LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
8. PAUSE FOR THOUGHT

THE START OF SOMETHING BIG

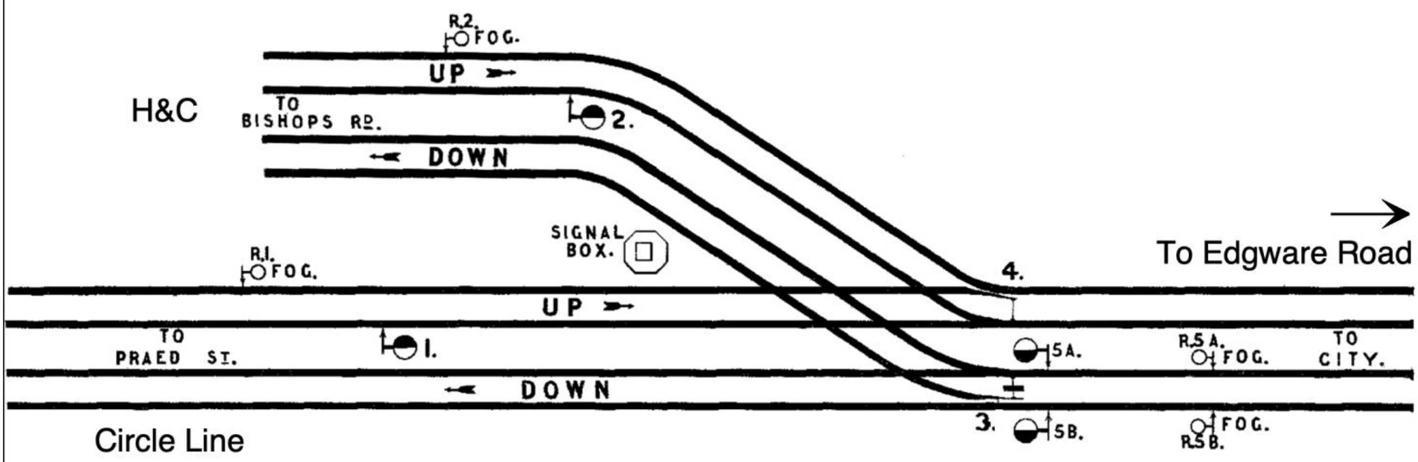
The opening of the Great Northern & City Railway (GN&C) in February 1904, marked the end of what we could call the transition phase in signalling technology on the London Underground railways, where they moved from the largely mechanical systems of the Victorian era towards cutting edge, 20th Century automatic systems. It also marked a move from almost total reliance on human observation and compliance towards more automation and towards so-called "fail safe" systems. In noting all this, I thought that here would be a suitable place to pause for a summary of some of the more important features of railway signalling and safety that were established by this time, both in operations and engineering. A bit of revision, if you like, before I take the story into the step-change in signalling technology that was introduced with the electrification of the District Railway and the opening of the new tube railways that became the Bakerloo, Piccadilly and Hampstead lines. I am also including some corrections, updates and additional information that have been passed to me since the series started.

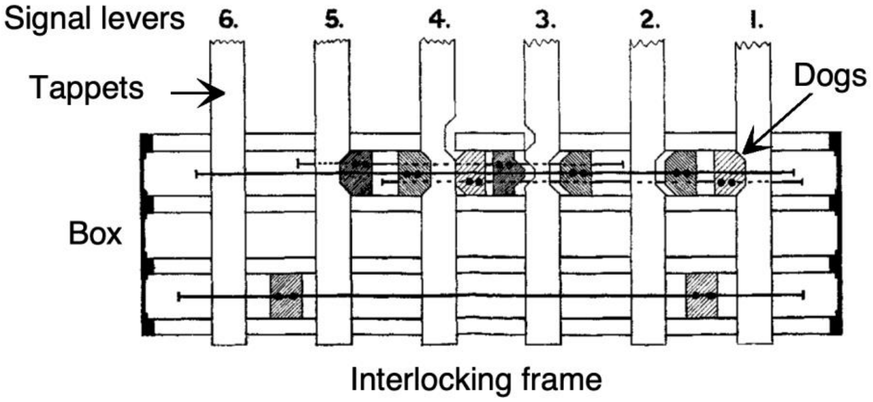
PRINCIPLES

It was established early on in the development of railways that trains needed a long distance in which to stop and that, as a result, drivers needed early warning of the need to stop. They also needed to know that the line ahead was clear of other trains before they could proceed. Thus was born the notion that the line should be divided into sections or 'blocks', each block being protected by a 'home signal' at its entrance. The early warning was provided by 'distant signal' being positioned so that, once seen, a train at speed could be slowed down and brought to a stand at a stop signal. Eventually, it was generally considered best practice to locate a distant signal a quarter of a mile (402m) in rear of the home signal.

