LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
25. LEVERS AND FRAMES

LOCKING

As I described in Article 8, signal and point levers in a signal box were linked through a mechanical interlocking system. Although, these days, the word 'interlocking' is bandied about to mean a number of different features in a signalling layout or even the whole layout, the original definition refers to the system in a signal frame that prevents a conflicting route being set up. This was achieved by designing the lever arrangements so that a lever would not move if another lever was being used to set up a conflicting route or movement. It was locked. Traditionally, this was achieved by a complex system of horizontal and vertical bars that moved in concert with the movement of the levers. The system was referred to as the locking frame.

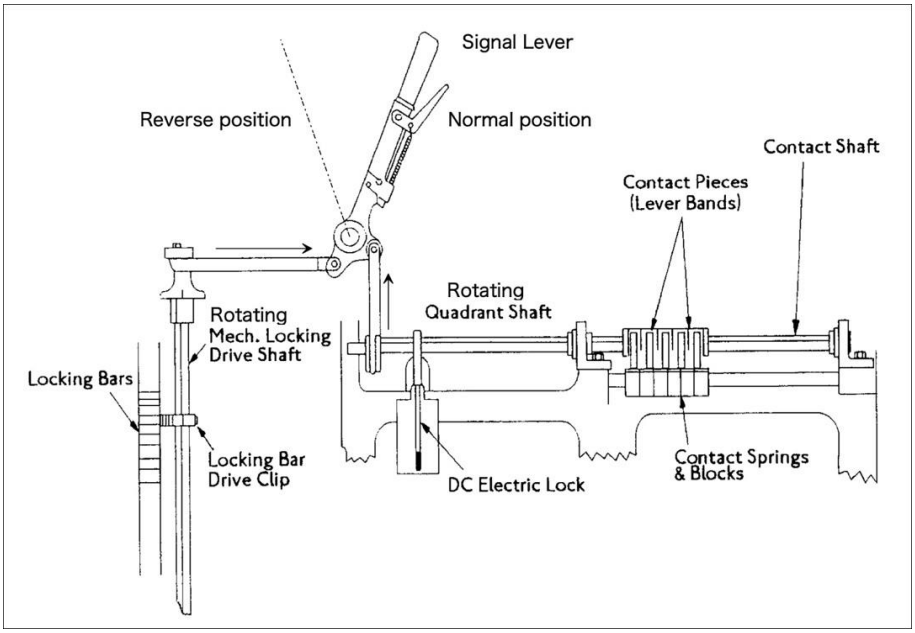

Figure 1: The lever and shaft drive system on a Westinghouse Style B signal frame. When pulled from Normal to Reverse, the lever causes two shafts to rotate, one horizontal, (the contact shaft) and one vertical, (the locking drive shaft). The vertical shaft had a "drive clip" which had a small, geared section that meshed with a toothed rack on the locking bar to move it left or right. The DC operated electric lock was used to hold the shaft to prevent the lever being restored fully to normal until the route was cleared. The contact pieces connected the electrical commands, selected by the lever position, to the signal and point drivers. Drawing from Signal Design Handbook, Vol.2, LU 1999 modified by P. Connor.

The traditional, full size interlocking system used by most railways, had bars called tappets that moved with the movement of the lever. As the tappets moved, locks on a horizontal locking bar moved sideways to lock or release the lever. On the Underground group's lines, the Westinghouse miniature lever frames worked differently. Movement of the lever from Normal to Reverse caused a vertical shaft to rotate as the lever was pulled (Figure 1). It also rotated a horizontal shaft (the contact shaft) which carried the electrical contacts to send commands to the point and signal motors.

