent drawing shows the feed for the electrical circuits coming off a 3-rail track with a positive centre rail (Figure 4) and it is probable that it was the same scheme as tried on the Central London, although Lascelles doesn't mention the traction supply element. He probably didn't know about it. It seems likely that it was installed around 1902.

It operated somewhat like the proposed Sykes scheme but Lascelles mentions that it required the train crew to insert the treadle operating fuse at the rear of the train every time they changed direction and then remove it at the end of the trip[7]. Otherwise, the working was relatively simple, if intuitively not entirely satisfactory. The system was tried experimentally on the CLR between Tottenham Court Road

6 Most later systems used a separately generated supply.
7 The provision of on-board batteries in the Sykes proposal removed the need for this arrangement.

and Bond Street stations but, after a false clear incident apparently caused by a wiring defect, the CLR lost confidence in it and the equipment was removed. One cannot be all that surprised.

Despite its drawbacks, a very similar scheme was installed on the Great Northern & City Railway for its opening in 1904 but it proved troublesome over there too and needed extensive and expensive modifications. We will see more on this in next month's article.

A PROGRESSIVE RAILWAY

The CLR was quite a progressive railway. We see evidence for this in the rapid change from locomotive haulage to multiple unit operation within three years of opening, in its withdrawal of assistant drivers and in its persistent attempts to make its train control system more efficient. Another example was in its trial of headway clocks. It's not clear when this was started but it was probably before 1906.

The clocks were, according to Lascelles[8], only introduced at one or two stations, the equipment supplied, he suggests, by Chadburn & Sons, the ships' telegraph engineers. Large illuminated 'clocks', equipped with pointers in the style of a marine engine order telegraph[9], were placed at the ends of the platforms and were operated by transmitters set up in the signal box. The central position of the pointer showed right time, while other segments were marked out in time intervals to indicate early or late. They don't appear to have lasted very long but they might have been the first attempt to provide drivers with an indication of their performance. Whether this information was actually of any use is an interesting point but headway clocks of various types were tried by a number of the Underground lines, as we will see in future articles.

The CLR's search for a more efficient operation culminated in 1911 with them making the decision to abandon the Spagnoletti block telegraph signalling in favour of track-circuited, fully automatic signalling. It was to be introduced first on the extension of the line eastwards from Bank to Liverpool Street, then under construction. It was considered possible because of the development of the alternating current (AC) track circuit. This first appeared in the United States in 1903 and it was to mark a big step forward in signalling technology. It provided the opportunity for automatic signalling to be applied relatively easily to any electric railway but it took some years to become adopted on the Underground, largely because they had already adopted DC track circuits.[10].

To be continued …

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[8] Lascelles, T.S. (1950), "Jubilee of the Twopenny Tube", *Railway Pictorial and Locomotive Review*, Vol.3, No.15, August 1950.

[9] A ship's telegraph, otherwise known as the engine order telegraph, or EOT, was used to transmit orders from the bridge to the ship's engine room. Chadburn's were the best known suppliers to the extent that the system was sometimes referred to as 'the Chadburn'.

[10] MRFS suggested that I should point out here that the Liverpool Overhead Railway had a form of automatic signalling, designed by J.A. Timmis and introduced from 1893 but it didn't use track circuits, the detection system being electro-mechanical.