LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
28. STANDARDISATION

STANDARDISATION AT LAST

From around 1930, as we've seen in previous articles, new versions of signals began to appear on the Underground as replacements for existing equipment or for new installations but there were a lot of places where older equipment was still used. For example, although outdoor colour light signals were widely accepted all over the country by 1932, the western extension of the Piccadilly Line from Hammersmith to Acton Town, opened in that year, had electro-pneumatic semaphore signals installed rather than colour lights. As I mentioned in Article 13, the reason for this is obscure, although I did wonder later if it had something to do with the continuing use of steam locomotives on the freight trains running over the line between Turnham Green and High Street Kensington but I'm not entirely convinced of this.

Figure 1 (left): A range of automatic electro-pneumatic semaphore signals as seen looking west from the westbound platforms at Stamford Brook. Many of them were installed for the four-tracking between Hammersmith and Acton Town, completed in 1932. The signals were replaced by colour lights in April 1952. Photo: LURS collection.

Figure 2 (Below left): This apparent four-aspect signal between Hammersmith and Ravenscourt Park on the westbound District is actually two signals – a green/red stop signal A592 above a green/yellow repeater R590A. It is displaying the same information to drivers as the two semaphore signals shown on the left of Figure 1. Originally, the colour light version was capable of showing exactly the same indications as the semaphore version, so it was possible to see a red lamp with a yellow lamp below it but later, the circuits were redesigned to extinguish the yellow if the red was lit. Photo: Kim Rennie

From the early 1930s, the use of short-range colour light signals for shunt moves continued to be the standard for those shunt moves being signalled from the same location as main line signals, while disc signals were normally used on the ground. There were some variations, seen as the result of recycling old equipment or not upgrading signals that weren't considered life expired.

The disc type shunt signals were electro-pneumatically operated and required an air supply as well as the usual electrical controls and power for the illuminating lamp – quite expensive when you add it all up. A short range colour light might be quite a bit cheaper but perhaps less effective at reminding a driver that the route shown required a restricted speed.

A new campaign of 'standardisation of signal aspects' (as it was referred to officially) was begun, albeit rather tentatively, during the Second World War. All shunt signals were to be converted to discs. The idea was that there should be a clear distinction between a main line move (proceed at normal speed) and a shunt move (proceed at caution). The earliest recorded conversion of a colour light shunt signal to disc was at Queensway in 1942[1].

There was also a system-wide implementation of the modification for repeater signals mounted under stop signals (described in Article 24) so that a yellow light didn't appear under a red. This was started before the war but it didn't really gain pace until the early 1950s. From then on, there was a policy of upgrading signals as the opportunity arose and of ensuring that any new installations conformed with the standards. This work accelerated during the 1950s and continued into the early 1960s.

Figure 3: Standard Underground shunt signal with theatre type route indicator at Parsons Green (Code WF). The arrow on the signal plate points to the track that the signal affects. The signal rotates anticlockwise to show it is lowered. It is referred to as a lower quadrant shunt signal. The route indicator is showing '3', meaning it is set for the third route from the left. Photo: Kim Rennie.

Another feature being standardised during this period was the arrangement of junction signals. Splitting signals were replaced by a single signal and a route indicator of the standard 3-light pattern. Repeating signals were also fitted with junction repeaters where appropriate. These were miniature, three-lamp versions of the main junction indicator.

Figure 4: A 2-aspect repeater signal at Queen's Park that has been recycled from a Metropolitan Railway 3-aspect signal. The bottom aspect has been blanked off by a plate lettered BP. BP was the British Power Railway Signal Co., who supplied some signals and signal frames for the Metropolitan Railway. Note the rusted condition of the upper of the two 'pigs ears' to the side of the main lens. This signal dates from the 1925-32 period. Photo: Kim Rennie.

A major part of the standardisation campaign was the elimination of anything Metropolitan, including their 3-aspect colour light signals and all their electric point machines and trainstops. As systems became due for renewal, the full-sized mechanical frames were removed and points and trainstops were converted to e.p. operation. The reasons for the conversions was simple – the Metropolitan's electric point machines and trainstops were vulnerable to damp conditions and they were up to three times slower in operation. We will be looking at point machine development in detail next month.