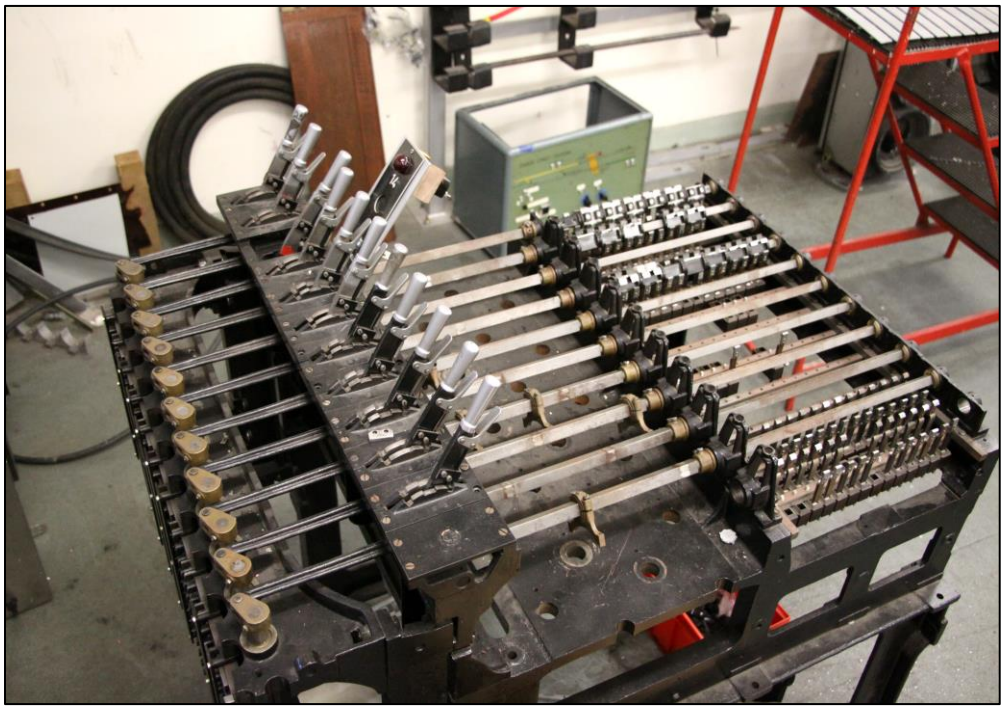

Figure 2: The guts of a single, 11 lever section of the Style B frame, showing it with the covers removed. This photo shows the main internal features of the frame but with the electric lever locks taken out. The names of the parts are shown in Figure 1 above. Photo by Tom Crame.

The rotating shaft design was another import from America. It was known at the time as cross-locking or Hambay locking. It was designed by James T. Hambay of the Union Switch & Signal Company (US& S) and he was a US patent for it in 1889[1]. It had been fitted in a larger form to Saxby & Farmer full size mechanical frames in the US before being adopted for power frames manufactured by US&S. It was seen in Britain first in the frame installed at Granary Junction (GER) as I described in Article 10.

Unlike the traditional locking frame with full sized levers, the Underground's miniature levers moved the horizontal locking bars while the vertical bars, known as 'crosslocks' on the Underground, were moved up and down by the 'dogs' on the bars. The name 'crosslocks' is rather odd, since they didn't move across; they moved up or down. Figure 3 shows the basic operation.

FRAMES

The standard lever frame used by the Underground group was the Westinghouse Style B type (Figure 1), which was adapted from the US&S design installed at Granary Junction and was used for most of the new installations on the District and LER lines from 1905 up to 1932, as I mentioned in Article 10. On the Metropolitan, they generally stuck to full sized lever frames adapted for power operation of points and signals as necessary after electrification in 1905. Some boxes had a mixture of direct mechanical operation and power operation of points.

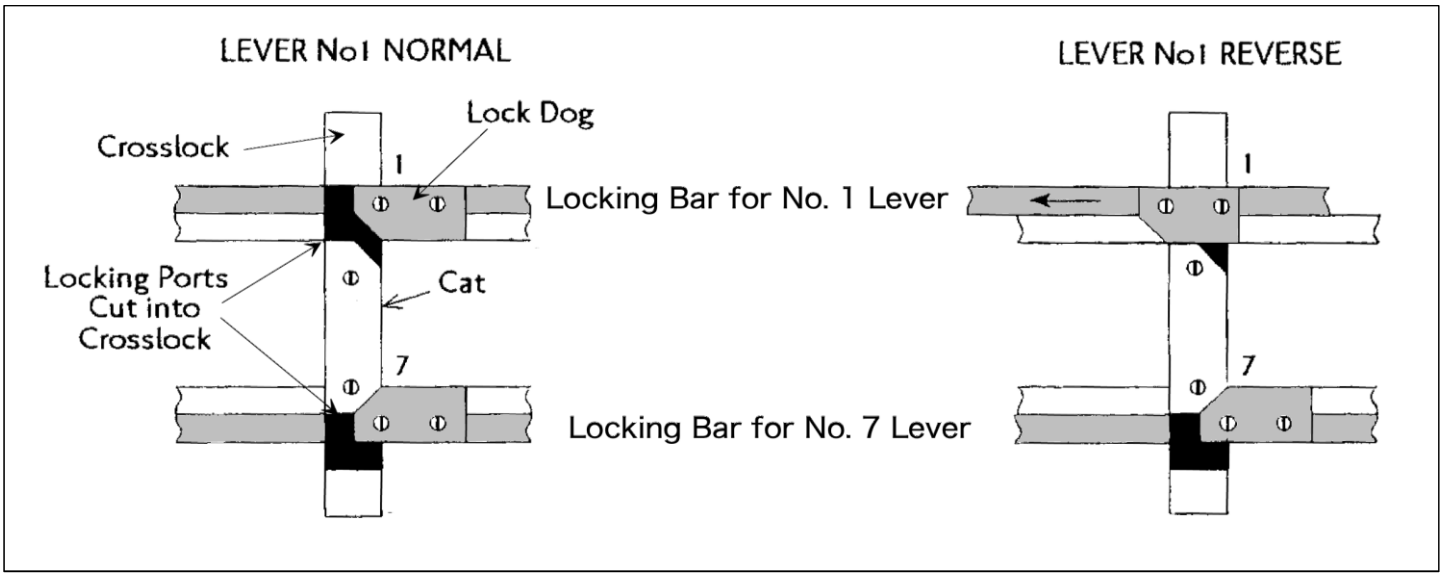

Figure 3: A diagram showing the basic operation of mechanical locking on the miniature lever frames used on the Underground. Each lever drives its locking bar (in grey) from right to left as it is moved from Normal to Reverse. The 'lock dog' is fixed to the locking bar and moves with it. With Levers Nos.1 and 7 in the Normal position, the locking is as shown on the left. If Lever No.7 is reversed, its locking bar will move to the left and force up the crosslock so the 'cat' is in contact with the 'dog'. This prevents Lever No.1 from being reversed because its locking bar is locked. If Lever No.7 is in the normal position and Lever No.1 is reversed, its locking bar moves to the left, as shown in the right hand diagram and the 'dog' moves to the left to sit fully over the port cut into the crosslock. The crosslock is now locked in position and prevents Lever No.7 from being reversed. Drawing from the Signal Design Handbook Vol.2, LU, 1999, modified by P. Connor.

