LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
16. SIGNALLING FOR EXTENSIONS

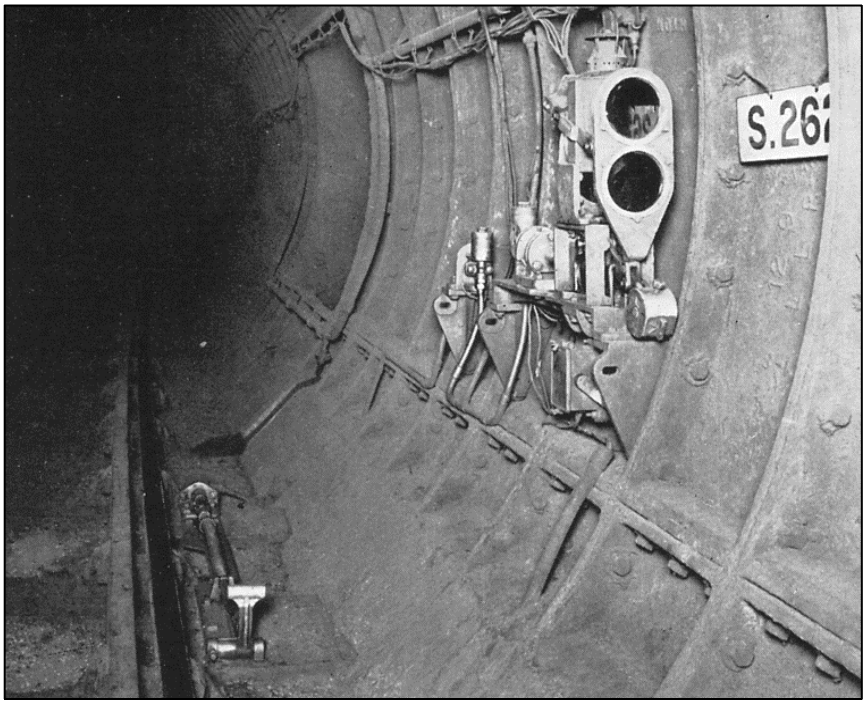
THE BAKERLOO & CHARING CROSS

The Bakerloo Line was opened in sections, the first between Baker Street and Lambeth North on 3 March 1906, followed by the extension south to the southern terminus at Elephant & Castle in August 1906 and then north to Marylebone and Edgware Road in two stages in 1907. The line then remained static for four years until, on 1 December 1913, the line was extended to Paddington and, over the next two years, it was opened in stages to Queen's Park.

The signalling supplied for the Baker Street to Marylebone extension had the usual DC track circuits in use at that time but it is likely they had new DC operated colour light signals (Figure 1) in place of the electro-pneumatic, moving spectacle type. According to the name cast on the door of the case seen in Figure 1, these were supplied by the Westinghouse Brake Company, dating its manufacture to before the relationship with McKenzie & Holland was formalised later in 1907. This is likely to have been the first example of an electric colour light signal installation on the LER tube lines.

There is a drawing of this design, dated 1909 (Figure 3). The design includes an integral DC relay behind the signal lamps and is similar to some of the DC signals supplied to the Metropolitan Railway pre-1913. Signals of this design also appeared on the Hampstead extension to Charing Cross (now Embankment) and the associated terminal loop that was opened in 1913. Although AC fed track circuits and AC fed signals were already in use on the Central London at this time, it is likely that the Hampstead installed AC track circuits on the loop but had DC fed signals, as used for the Met's Baker Street station area resignalling in 1912-13. This order must have just pre-dated that for the Bakerloo's Paddington extension, which was opened with AC signals.

Figure 1: A colour light signal supplied by the Westinghouse Brake Company, confirming that it was designed before the formation of the McKenzie Holland & Westinghouse Power Signal Co. in 1907. This signal is believed to be located at Marylebone. Photo: Collection B.R. Hardy.



Another oddity about the signalling on the Charing Cross extension is that they used the original e.p. moving spectacle signal type in at least one location (Figure 2). There may have been others. This could simply have been because they had some spares to use up or perhaps the alterations required at Strand for the extension released some of the original signals for use on the loop.