With the need for junctions came the need for further measures to allow the safe movement of trains over potentially conflicting routes and the principles of lever interlocking. Since then, we have seen a whole range of enhancements and developments that have given us a number of very complex schemes in some locations. We will see how some of these arose in future articles but, for now, we should check the basic principles of safe signalling and how they were managed as follows:

1. Normally, only one train is allowed into one section at one time. If you have to bring another train into an occupied section, say for coupling purposes or assistance, stop it first and tell the driver, usually by showing a special signal, what he might expect. This was how shunt signals and calling-on signals were developed.
2. You should not allow a train into your section until you are sure that the previous train has cleared it. This follows from Principle No.1. How you know will vary from place to place but in the early days it was entirely visual and, naturally, not 100% reliable. Then treadles were invented and later we got track circuits. Now we have axle counters and transmission based 'detection' as well.
3. It should not be possible to set up conflicting routes. As I described in Article 2, it was quickly realised that if there were junctions and other places where two trains could occupy the same track, the levers controlling the signals reading over them and associated points, should be interlocked so that no conflicting routes could be set up. This was known as mechanical locking and the levers were mounted in 'locking frames'. In a signal box, the levers were mounted above the floor, with the locking frame beneath. An illustration of an interlocking is shown in Figure 1 below, showing the arrangements at Praed Street Junction as they were in 1924.
4. Facing points must be locked in advance of and during the passage of a train. This was the facing point lock (FPL). In many locations, they were operated by a lever additional to the point lever. Next, the locking bar was developed. This was fitted on the approach to the points so that the flanges of the wheels depressed the bar and prevented them from being moved while the train was passing over them. Now we still use FPLs but locking bars are largely superseded by electrical train detection in the form of track circuits. This detection should not be confused with the use of electrical point detection, which confirms to the signal box (usually with a light) that the points are set and locked in the correct position.





When levers reversed:

Nos	Releases.	Locks.
1.		④.
2.		4.
3.		4.
4.	1.	2. 3.
5.		3. ③.
6.		

Figure 1: A diagram of the very simple interlocking frame and locking table for the signal box at Praed Street Junction, between Praed Street (now Paddington) and Bishop's Road (also Paddington), Metropolitan Railway. This diagram was drawn by a Mr. F.J. Addis who apparently worked for the Metropolitan Railway. I have added some additional labels. The signalling scheme shown here was installed in July 1908 and it lasted until the original signal box (in the tunnel in the divide between the two routes and believed to date from 1863) was closed in 1926 and the control passed to the new signal box at Edgware Road station. The track layout is just as it is today but the signalling, if you can call it that, is now the Thales CBTC automated system.

The locking frame shown here consists of 'tappets' that move up or down as the signal levers are moved from normal to reverse and back. A series of tracks (known as a box here) with sliding 'dogs' interacted with 'ports' cut into the tappets to provide the interlocking. This was a very common system at the time and has survived with little change to the present day. The table showed how the locking affected the operation of the signals. For example, if the lever for Signal No.1 is reversed, lever 4 is locked in the reverse position – hence the circle round the number 4. If the number doesn't have a circle round it, the lever is locked in the normal position.

Apart from a short section towards Praed Street station, all of this area is in tunnel but uniquely, it is equipped with fog signals. These were installed in the early 1920s following complaints from drivers about the difficulty of seeing the signals because of the smoke from steam engines drifting into the tunnel from Paddington main line station. The fog signals were simple yellow/green repeaters of the stop signals.

Unusually in this scheme, the normal position for No.4 points is the opposite to that for No.3 points. Drawing from Addis, F.J, (1924) 'Mechanical Interlocking, Proc. IRSE, Part 1, 1925 pp.92-112.