The Metropolitan Railway generally kept their full-sized lever frames but they did purchase Style M1 miniature lever frames for Aldgate and Praed Street signal boxes in 1908 (Figure 4). These were based on the very earliest miniature frames which retained the traditional form of vertical tappet which drove the horizontal locking bars. These were modified versions of the original Style A miniature lever frames used with Westinghouse electro-pneumatic (e.p.) systems up to mid-1903 but with the circuits arranged for electric operation of points and signals. There were a few examples of them on the main line railways but none on the Underground. Baker Street got a Style M2 frame in 1911 (Figure 5). This was a modified version of the M1 frame. As we've seen, most other Metropolitan signal boxes had full sized levers and mechanical interlocking with electric connections added as required for point and signal operation and for lever locks and indications. Some of these were built by the Metropolitan's own signal staff and some were purchased from other suppliers, like the British Power Railway Signal Company frame installed at Farringdon in 1932.

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[1] Tilly, J. (2010), *'The "V" Style Interlocking Machine',* published by author at **https://tillyweb.biz/crossings/vstyle/history.pdf.**

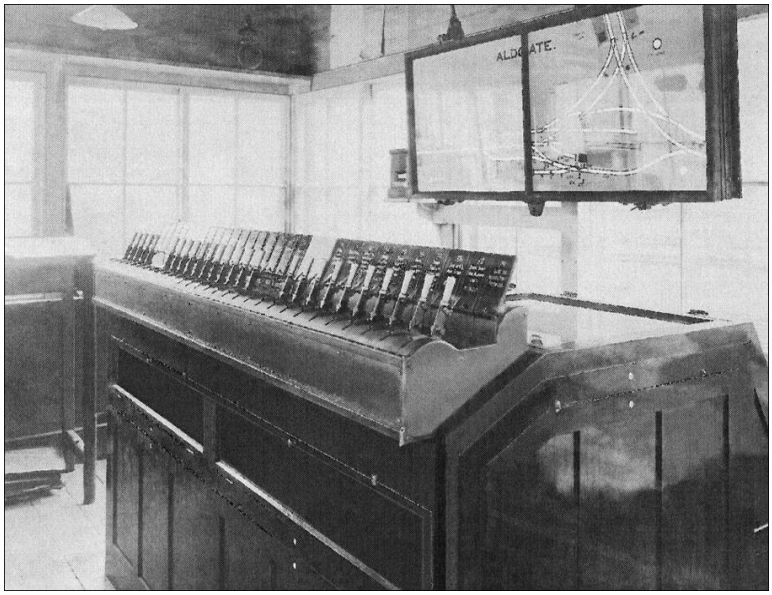

Figure 4 (Left): Westinghouse Style M1 frame in Aldgate signal box used from 1909-1927. This box was located at the end of the Circle Line Inner Rail platform. As part of the station rebuilding in 1927, a new box was built further west and this frame was moved there. It was replaced when a new box was built over the station and opened in 1946. The M1 frame design is quite distinct compared with the Style B frame. It looks as if the levers were added as an afterthought. Note how the lever nameplates are stand alone rather than being incorporated into the cabinet as on the Style B frame. Photo: Originally Westinghouse.

Figure 5 (Right): The newly installed Style M2 frame provided for the rebuilding of the junction at Baker Street in 1911. This design is derived from the M1 frame provided at Aldgate. This frame was replaced in 1925 when the track layout at Baker Street was modified for the building of new offices and the Chiltern Court flats. A new signal box was built at the same time. Photo: Railway & Travel Monthly, November 1913.

FRAME DEVELOPMENTS

For the electric points and signals on the extension of the Hampstead Line from Golders Green to Edgware in 1924, Style K frames were used. These were essentially the same as the Style B but with contacts arranged for electric operation rather than e.p. The Metropolitan also had Style K frames installed to replace older equipment at Baker Street, Edgware Road and Whitechapel (East London) in 1924-26. Then, in 1930, a new design of frame known as the Style L, appeared at Wembley Park (Figure 6). This was to be the only Style L frame on the Underground. The Style L frame was the first design to eliminate mechanical locking of levers. The interlocking was electrical, achieved via lever contacts, completing or breaking the circuits to the electric lever locks.