Figure 2: Signal S262 on the Charing Cross loop of the Hampstead Line. This signal would have been installed for the opening of the loop in 1914, although, by then, the design was long out of date, having been superseded by colour lights. It had been superseded by the design shown in Figs.1 and 3. Photo: Thomas, J.P. 'Handling London's Underground Traffic, 1928, p.95.

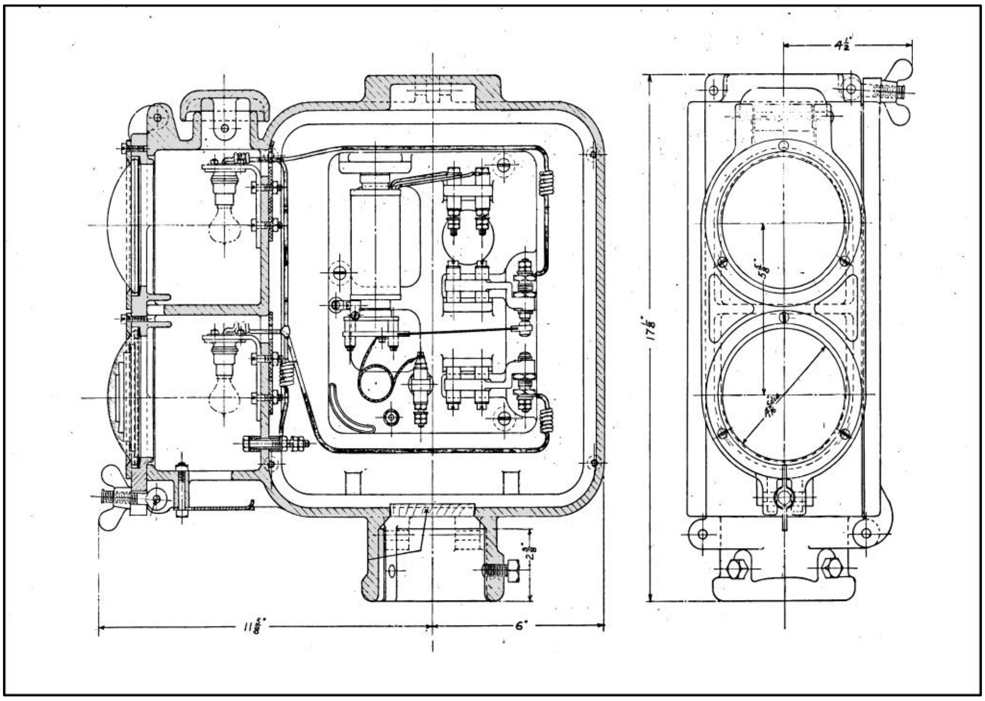


Figure 3: A drawing of a Westinghouse signal from 1909. It's very similar to the design seen in Figure 1. The design used DC circuits and was most likely the next type used after the electro-pneumatic mechanical signals installed for the original tube lines in 1906-07. In this design, the signal operating relay is inside the case behind the lamps. There is a single lamp for each lens. Later designs had two lamps in case one failed. Some internally modified versions of this design have survived around the system on both tube and sub-surface lines. Drawing adapted from Westinghouse C636, courtesy Westinghouse Archive and Chippenham Museum.

When the Bakerloo was extended to Paddington, the station had a simple two platform layout arranged with a scissors crossover at the northern end. Trains arrived in the northbound platform and departed from the other. Reversal was through the crossover to one of two dead end tracks beyond. The extension appears to have used AC track circuits and Westinghouse 'Style A' colour lights (Figure 4) for all signals, including shunt signals, similar to the Central London resignalling of 1912-13. At the northern end of the station, the shunt signal is reported to have been provided with an arrow system separately indicating which siding had been selected[1]. This is also the first recorded instance of a platform repeater for a shunt signal. The signal is described as having a small green lens and a normal size yellow lens.

Figure 4: The current northbound inner home signal at Paddington Bakerloo. The case is the original AC supplied 'Style A' design used when the extension from Edgware Road was opened in 1913 and it is labelled McKenzie Holland and Westinghouse Power Signal Co. Ltd. This design was unique in having a circular case. Over the years, the signal has been renumbered and the position of the case may have changed. Photo: Tom Crame.