5. A signal protecting a section cannot be lowered until the section is proved clear. This principle is clearly related to No.2 above where there was a process to pass a train from section to section. Each section had its own signal box, where the signalman operated the signals and points in his area. A train was passed from one box to the next by bell coded requests, 'Can I send a train into your section?' 'Yes, the line is clear'. 'OK, here it comes', 'OK, it's arrived' or variations on that theme. All of this relied on the signalmen doing it correctly and on their correct observance of the to-ing and fro-ing of trains they accepted and sent forward. Unfortunately, it was not always the case and the development of electric locking allowed safer operations. It was a gradual process but it continued for the next 150 years and is still ongoing today. Nowadays, most railways prove absence of track occupation by track circuit or axle counters.
6. When a route has been set and cleared, it cannot be changed once a train has approached or is occupying the route. This was achieved with an electrically operated 'backlock', originally activated by a long fouling bar but later by using track circuits. The backlock was used to prevent the

mechanical locking between a signal lever and a point lever being freed if the signalman attempted to restore the signal lever to the normal position before the approaching train had cleared the route[1]. It was arranged so that the signal lever could be put back towards the normal position far enough to replace the signal to danger but not all the way back to the normal position to release the mechanical locking of the points. The ability to replace a signal to danger was important in case an emergency situation arose in front of an approaching train.

7. Drivers must be given enough distance in which to stop. You might think this is obvious but it wasn't always. Trains are notoriously difficult to stop accurately but it wasn't until the mid-19 century that it was recognised it would be useful to give drivers some overrun space beyond a stop signal. This was done by placing stop signals some distance back from the entrance to the section being protected. This space was called an 'overlap'. It became even more important when automatic signalling with train protection was introduced, as we shall see in future articles.
8. Exits from sidings must be protected to prevent trains running onto the main line in error. Traditionally, this was done with trap points, where a set of points was provided just before a siding joined a main line in order that a train or loose vehicle overrunning the exit signal would be diverted into a short length of track with sand or buffers to bring it to a halt[2]. In places where space was limited, the District Railway used instead derailers (or "scotches" as they were sometimes called) somewhat similar to those used later by the C&SLR and Waterloo & City lines. They were also used on the Metropolitan (Figure 2).

Figure 2: A derailer on the exit of No.6 Siding at Edgware Road, Metropolitan Railway, after the completion of the station rebuilding and resignalling in 1926. It can be seen on the left hand running rail. It was operated by its own lever in the signal box. Your author was familiar with this device as it was still in place in the 1970s, even though the area was resignalled in 1951. At that time, the siding became known as No.26 Road and the Signal $B5^A$ became OP10 and was replaced by a disc shunt signal. The derailer worked by lifting the wheel flange up over the running rail, dumping the wheel into the ballast, effectively stopping the train. Interestingly, signal $B5^B$ seen here was not used but it was installed in anticipation of the proposed loop line to Willesden Green. The derailers were finally removed in 2010. Photo: Westinghouse Archive & Chippenham Museum.

9. Distant signals on the same post as a stop signal could not be lowered if the stop signal was on. This principle introduced the idea of 'slotting'. A mechanical link was provided between the balance weights of the two semaphore arms so that the distant arm could not be lowered unless the arm of the stop signal was also lowered. I described this in Article 3 (Figure 3), showing the original arrangement used on the District Railway. Often, slotting was used in areas where two signal boxes had to co-operate to set up a route, so you couldn't pull off a signal unless the other cabin had pulled off their corresponding lever. The arrangement survives today both in mechanical form and various later electrical substitutes.

For all these principles there was a wide range of solutions and lots of local variations. There were also many developments and improvements over the years and they continue to the present day. There were some operating rules that became embedded over the years too, although many railways often took a different approach from others, depending on their experience and the circumstances. One such was the rule that, if the starting signal was on, the home signal should remain on until the next train had been brought to a stand at it. Another was that some railways insisted that the starter should remain on until the train had stopped at the station, while others preferred that the starting signal was off, if safe, to give the driver more leeway to stop his train at the platform and not be put in the position of overrunning a stop signal.

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1 Over the years, there were a number of designs of backlocks and frontlocks and a number of different uses of both systems. To add to the confusion, some backlocks were mounted in front of the lever and some frontlocks were at the back.

2 As I noted in a footnote in Article No.5. trap points are often confused with catch points. Trap points divert trains away from the main line, while catch points divert trains off the main line, usually at the bottom of a long steep incline. The term 'catch points', is often used to mean trap points.