DELTA TRACKS

In Article 21, I described the use of the system known as a "delta track". It was also known originally as a "rail circuit". It was introduced to detect that a train had reached a certain position on the track that was more precise than that you could get from a standard track circuit. Initially, it was used to detect that a train had arrived at a signal before allowing it to clear, like the speed control setup installed on the approach to Archway in 1939. Although I wrote that this was the first installation of a delta track, new information has come to light that the idea was first adopted at West Kensington in 1934 as part of the resignalling that took place for the first remote control setup (Article 25 in this series).

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1 LPTB Traffic Circular No.17, 1942.

Another use was at a calling-on signal where it had to be established that the train had come to a stand at the signal, or nearly so, before it was allowed into the platform to couple up. Before this, various types of treadles were used, like the tripcock treadle used at Arnos Grove (Figure 12, Article 19) but, being mechanical devices, they were troublesome to look after and were prone to failure.

The original Delta was a short section of rail – 11 foot 6 inches (~3.5m) long – inserted into a track circuit[2]. It was insulated from the track circuit by conventional insulated joints and was normally de-energised. However, it was bonded out, so that the track circuit could continue to function as normal (Figure 5). It was designed so that even the shortest train could stand on it and still occupy the track circuit.

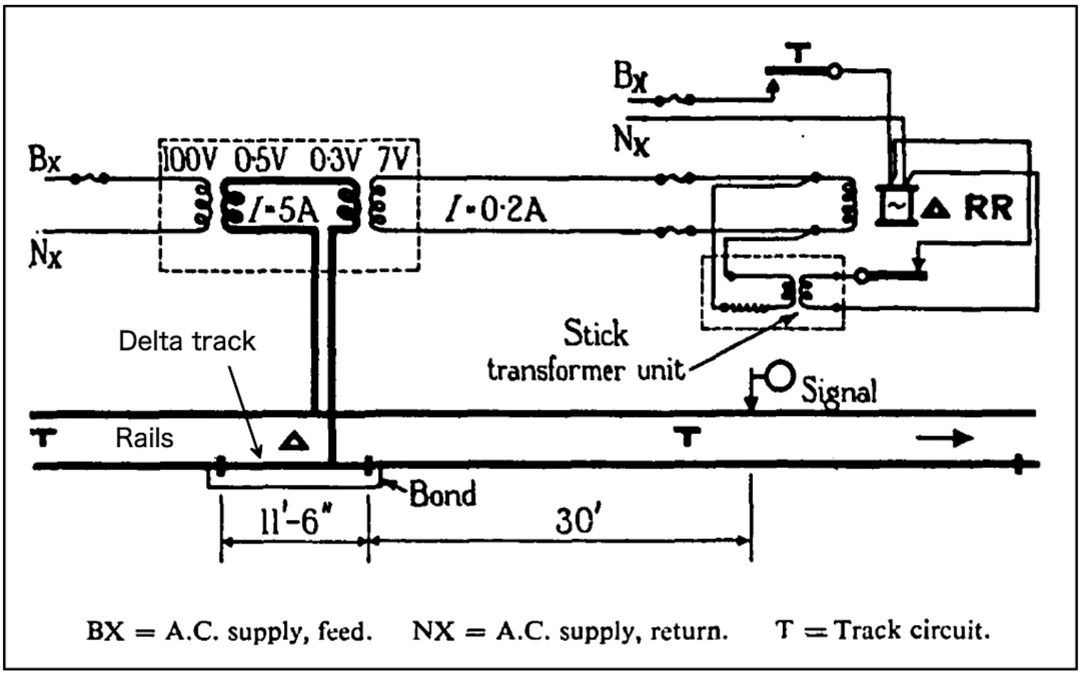

Figure 5: A diagram of a delta track circuit as originally introduced in 1934. The delta track was provided in one rail within a track circuit. It was a system that remained open circuit until the front wheels of the train entered the short section allowing the relay to energise. A "stick" circuit was installed to hold up the relay of the rail circuit once it had been operated by a train. The operation of the standard track circuit was unaffected. Drawing from Dell (1944) modified by P. Connor.