The Bakerloo's Queen's Park extension also used AC track circuits and colour light signals in the tunnel section. The signals at Queen's Park were upper quadrant semaphores[2], following the precedent set by the Central London in 1912 with their new upper quadrant signals at Wood Lane. Railway managers still hadn't accepted the idea that colour lights were acceptable for open sections. The semaphores, and the points and trainstops, were electro-pneumatic, as usual. Although not recorded, it is probable that the points in tunnels or confined locations were similar to the four-foot design used on the Central London's Liverpool Street extension. It is also probable they used track circuit point lever locking in place of fouling bars. I doubt that any future new installation would use fouling bars when track locking was so much simpler. The locking bars on existing points are recorded as being removed and replaced by track circuit locking from 1913[3].

FLUX NEUTRALISER

The new Westinghouse AC electric Style A colour light signals used for the Central London Railway resignalling of 1912-13 and the Bakerloo extension to Queen's Park, introduced a new system of lamp switching. It was known as the 'flux neutraliser'. In simple terms, it operated by feeding a supply to the red lamp permanently but it was suppressed electrically when it was required to show the green lamp.

---

1. Railway Magazine, January 1914, p.68.
2. Railway Magazine, December 1915, p.487.
3. Horne, M. (2007), 'The Last Link' Nebulous Books, TfL, LTM, p.58.

It had the effect of causing a red aspect to show if something went wrong with the electrics. It was done this way to remove the need for a relay inside the lamp. Relays were mechanical and therefore needed regular maintenance. The DC colour light signals used on the Metropolitan Railway had up to three relays inside the signal casing and space had become tight. The next design of Westinghouse AC lamp signal, Style B introduced in 1913, went back to being housed in a rectangular box that included a flux neutraliser. A later version (Style E of 1915) was used on the Underground. Many of the circular Style A units survive to the present day, although the flux neutralisers have been removed and the rest of the contents have been updated or replaced. The design that replaced them in the mid-1920s used separate relays mounted in trackside boxes, as we will see later.

EALING & SHEPHERD'S BUSH

There had been an aspiration for a rail connection between the West London Railway near Wood Lane and the Great Western main line at Ealing Broadway since 1905. It was originally intended as a freight route but it was soon decided that it should be also connected to the end of the Central London Railway at Wood Lane so that their trains could work through to Ealing Broadway. Although construction work was completed by 1914, it wasn't until 4 August 1920 that the electrification and full signalling of the 'Ealing & Shepherd's Bush Railway' (E&SB) was completed and opened for passenger traffic. The line was electrified with the Central London's 3-rail system, using a central conductor rail. The service was operated by Central London trains working to and from Liverpool Street. The line was fully track circuited, using AC track circuits and a mix of galvanometer track relays and 2-element vane line relays.

Because the route was built and equipped almost entirely by the Great Western Railway (GWR), the signalling was to their specification. They decided to try out 3-position semaphore signalling on the line, based on a system designed in the United States. They had already installed a signal as a trial on the down main out of Paddington station in 1914 and a number of other railways in Britain had tried them on short sections between 1916 and 1920.