BOX OR CABIN

On a completely different theme, I have wondered from time to time during the preparation of this series about the two names used for the building that described where the signalman and his (or her) levers live. I had always thought that the use of the word 'cabin' in reference to a signal box seemed to be much more common on LU than on main line railways. But, in the LU vernacular, we used to call the lads who booked trains 'box boys'. I suppose calling them 'cabin boys' might have been mistaken for a nautical post and, anyway 'box boy' rolls off the tongue much more easily. More seriously, I thought 'cabin' was an LU derived term imported from America but then I remembered that they are usually called 'signal towers' there[3]. Then, some research showed that the term was already used by British main line railways as early as 1863[4] and I'm sure it wasn't new then but even LU struggled to decide what to call them. They used the term 'cabin' at least as early as 1910 on line diagrams but they used 'box' in traffic notices as late as 1990. Today, whether boxes or cabins, they're nearly all gone, replaced by 'control centres'.

HOME SIGNALS

The Great Northern & City Railway (GN&C) was the last London Underground line to be equipped with a Spagnoletti designed signalling system, well, an updated version of it anyway. The three lines that had it, the City & South London, (C&SLR) the Central London and the GN&C, usually had a two-home signal arrangement where a station had an inner home and an outer home, although the C&SLR opened with just one home signal; the others were added later. Last month, I questioned how they were controlled but there was, for me, a further puzzle in this arrangement – why they had home signals at all.

On a conventional main line railway, the home signal both protected the station area if shunting was taking place and it allowed a following train to be sent forward before the train ahead had cleared the station. This arrangement allowed a higher throughput of trains. In effect, the block sections ran from the starter at one station to the home signal at the next. As we've seen earlier in this series, the area between the home and starting signal formed 'station limits'.

This wasn't the arrangement on the C&SLR originally, since the treadle for the starting signal of the station ahead had to be activated by the departing train before the lock on the starting signal of the station in rear could be freed and the signal lowered. This leads to the question as to why the C&SLR and the other Spagnoletti designed tube lines had home signals at all. There was no shunting to do at most of the stations and the home signal levers do not appear to have been backlocked in the original setup. I don't know the answer.

Later, when the need arose for more trains per hour, they divided the station to station sections into two. An additional signal was installed – the outer home, so called because it was operated by the same signal box as the existing home signal, which was now called the inner home. The outer home lever was backlocked and it was released by the starting signal treadle. The starting signal in rear was in turn released by a treadle provided in advance of the outer home signal. What is curious about this is that it still doesn't explain what the inner home was for.

Reflecting on this setup, I wondered if it was due to the philosophy of insisting on cautious working for trains in tunnels that was originally adopted for the Metropolitan Railway. It was the stated philosophy of the original Board of Trade inspecting officer, Colonel Yolland. The early tube lines didn't have conventional distant signals, so there were almost no warning arrangements showing the status of signals ahead[5]. It also seems to me that the idea of only allowing trains to run at "caution" speed that had been introduced on the Metropolitan Railway was retained for the tube lines, to begin with anyway. The philosophy of cautious working when running trains in tunnels really hadn't gone away. Adding up all these thoughts might explain the desire to retain an additional signal protecting the station and its starting signal.

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[3] Just to confuse matters, I have seen references to 'signal cabin' in Canada.

[4] Preece, W.H., (1863). Discussion on 'On Railway Telegraphs, and the Application of Electricity to the Signalling and Working of Trains.' *Minutes of the Proceedings of the Institution of Civil Engineers* (Vol.22, No.1863, pp.167-192).

[5] The GN&C did have repeaters on the approach to the terminals.

A CORRECTION

Reader David Lyall picked up an error in a caption I wrote in Article No.2 and kindly wrote in to alert the editor. My thanks to him. My error concerned the use of the non-pegging block instrument for Spagnoletti's system on the Metropolitan Railway. Of course, the non-pegging instrument was provided so that the signalman in rear, at the entrance to the block, could see the indications sent by the signalman in advance at the exit of the block. Thus, the caption for Figure 3 in Article 2 should read as shown in Figure 3 here.

Figure 3: A Spagnoletti 'non-pegging' block indicator. This showed the indication at the signal box at the entrance of the block section that had been sent by the box at the end of the block. This is of the same design as the one shown in Figure 2 but without the keys. Early versions of Spagnoletti's block instruments had the flag indicator above the line description label, not below as shown here. Photo: Author's collection.