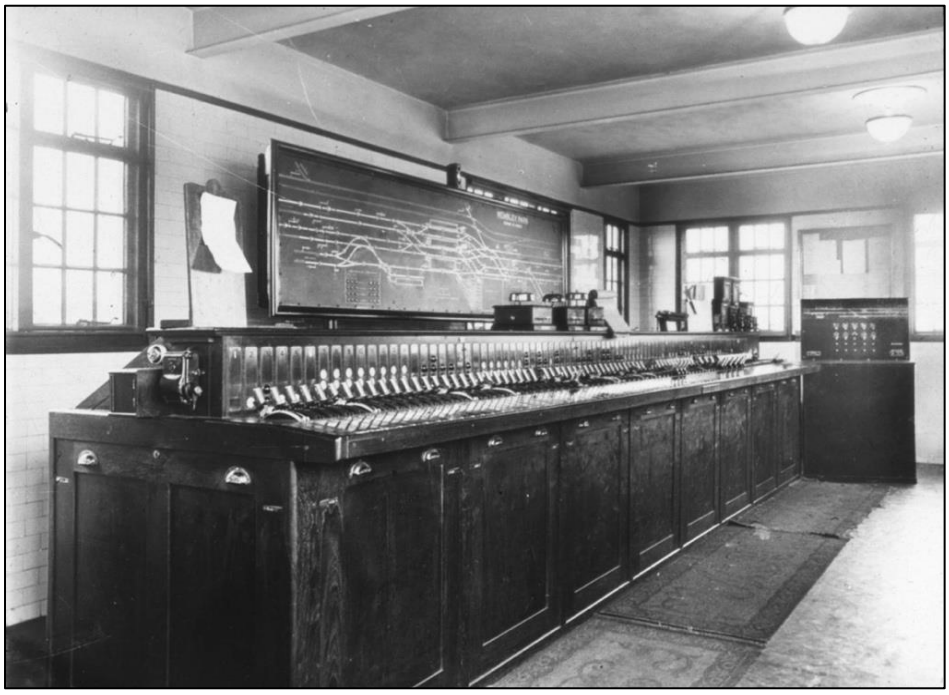

Figure 6 (Left): The all-electric Style L lever frame in the signal box at Wembley Park. It was supplied in 1930 by Westinghouse for the resignalling for the building of the junction for the Stanmore branch in 1932. This photo shows the dark screen type of diagram used by the Metropolitan in its later installations at places like Edgware Road and Farringdon. At the far end of the frame, the small control panel installed for the Stanmore branch in 1932 can be seen. This was the panel that used the system known as Centralised Traffic Control or CTC, as described in last month's article. Photo: Courtesy Westinghouse Archive & Chippenham Museum.

The Style L frame was designed by Walter Pearce who, as I mentioned in Article 10, was responsible for the development of the B Style frame back in 1903. He was already approaching the then retirement age of 65 in 1928 but he was still developing new ideas like electric interlocking for signal frames. The Style L was first installed at North Kent East Junction on the Southern Railway in January 1929 and the design became popular on that railway, with large versions of it appearing later at places like Waterloo and Brighton.