THREE-ASPECT SIGNALLING

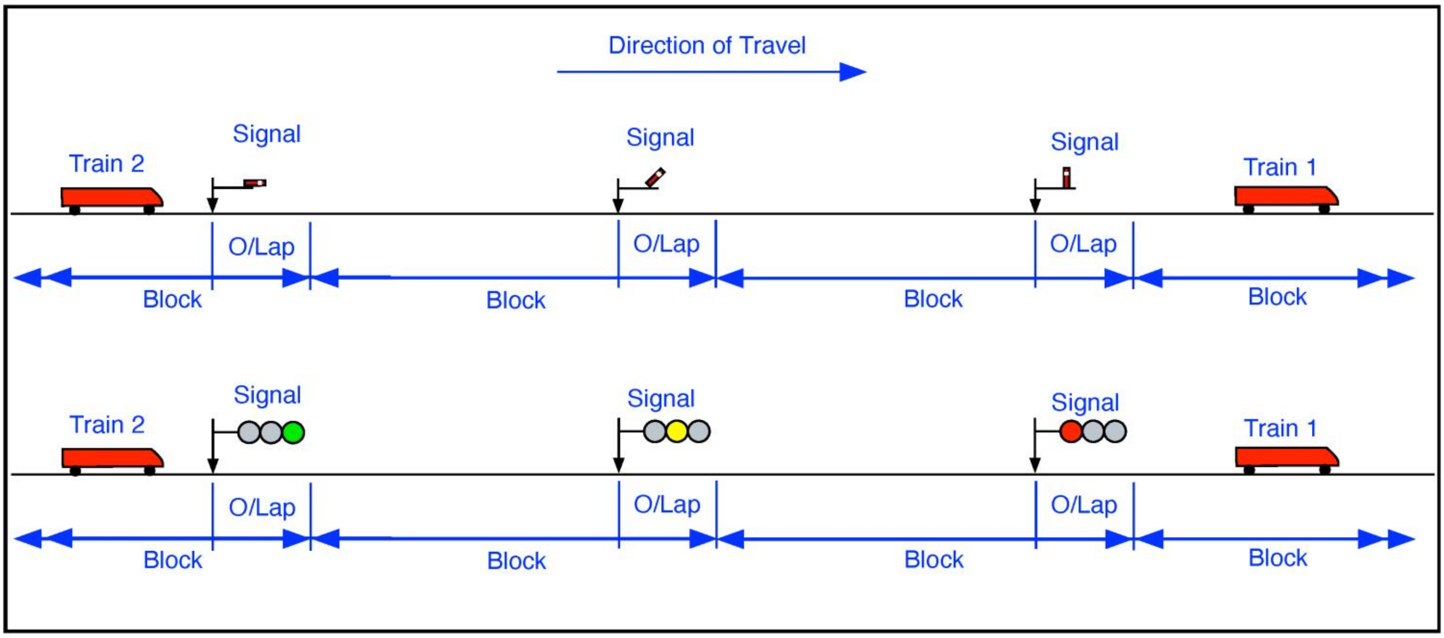


Figure 5: The basics of 3-aspect signalling. The top diagram shows the semaphore version with, from left to right, the clear signal in the vertical position, the caution signal at 45-60 degrees and the stop signal at 90 degrees. The colour light equivalent is shown in the lower diagram with green, yellow and red aspects respectively. The upper diagram demonstrates the system used on the Ealing & Shepherd's Bush line. The colour light version was used on the Metropolitan Railway for new installations after 1924. Drawing by P. Connor.

In last month's article, I briefly mentioned 3-aspect signalling in connection with the provision of 3-aspect fog repeaters on the Metropolitan Railway but, as we've noted throughout this series, railway signals were (and still are, really) basically about 'stop' or 'go'. A signal protects a section like a gatekeeper – you may enter if it's vacant inside, but not if it's not. Nowadays, we would call it 'the limit of movement authority'. Distant signals were a warning, set a nominal braking distance back from the home signal, to give trains space in which to stop if necessary. Repeaters on the Underground, we should remember, weren't the same as distants. They were only provided where sighting was poor. Elsewhere, with the lower speed of trains, stop signal sighting distances were sufficient to give drivers time to stop. However, three-aspect signalling was a development based on different circumstances.

`Three-aspect signalling (or '3-position' for semaphores) came from the US as a result of the desire to have automatic signalling with track circuits on higher speed main line routes. They also wanted to increase capacity and, at the same time, eliminate signal boxes (and staff) over long plain sections of track. The basic idea was to provide for train speeds that varied between a slow-moving freight train, a stopping passenger train and an express passenger train. With the higher speeds, it was realised that two-position, stop/go signalling wouldn't do. If you wanted to apply automatic signals to main line railways, you had to provide early warning of stop signals for higher speed trains (Figure 5).