W&C FLAP SIGNALS

Readers might recall that, in Article No.5, I wondered about the "ground disk" signals described as used on the Waterloo & City (W&C) Line. I thought they presented a bit of a problem from a historical point of view since they were referred to as "ground disks" in both Szlumper's and Jenkin's papers to the Institution of Civil Engineers on the W&C in 1900 but there were no illustrations of these signals and no design details were offered. However, the historian T.S. Lascelles said they were of the LSWR's flap target, or "Stevens, type."

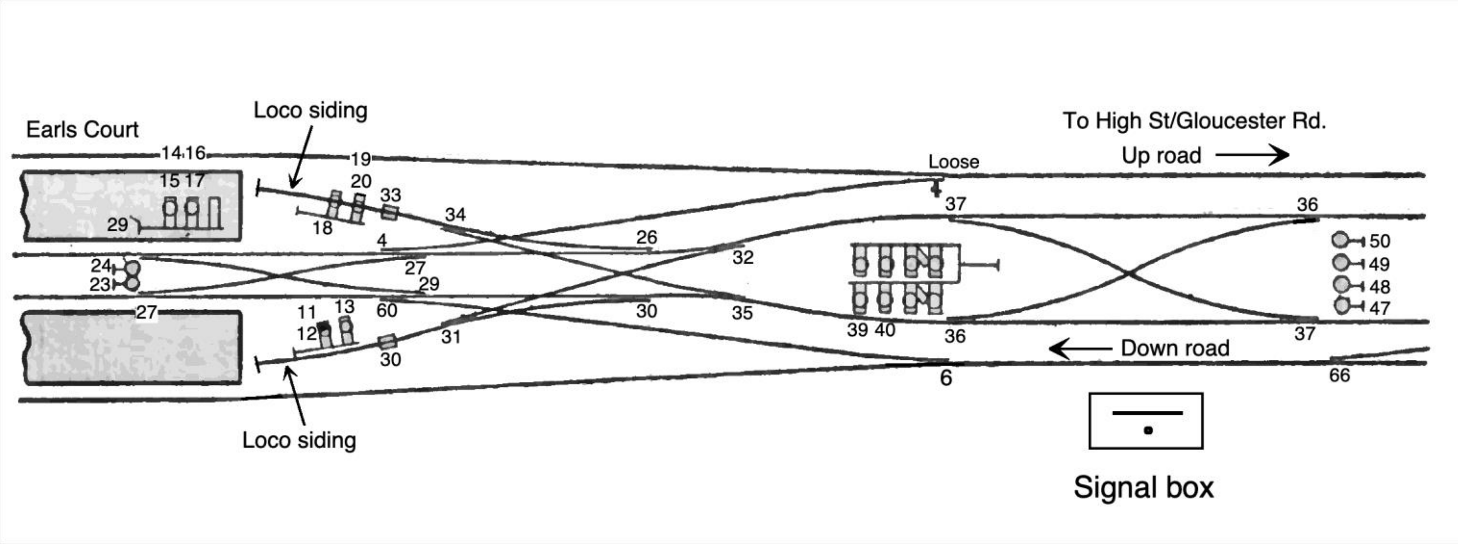
The problem was resolved with the discovery of a photo (Figure 4) by our esteemed editor that shows the entrance to Waterloo station from a position in the sidings that allows several of the signals to be seen. These are indeed of the Stevens flap type, confirming Lascelles description and eliminating any doubts I might have had.

Figure 4: A photo of Waterloo station looking from the depot sidings through the station towards the City shortly before the line opened in 1898. The arrival platform is on the right and the departure platform on the left. Three of the Stevens flap signals can be seen. They were also referred to as "disk" signals. Note also that the points into the centre siding are fitted with a trailing move locking bar. This was used to lock the route until the train was completely in the siding. When freed, it would free the lock to allow the lever of the home signal to be reversed for the next train. Photo: Collection B.R. Hardy.

TIMMIS

The Victorian engineer, with the imposing name Illius Augustus Timmis, was best known in his day for his development of the 'long pull magnet' for use in electrically operated railway signalling. He used it in the signalling he installed on the Liverpool Overhead Railway. The railway was opened with electric traction in March 1893 and, as a result of his success in in getting his new system installed and working, Timmis persuaded the District board to let him run a trial of it at Earl's Court. It was installed in 1895. It was restricted to a scissors crossover at the east end of the station and some of the signals protecting it. The crossover was located at the ends of the two reversing sidings laid between the Up and Down running lines. Conveniently, it was directly opposite the east end signal box, which was then located at the side of the Down road. I have found a diagram of the area (Figure 5), published in 1896[6] that shows the layout around the area of the Timmis installation. A more detailed diagram of the electrical connections appears in the late Mike Horne's 'London's District Railway' Vol.1, p.267.