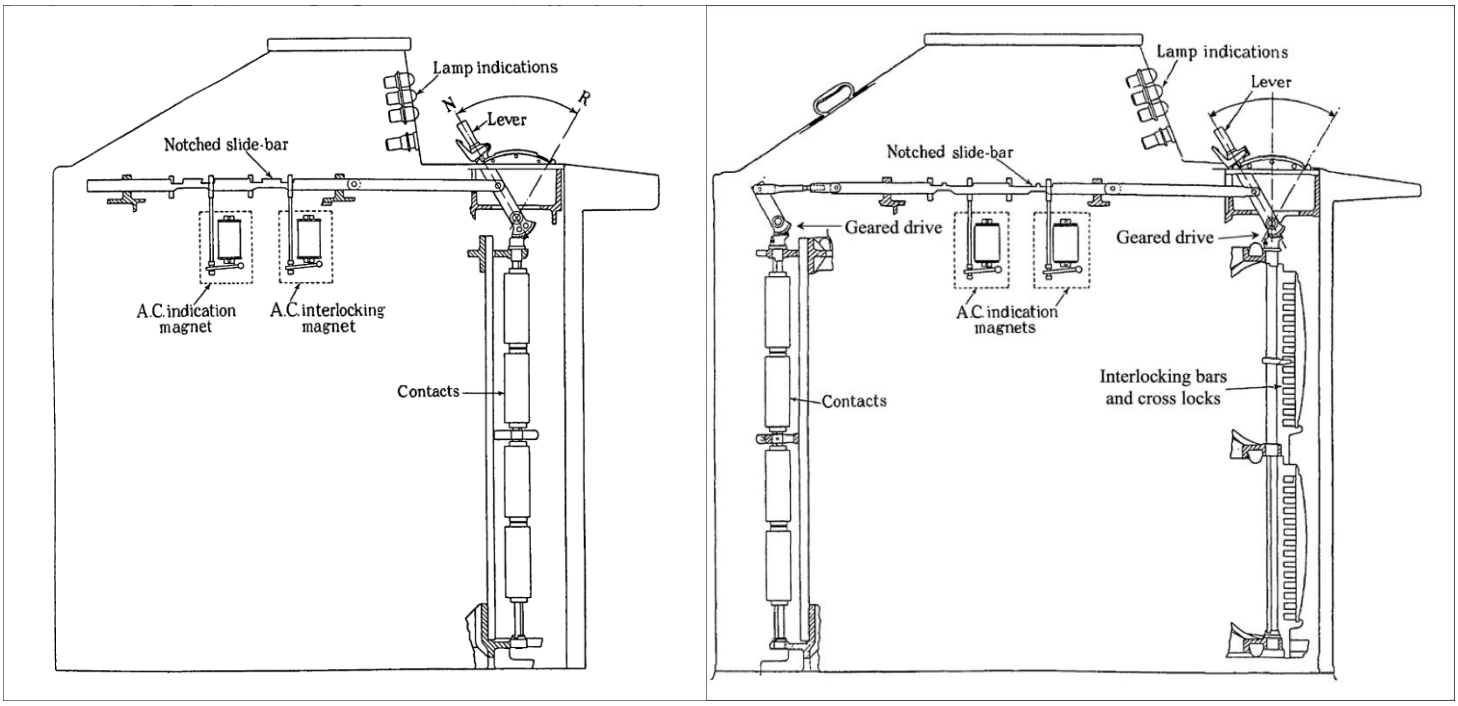

Figure 7: Side views of the Westinghouse Style L (left) and Style N (right) lever frames showing differences between the two types. The mechanical locking has gone on the Style L frame as it has all-electric interlocking connected through the contact shafts at the front of the frame under the levers, together with the control circuits for signals and points, whilst the Style N frame has mechanical locking at the front and the electric contacts for the control circuits at the rear. The only Style L frame on the Underground was at Wembley Park but a total of 47 Style N frames were supplied to LU between 1930 and 1946. Drawings from: Peter, L.H., 1936. 'Modern developments in railway signalling'. Journal of the Institution of Electrical Engineers, 78(472), pp.353-371.

THE STYLE N FRAME

On 18 September 1932, a new signal box was brought into operation at Wood Green for the opening of the Piccadilly Line extension from Finsbury Park to Arnos Grove. It had a small, 15 lever Westinghouse Style N frame (Figure 8). It was installed to control the reversing siding at that station but the area was also designed for a form of remote control and, as part of this, it introduced relay interlocking to the Underground group.

The Style N frame was a new product by Westinghouse. It was specially designed for the Underground group and it was never used on any other railway apart from on some heritage railways that have acquired redundant ex-LU frames. It was developed from the Style L electrically interlocked frame but it retained the mechanical interlocking familiar to the Underground's signal engineers.

The first Style N frame entered service at Hyde Park Corner in 1931 as part of the alterations to the signalling in the area needed for the introduction of the Down Street siding. This particular installation was unusual in that the Style N frame was added to the existing Style B frame to form a hybrid. The Style N then became the standard for new installations up to 1954, when a new design of frame, the Style V frame was introduced. The Wood Green frame was the third N frame in the series built by Westinghouse, following the 119 lever frame at Acton Town. Eventually, the Underground bought a total of 47 of them[2].

RELAY INTERLOCKING

The new Style L frame introduced at Wembley Park in 1930 brought with it electrical interlocking of signal levers, otherwise known as 'relay interlocking'. It was the next step from the mechanical

[2] Nock, O.S. (2006) *A Hundred Years of Speed with Safety*, Hobnob Press.

interlocking of levers. The problem with mechanical locking is that it works on the basis of the movement of steel bars in a steel frame, so the bigger the area under control, the more steel you need, the bigger the frame becomes and the heavier it becomes. The frames need to be set up in a rigid structure and all in the same plane to allow the bars and crosslocks to slide freely. Maintenance of these systems is expensive and specialist. The problem was clearly demonstrated with the work required to install the 311 lever frame at London Bridge on the Southern Railway in 1928. The frame was huge and, when complete, it weighed 23 tons. Something needed to be done. Another problem was that alterations to trackwork or signalling in areas with large frames often involved extensive alterations to the locking frame and long downtimes to do the work. The solution was found in relay interlocking.

We have seen that, in mechanical interlocking, when one lever locks another, pulling the first lever moves a 'dog' into the crosslock of the second lever, preventing the second lever from being moved. In electric interlocking there is no mechanical connection between levers. Levers are locked by de-energised electro-magnetic relays acting on the horizontal slide bar operated by the lever (see above, Figure 7 – left hand diagram). When the movement of one lever is required to lock another, it simply opens the circuit to the electro-magnetic lock on the second lever to prevent it from being pulled. Because, in electric locking, each lever is held by a de-energised relay, it is only released when energised by a circuit from other levers which are either in the normal or reverse positions.[3] Relay interlocking a direct replacement for mechanical locking. It was first introduced on the Underground at Wood Green in 1932.

FRAME DETAILS

In a series like this, it is impossible to list all the signal boxes and their frames and cover all the changes that took place over 150 years on the London Underground railways. However, there are some excellent resources listing and describing the signal frames used on the Underground as follows:

'Inventory of Signal Cabins on the London Underground Railways 1863-2020' by the late Mike Horne, available on line at:

http://www.metadyne.co.uk/pdf_files/LTSB_new.pdf

… with a near complete database of all boxes, frames and replacements. Sources and outstanding queries are included.