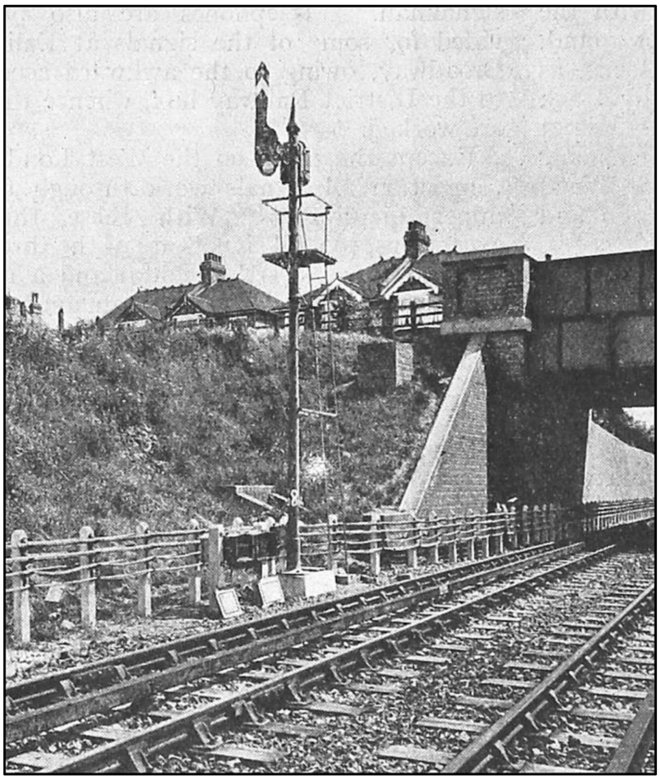


Figure 6: This is an example of an automatic 3-position semaphore signal as provided for the E&SB line between Wood Lane and Ealing Broadway. This is S81, the first automatic signal seen after leaving Ealing Broadway, going east. The signal is in the all-clear position showing that there are at least two clear sections ahead. The semaphore arm is pointed to denote it is operated automatically. Controlled signals had square ends. The photo was probably taken before the line was ready for the Central London as the trainstop has not been fitted and equipment cases are open. Also, the rails look as though they haven't been used in a while. The bridge behind the signal carries Hanger Lane, now part of the North Circular Road. Photo: From a Westinghouse original.

In Britain, since there was little experience of 3-position signalling, the Institution of Railway Signal Engineers (IRSE) set up a committee in 1922 to review the question as to whether and how it should be implemented. Their report was published in 1924[4]. It had taken two years and, in the process, the coverage had been expanded beyond the original 3-position remit and the recommendations included proposals on shunt signals, route indications and 4-aspect signalling. They also recognised that semaphores were on the way out and that colour light signals were now the go-to solution, so they decided to call the system 3-aspect rather than 3-position signalling.

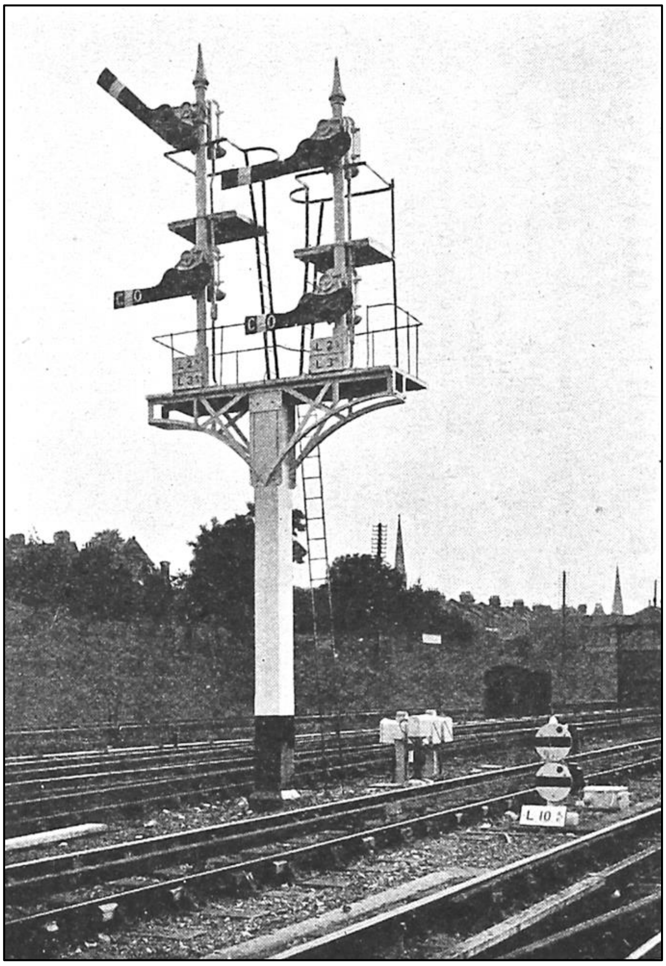


Figure 7: The inner home signals on the approach to the new Central London Railway terminus at Ealing Broadway in 1920. The ends of the signal arms are square to show that they are semi-automatic. Two sets of signals are provided. The top two arms are for the two platforms of the terminus. The lower arms are calling-on signals to allow coupling of trains. The letters 'C' and 'O' are displayed before and after the white band respectively on the semaphore arm. The two disc ground signals are to a GWR design with red and green aspects but with upper quadrant movement to match the semaphores. The main signals here only operated to the caution level as they were covering a route into a dead end. This was another new feature of the 3-position system. Photo: From a Westinghouse original.