Figure 5: A contemporary diagram of the track layout at the east end of Earl's Court station on the District Railway in 1895 showing the scissors crossover (Nos.36 and 37 points) at the entrance to the two sidings that were



equipped with I.A. Timmis' design of electric point machines. The drawing shows the signal and point lever numbers, apart from the eight shunt signals at the west end of the crossover. This just seems to be an error by the original draughtsman but we know from another drawing that the top two left hand signals were Nos.39 & 40. There is no key provided with this drawing but we know from the contemporary description that the shunt signals were mostly semaphores of the usual District pattern with some ground signals of "disc" pattern where space was tight. The trackwork between the scissors crossover and the ends of the platform is very complicated and was later simplified when it was no longer necessary to cater for regular reversing of trains hauled by locomotives. Drawing from Pigg (1899), p 381 modified by P. Connor.

For the Timmis trial, the two sets of points (Nos.36 & 37), their locking bars and bolts, associated semaphore signals and ground 'discs' were all electrically operated and included electrical interlocking on the levers. The semaphore shunt signals 39 and 40 and the ground discs 47-50, were operated electrically. The operation of levers 11-24 depended on the position of the point detectors on the crossovers (Figure 6).

The use of the long pull magnet for point operation was relatively simple. An electrical contact on the signal lever completed a circuit to the magnet which shifted the points to the reverse or normal position as required. The points were locked in place by another long pull magnet driving the locking bolt home. At the same time, a detection circuit was completed to confirm the lock was complete.

Each signal was also operated by a long pull magnet. To lower the signal, its lever was reversed, energising its operating magnet. To maintain the signal in the lowered position, the magnet had to be permanently energised so, in order to avoid maintaining a full operating current on the magnet, a switch on the signal brought a resistance into the circuit once the signal was detected as fully lowered. This arrangement added a fail-safe element, where loss of current would cause the signal to return to danger. In addition to the electrical detection and control, the levers were mechanically interlocked in the frame in the usual way so it was impossible for a signal to be operated unless the points which it controlled were properly set and locked.

The system was quite advanced for its day and it seems to have worked well. It only lasted until the resignalling of the District in 1905-06 but the earlier version survived on the Liverpool Overhead Railway until the early 1920s after almost 30 years' service. The difference between the two systems was that the Earl's Court installation had electrically operated points, whereas the Liverpool system used traditional, mechanically operated points.

[6] Pigg, J. (1899), Railway Block Signalling, Biggs & Co., London, p.381.

As for the long pull magnet, it was invented by Stanley Currie about 1884[7] and it was developed by Timmis over a period of ten years before he finally got it accepted for the Liverpool system. As we've seen before in this series, there was a lot of scepticism amongst railway companies about the electrical operation of equipment, largely because it was regarded as expensive to buy and difficult to maintain and it required skills that were in short supply. There was also the problem of maintaining a battery fed power supply, as main supplies weren't common and, if you wanted one, you usually had to build your own local power station.