'Signal Box Register, Volume 8: London Transport', by The Signalling Record Society, 2019. This lists all LU boxes by alphabet and by line. There is a wide range of photos but there are occasional errors.

Nock, O.S. (2006) 'A Hundred Years of Speed with Safety', Hobnob Press. A typical Nock manuscript on the history of his employers Westinghouse but edited by S. Angell, J. Francis, M. Glover and M. Stone and published after his death. It has useful background information and a list of signal frames built by Westinghouse.

Tilly J. (2010), The Style V Interlocking Machine, published by the Author on line at:

https://tillyweb.biz/crossings/vstyle/history.pdf

Further information is also available in various issues of *Underground News* from an occasional series on London Underground signal boxes by the late John Talbot, starting in *Underground News* No.346 October 1990.

REMOTE OPERATION

The Wood Green siding was intended to become a regular service reversing point for the Piccadilly Line and it was decided to try a system of automated remote operation there but still with the capability of using the signal box manually in the normal way if required. The remote operation used the descriptions of trains arriving at Wood Green as the trigger to set the route for the train, either to continue east toward Arnos Grove or to go into the siding to reverse and then start a westbound trip. The routes were set by relays that mimicked the mechanical locking of the levers. When the frame was worked by a signalman, the locking was enforced by the movement of the levers and their bars and crosslocks as normal. When the points and signals were being controlled by the train describers, the levers remained static and the interlocking was performed by relays.

Figure 8: The interior of the new signal box at Wood Green in 1932. The Style N frame had the capability of being operated normally by use of the levers as shown here or automatically, through relays operated by the train description system. Photo: Railway Magazine, Feb. 1936.

[3] Such, W.H. (1963), '*Mechanical and Electrical Interlocking (British Practice)*', IRSE Green Book No.3.

In order to allow the route to be set up for a westbound train to come out of the siding at Wood Green, the descriptions of westbound trains sent from Arnos Grove included those for train starting from Wood Green siding. To transfer control to the train describers, Wood Green had two additional levers, No.8 for the operation of Nos.5 and 6 crossovers and No.9 for the operation of signals. During manual operation, the two additional levers were in the normal position and point and signal levers were operated in the usual manner. For remote operation, all signal levers had to be placed in the normal position and No.8 lever had to be in a mid position half-way between normal and reverse. Nos.5 and 6 levers were also put in the mid-position, after which No.8 lever was fully reversed for point operation and No.9 lever reversed for operation of the signals. These actions set up the operation for relay interlocking. There was no corresponding lever operation at Arnos Grove but there was an additional lever there which needed to be operated to set up a description for a train in Wood Green siding. The diagram at Arnos Grove just had an indicator light that showed Wood Green was in remote control.

Experience with this setup soon showed that, if there was a wrong description or any sort of equipment failure, it was necessary to get the signal lineman to release the system at Wood Green and free the locking on the wrongly set up route. The number of occasions that this happened soon led to it being necessary have a lineman stationed there permanently. Since he was better employed at Arnos Grove, it being a much more complex area requiring more attention, emergency release arrangements were put in at Wood Green from 25 February 1940 that allowed the supervisor there to obtain a time-based release from the system and work the frame manually. The lineman was moved to Arnos Grove.[4]

ROUTE LEVERS

In the early 1920s, ideas began to evolve in Britain that a single lever could be used to set up a complete route rather than having a separate lever for each signal or set of points. Provided the route was clear, the movement of the lever from normal to reverse would operate points on the route and then clear signals once the point detection was proved and the lever reached the reverse position. The levers would be mechanically interlocked as usual but the route would be set up and validated by relays. Various locations had systems of this sort tried out at places like Winchester and Newport on the Great Western Railway and Thirsk on the London & North Eastern Railway[5]. The Underground watched this with interest but, as was by now usual, it went its own way, trying the Wood Green train describer driven scheme first and only then, on 1 July 1934, bringing in a new scheme at West Kensington using route levers and relay interlocking.

There were two signal boxes at West Kensington, West Kensington East (code WB) and West Kensington West (code WC). The box at West Kensington East was built away from the District's main route, overlooking the entrance to Lillie Bridge depot, while the West box was mounted on a steel bridge over the Piccadilly Line tracks where they descended into the cutting leading to the tube tunnels. The West box opened in 1906 while the East box opened in 1908. Both had Style B lever frames and both replaced older mechanical boxes left over from steam days. The territory originally covered by these boxes was divided by West Kensington station. However, following the change of use of Lillie Bridge Depot from being the Piccadilly Line's main depot to being the civil engineer's depot, the box at West Kensington West was only used rarely to signal trains manually. The box was normally left unmanned and in automatic operation and this led to the idea of controlling it remotely, using route levers installed in the nearby signal box at West Kensington East.

PUSH-PULL

The remote control levers in the box at West Kensington East were added to the existing frame. They were designed so that each one could set up two routes. The normal position of the lever was in the middle of the stroke. Pushing the lever forward selected one route and pulling the lever to the opposite position set another route. They quickly became known as 'Push-Pull' levers. The basic operation is shown by the example in Figure 9 below.