The 1920 Ealing extension installation pre-empted the IRSE report and it was the leader in being the first full implementation of 3-position signalling in Britain.

---

[4] IRSE (1924), Report of the Committee on 3-Position Signalling, 10 December 1924.

It was chosen because of the requirement to mix occasional freight trains with long braking distances and frequent electric passenger trains with shorter braking distances over the same lines. They also wanted to reduce the number of signal boxes by automating the signals where they could.

The equipment had a number of interesting, perhaps odd, features. The semaphores and trainstops were electrically operated, using AC motors. The track circuits had galvanometer type AC relays, similar to those used for the Metropolitan Railway's resignalling at Wembley Park and up to Harrow South Junction in 1914. The ground signals were designed to the Great Western disc format (Figure 7) but they were made to rotate clockwise for the installation at Ealing Broadway instead of the GWR standard anticlockwise pattern. In this, they matched the upper quadrant operation of the semaphore signals. As shown in Figure 7, the pair provided for the eastbound track reading over the routes into the terminal platforms are stacked vertically rather than horizontally like the semaphores. This was doubtless due to the cramped location in the 6-foot. They were also electro-pneumatic, using the air supply from the District Railway next door. This meant that the main signals were electric while the ground signals were E.P., a rather odd combination. These were probably (since I can't find a reference to any earlier instances) the first disc shunt signals to be used by Underground trains.

Despite E.P. operation at Ealing Broadway, the points at North Acton and West London Junction were mechanically operated. North Acton had the traditional individual, lever operated facing point locks, while the West London Junction facing point operating lever was locked by the 400 foot long approach track circuit, another odd mix. Even more curious was that the terminus was controlled from a new miniature lever frame installed inside the District signal box. This meant that the Central London platforms at Ealing Broadway were built by the Great Western and controlled by signals supplied by the Great Western, partially powered by air supplied by the Underground and controlled by a signal box on the Underground. The signalling equipment was supplied by the newly reformed Westinghouse Brake & Saxby Signal Company and installed by Underground staff. According to the Railway Magazine[5], the maintenance of the equipment was done by the Underground.

Some of the overlaps on this line were very long, no doubt because of the intended use by long, unfitted freight trains. The overlaps ranged between 400 and 450 yards, at least three times as long as the 400 feet normally installed on the open sections of the District. The line was equipped with 2-aspect fog repeaters but, again because of the freight operations, they were placed 200 yards in rear of the signal they repeated rather than the 100 yards set for the Metropolitan[6].

EDGWARE

Figure 8: A 4-car train of new 1923 Tube Stock approaching Golders Green after the completion of track alterations for the extension to Hendon. The outer home signal is an upper quadrant semaphore. Nearer to the camera is a pair of 2-aspect fog signals for the inner home junction signal. Photo: LT Museum.

Meanwhile, the Underground group was working on their extension of the Hampstead line from Golders Green north to Edgware. Although this was to be part of the London Electric Railway tube network, the signalling technology adopted for the extension was new to the Underground group. It was all electric. This was a divergence from existing policy and followed the technological path taken by the Metropolitan Railway. It was adopted as an experiment, to get a direct comparison with the all-electric system, probably because the Met.

---

5 Railway Magazine (1920) December 1920, p.387.

6 A full technical description of the new signalling is provided in 'The Signalling of the Ealing & Shepherd's Bush Railway', Railway Gazette, 29 October 1920.

seemed to do OK with it and it would have been recognised amongst some engineers that it would be useful to get rid of the air main and all the paraphernalia needed for the electro-pneumatic operation[7].