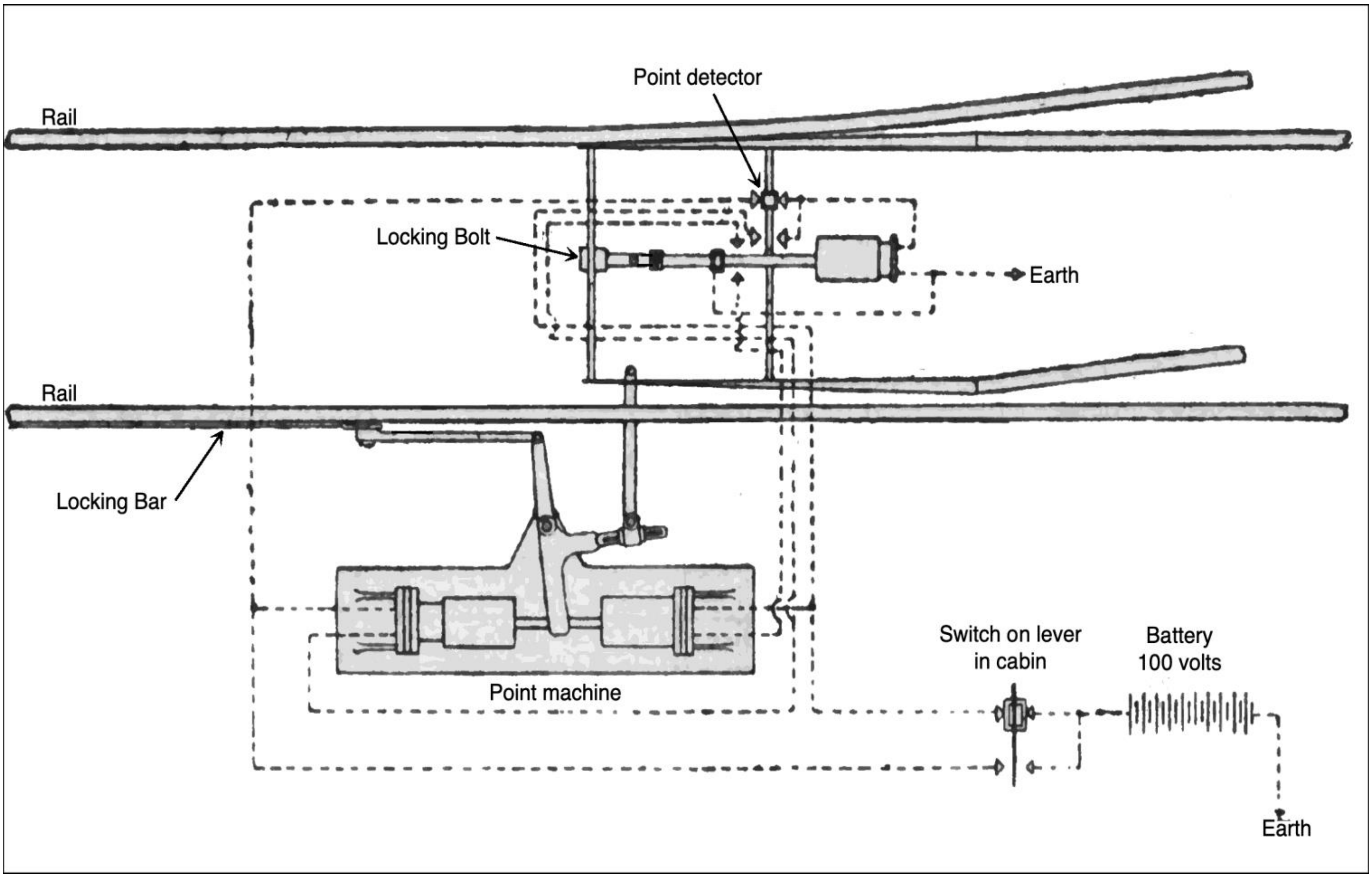


Figure 6: A diagram of a Timmis electric points system using long pull magnets and electrical point detection. The machine had two magnets, one each for the normal and reverse operation. A third magnet operated the facing point lock. A mechanical locking bar of the standard outside type was provided to maintain the lock during the passage of a train. In this drawing there is no circuit showing that an indication was provided in the signal box to indicate the detection but another drawing suggests that there was. Drawing from Pigg (1899), p.383, modified by P. Connor.

In his description of the Timmis system, James Pigg[8] made some interesting comments. He suggested that "*The advantages … for the system are its capability of working signals etc. safely at any distance from the point of operation and the possibility of dispensing, in many cases, with intermediate cabins …*". He was to be proved right about the use of electricity for remote signal operation when automatic signalling came to the Underground a few years later.

He went on to remark, with a degree of cynicism, that the idea of using electrical systems in signalling wasn't new saying, "*Such methods are of old standing … but have never passed much beyond the experimental stage, probably owing to the fact that electrical apparatus was, until recent years, constructed with a view to the electrical effects intended, … without sufficient consideration to the conditions under which it would have to be used …*". He would not have been much comforted had he the knowledge that, over 120 years later, such problems haven't gone away.

To be continued

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7 A description and drawing of Currie's long pull magnet appears in Fleming, J.A. (1892), 'Short Lectures to Electrical Artisans' Spon, London, pp. 65-66. See also Timmis, I.A. (1885), 'The working of railway signals and points by electro-magnets, and controlling them, in conjunction with a complete block system, efficiently and economically by a current from a primary or secondary battery', *Journal of the Society of Telegraph-Engineers and Electricians*, *14*(56), pp.82-90.

8 Pigg, J. ibid.