There were seven push-pull levers in the frame at West Kensington East, controlling a total of 14 routes in the West Kensington West area. To transfer control from the West box to the East box, certain levers in the West box had to be reversed: a special control lever (No.16) put into the mid position, followed by several point levers also put into the mid position, and then the control lever moved to the reverse

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4 A useful technical description of the system used at Wood Green is available in the IRSE 'Green Book' No. 19 (1963), *Route Control Systems, LT Practice*, pp 32-36 and Figure 14.

5 Woodbridge, P. (2020) A Chronology of UK Railway Signalling 1825 – 2018, 3rd edition, published by author.

position. The signalman in the East box then reversed his special control lever (also No.16), giving him control of the West box, using his push/pull route levers[6]. The frame itself only lasted until 3 October 1948, when the box was replaced by a new one built next door but the push-pull operation was retained.

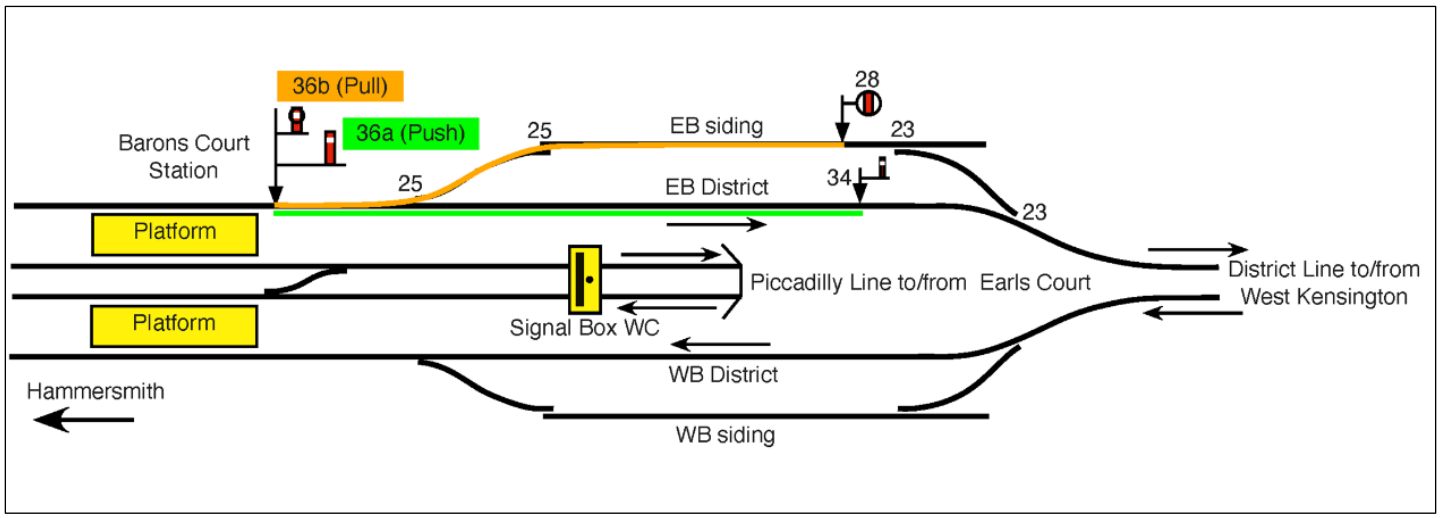

Figure 9: A diagram of the area east of Barons Court as it was in 1934 after the conversion of certain routes to push-pull lever operation and showing how the system operated for one lever. The lever in this example is No.9 in the frame at West Kensington East. In the Push position, it set up the route (in green) along the eastbound District Line from the starting signal at Barons Court (WC 36a) to the next signal WC 34. The route included No.25 points, which had to be in the normal position for Signal 36a to clear. In the Pull position, the lever set up the route (in orange) from Barons Court Signal WC36b into the eastbound siding as far as the outlet shunt signal WC28 at the other end. The signal numbers were all given WC code letters, as their levers were in the frame at West Kensington West but the Push-Pull levers that were used to operate them were all in West Kensington East box (Code WB). Drawing by P. Connor.

There were some new capabilities in the route lever system, including the ability for the signalman to operate a route lever for a conflicting route before the train has cleared the preceding route – so-called 'pre-selection'. The conflicting route could be set up but the relevant signals would not be lowered until the first train had cleared the fouling track circuits. However, placing a route lever in the 'Pull' or 'Push' position only lowered the signals for the route for one train, so the route lever had to be re-stroked for each train using the same route unless the king lever (No.17) was reversed to allow through running. There were two king levers in the East box that operated over routes controlled by the West box. This was another new feature of the push-pull system – remote setting up of king lever operation.

None of this would work without relay interlocking. Describing London Underground's approach to relay interlocking in a paper to the Institution of Electrical Engineers in 1944[7], the Signal Engineer, Robert Dell, wrote,

"*The arrangement of the relay-interlocking system facilitates the signalman's operation of the frame, as although [mechanically] interlocked levers are still employed, they are not electrically backlocked, all the locking being done on the relay-interlocking circuit. The signalman can therefore operate the appropriate levers to set up a fresh route as soon as the front of a train has passed the signal controlling the route previously set up. After the signalman has reset the levers, the passage of the first train, when it clears the appropriate track circuits, completes the circuit necessary for the points to be thrown and the signal is then cleared for the new route".*

The relay interlocking system was described within the Signal Engineer's department as 'Deterflex', according to drawings of the period and later. The name appears on a drawing at least as early as 1937 but it does not seem to have been applied before this date. It never appeared in any operating instructions. To the best of my knowledge, it never appeared in any technical literature either, apart from in 'London Transport Railway Signalling', (Nebulous Books, 1999) and John Tilly's paper on the Style V Interlocking Machine[8].