The extension was opened in two stages, the first as far as a temporary terminus at Hendon on 19 November 1923, the second to the intended terminus at Edgware on 18 August 1924. The signalling equipment was supplied by Westinghouse and it was an updated version of the Metropolitan Railway's all-electric system that had been introduced in stages between 1913 and 1920. Part of the work for the extension involved building a new southbound platform at Golders Green, a northbound and a middle platform (both double-sided) and new single-sided southbound platform.

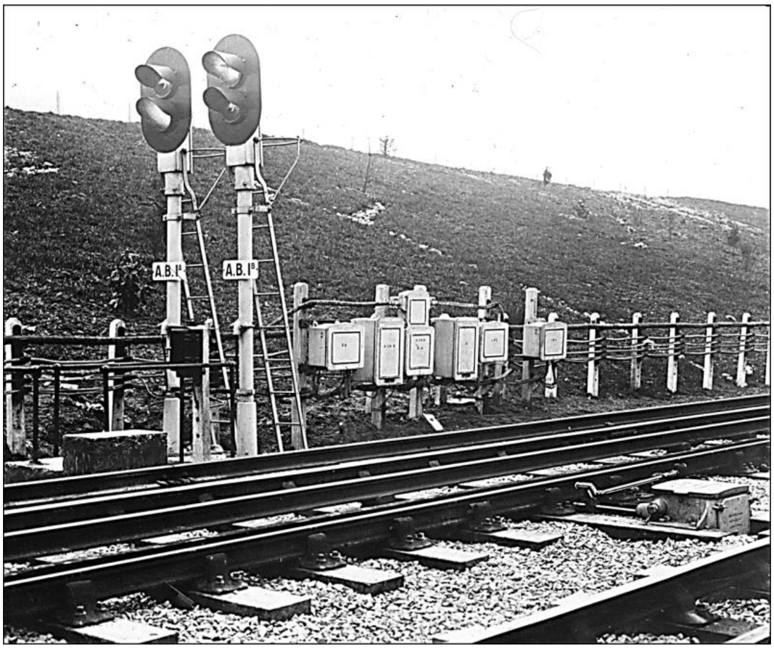


Figure 9: The new northbound junction home signals installed for the opening of a Hampstead line extension to Hendon (Cabin code AB) in November 1923. Two signals were provided, one for each route into the temporary terminus. Although the outdoor type of long rang colour light signals had already been tried by the Metropolitan Railway, this was the first use of the type on the Underground group's lines. Note also the electric trainstop between the two tracks. It is fitted with an external circuit breaker operated by a lever connected to the trainstop head to detect that it is in place and not broken. Photo: Westinghouse Archive and Chippenham Museum.

The new line saw the first use of long-range outdoor colour light signals on the Underground group's lines (Figure 9). These were to become the Underground's standard design, with minor modifications, until the 1970s, when new signal heads were procured to a modified British Rail off the shelf design. The first of these is believed to have appeared at Northfields in July 1974 when new signalling was commissioned there.

Another feature of the Edgware extension was the use of 2-aspect colour light ground signals for shunting purposes (Figure 10). Earlier examples of open section ground signals on the Underground group's lines had been miniature semaphores and it is likely that the ones installed on the Edgware extension were the first example of colour light ground signals used in the open. They became known as 'globe signals' because of their rounded lenses. When these signals were replaced by externally lit disc signals in July 1952, they were refurbished and used elsewhere around the system. Some of the type are still in use on the Whitechapel to Bow section of the District.

Despite the use of colour light signals on the extension, Golders Green retained some semaphore signals from the original set-up of 1907. The two new northbound starting signals and the southbound starter from Platform 3 (now platform 5) were new colour lights but the other two southbound starters, which were standard Westinghouse lower quadrant semaphores, remained[8]. However, as seen in Figure 8, the northbound outer home semaphore signal is of the upper quadrant design. This was unusual and led me to some further digging to find out why.

We saw in Article 13 that the upper quadrant type was first seen on the tube railways at Wood Lane on the Central London in 1912, so we could assume that the signal at Golders Green was installed after 1912. As it turns out, it was in 1917, when the original home signal was resited to be nearer to the station to allow the fitting of calling-on signals and its replacement outer home was the new standard of the time, an upper quadrant type. This policy of adding new types of signal whilst retaining older designs, as we will see in many future upgrading and resignalling schemes, led to a mixture of types and aspects that, in some locations, became quite complex.