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6 Tilly, ibid and LPTB, Supplement to the Traffic Circular No.25, 1934.

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 Tilly, J., ibid.

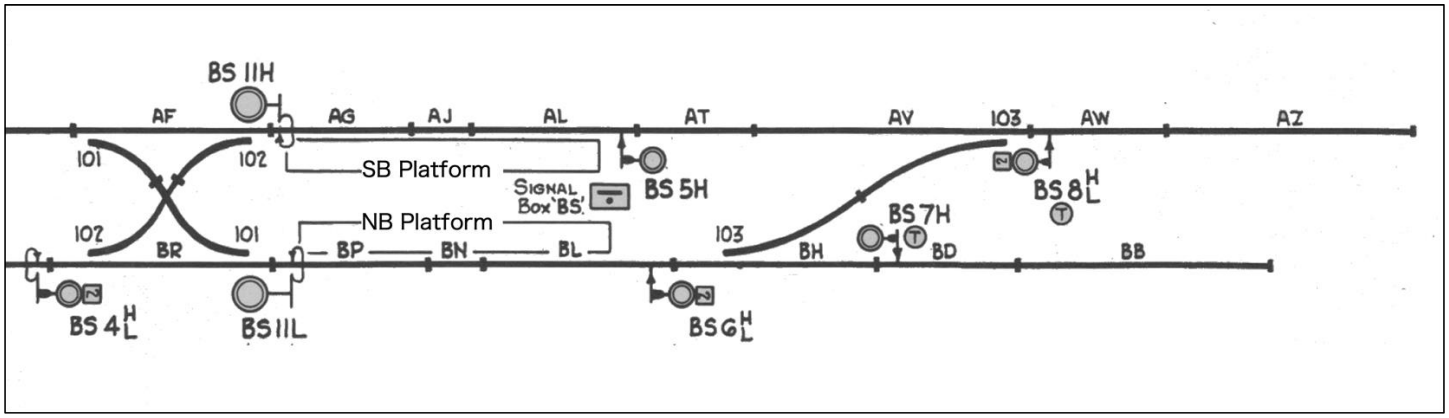

Figure 10: This diagram shows part of the layout at the terminus of the Bakerloo Line at Elephant & Castle after the installation of the new signal box in 1941 (Code BS). The layout consisted of a scissors crossover on the approach to the terminal platforms and a trailing crossover at the other end with two sidings beyond it. The signals were identified by the code of the signal box (and the lever number as usual but with the letter H or L added, according to whether they were lowered by pusHing or pulLing the lever. Some levers (e.g. No.11) operated one signal in the push position and another in the pull position. Others (e.g. No.4) operated different routes read over by the same signal. Some, e.g. Nos.5 and 7, only operated in the push position. No pull position was provided. The pull position was unused but available for future additions, like another crossover into the sidings. All the shunt signals were short range colour lights. There were no point levers. Drawing from LPTB, Supplement to Traffic Circular No.43, (1941), modified by P. Connor.

A number of signal boxes were equipped with the system up to 1941, including Rayners Lane on 20 October 1935 (with a relay room added for South Harrow Gasworks Sidings on 17 November 1935), Cromwell Road, in four stages during 1936 covering Earl's Court, High Street Kensington and Gloucester Road, Finchley Road on 25 July 1937, Drayton Park (for controlling Finsbury Park)[9] on 11 March 1939 and Elephant & Castle in 1941. There were variations between boxes. Finchley Road and Elephant, for example, didn't have separately controlled locations and not all 'push-pull' levers in a frame operated in both modes. Elephant & Castle, Bakerloo Line (Code BS), was a good example, as described in Figure 10 above. Although point levers weren't provided at Elephant & Castle, some of these areas retained their individual point levers so that they could still be operated if there was a failure of the route control system but they had to be placed in the mid-position while route control was in operation. A common feature of these relay interlocking schemes was the retention of mechanical interlocking between the levers used to set up the routes. It's an interesting example of the caution with which Dell and his boss, William Every, approached any new system. The mechanical locking didn't perform the basic safety function as it had no backlocks but it did provide a reminder to the signalman if he tried to set up a conflicting move. Despite all this, there were some doubts about the relay interlocking. A number of other areas that were resignalled after 1937 stuck to the standard, single operation lever system, using conventional Style N frames. Then, during the Second World War, a new experiment in remote operation was developed – the remotely operated mechanical interlocking frame.

To be continued …

[9] The original installation at the new Drayton Park box comprised a small switch panel with nine telephone type keys that operated the routes. There were no point levers. The newly installed lever frame with push-pull levers remained unused until it took over operation on 7 December 1941.