---

7 Dell, R. (1944), 'Developments in Railway Signalling on London Transport', *Journal of the Institution of Electrical Engineers-Part II: Power Engineering*, *91*(23), pp.400-415.

8 Murphy, S. (2005), Northern Line Extensions Golders Green to Edgware, Tempus Publishing, pp.65, 72.

Figure 10: Colour light ground shunt signals, set in concrete bases, another example of the first installation of the type on the Underground group's lines, seen in front of two stabled 1923 Stock trains at Edgware. Photo: LT Museum.

A feature of colour light signal design which appeared around this time was the removal of the signal controls from the signal head. The signal head now became simply a lamp box with some wiring terminals. All the rest of the kit was fitted in trackside boxes, alongside the boxes for the track relays, fuses, resistances and transformers, as can be seen in Figure 9. Again, this was to become the standard for future installations.

ELECTRIC OR AIR?

According to Robert Dell, who was London Transport's Chief Signal Engineer from 1941 to 1970 and who had been the signal installation engineer for the Edgware extension, the all-electric installation was closely watched but he wasn't convinced that it was worth adopting. He regarded the electro-pneumatic system, with a simple cylinder and piston able to provide all the force necessary to operate a trainstop arm or shift a pair of points, as better than the electric system[9], which he thought was too slow and more complicated. Less maintenance was needed for the pneumatics and the equipment was lighter, making it easier to replace. It was also more reliable than the electric system and it worked faster. Point operation was three times faster with e.p. operation. Even today, modern electric point machines do not get better lock to lock times than an electro-pneumatic machine.

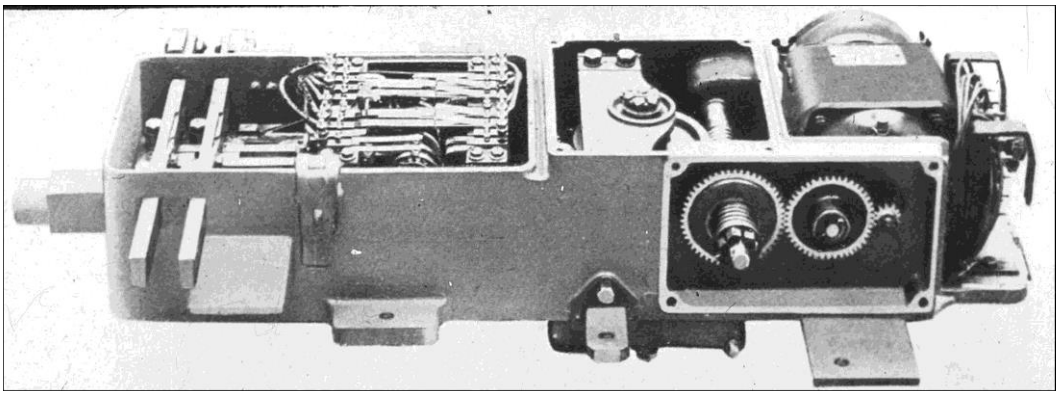


Figure 11: The Underground group's Edgware extension of 1924 saw the introduction of Style M2 electric point machines, to the Underground. The design also incorporated the facing point lock inside the machine rather than in the 4-foot. Photo: Westinghouse Archive & Chippenham Museum.

Despite a lengthy and hard fought rearguard action, the first of a series of battles for the retention of the e.p. system was lost to the commercial considerations of the new procurement regime introduced in the early 1990s when the contract for the new automatic train operation system for the Central Line was let to Westinghouse as a design-supply-install project. The first electric machines of Westinghouse Style 63 (a development of their M3 design) were installed at West Ruislip in 1991.

A repeat of the battle was fought as a result of the PPP (Public Private Partnership). In the associated upheavals to London Underground engineering in the early 2000s, the operational advantages of the e.p. designs were pushed aside in favour of commercial, off-the-shelf electric systems. By this time also, there were new issues over the operation and maintenance of the air main, particularly in respect of new safety and testing requirements for pressure vessels and pneumatics. There was also the desire to reduce the amount of equipment trackside. The combination of these considerations led to changed thinking and nowadays the electro-pneumatic equipment once common over the whole of the Underground is gradually being replaced.

To be continued …

---

9 Dell, *ibid.*