The rail circuit seems to have been the standard method of providing a delta track until the late 1950s when an electronic version was introduced. This was known as the 10 kHz delta rail circuit. The first mention of it appears in a signal engineer's note dated 27 December 1956 but it probably went into production rather later[3]. The main difference from the earlier version was that it used an AC supply and, being at a high frequency, it didn't require the circuit itself to be insulated from the track circuit inside which it was installed, so additional block joints weren't required. The AC was rectified to provide a DC supply to operate the relay.

JOINTLESS TRACK CIRCUITS

As we have seen in this series, the long-time standard track circuits used on the Underground were separated from each other by block joints. The block joint itself required insulating materials to separate the ends of the rails and the fishplates and bolts securing the two rails together. The support between the two rail ends relied entirely on the strength of the rail, the positioning and fit of the fish plates and the tightness of the bolts. Inevitably, the weight of thousands of passing wheel sets everyday would cause the ends to wear and eventually drop slightly, creating noise and ride problems. Not only that, but the constant movement of wheels along the top of the rails caused spreading of the metal so that the surface of one rail would spread over the joint to the next one and cause two track circuits to be joined. This was known as 'scaling' and it would invariably cause a failure. It was a particular problem in areas where trains braked regularly, as on the approach to stations. In some places, twin block joints were inserted to try to overcome this and they created short dead zones between track circuits but, as they were limited to 10 feet 10 inches (3.3m), they were not a risk to effective train detection[4]. Although it might seem (to me at least) counter-intuitive to try to solve a problem caused by a rail joint by inserting another rail joint, the real issue was service reliability and how this could be maintained.

There had always been an ambition to find a way of improving the insulation between track circuits or, even better, getting rid of mechanical joints between them altogether. Long welded rails were already

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2 The length was set according to the shortest rail between joint locations that could be tolerated by the P-Way engineer.

3 Note from Robert Dell describing them was issued on 27 December 1956, seen by Tom Crame.

4 Tom Crame (22 April 2022) notes that these were commonly referred to as 'ten' sections, though the dimensions varied and could be up to 11' 6". The idea was an application of redundancy – two joints had to fail to give a problem. The failure of the joints was announced by an indication lamp mounted nearby but these were subsequently removed.

being used where possible for replacement track and these helped to reduce the problems of jointed track but they still had to be cut in places to accommodate track circuit joints. However, with the development of better electronics in the 1960s-70s, getting rid of jointed track circuits became a practical possibility and, eventually, the jointless track circuit (JTC) arrived on the Underground. It replaced the traditional track circuit with one using audio frequency electronics. It eventually became the new standard on the Underground but it was a long time coming.

It proved quite difficult to track down the origin of the first jointless track circuit. There are several sources, each suggesting a different date and place for the first installation. These range from the original Japanese high speed Shinkansen route in 1964[5] and the Chicago Lake Street Line in 1965[6] but it is also recorded that a working audio frequency track circuit was first devised by a French company called Aster in 1969[7], although it had taken them over 10 years to get this far[8]. Experiments had been going on in Britain, amongst other places, for some years prior to this but, in Europe at least, it seems that the French were the first to market it. Through a series of takeovers, Aster eventually became part of Hitachi.

In Britain, it was thought initially that the JTC was not suitable for use on electric railways but later technical developments did allow its use on electrified lines and some JTCs first appeared on the East Coast Main Line in 1983. These were made by a company based in Plymouth called ML, who got a licence from Aster for the original design and then developed it so as to overcome its limitations on electrified routes. Another version, again developed by ML from a design by the Swedish company Ericsson, was known as the TI21 track circuit (TI = Traction Immune). ML eventually got absorbed into Bombardier (now Alstom). The other signalling suppliers like Siemens, Alstom and Westinghouse soon developed their own versions. London Underground, being very cautious about anything new, couldn’t find one on the market that they considered suitable for their own particular requirements, so they started work with Westinghouse on developing a specific JTC early in 1972 and, after a series of laboratory trials that went on over three years, a set of six JTCs were installed on the test track at South Ealing.

The science involved in JTCs is, for a layman, quite complex but there is an interesting paper on the subject presented jointly to the IRSE in 1974 by D.J. Norton of Westinghouse and L.S. Lawrence, an Underground signal engineer[9]. In it, they describe how the development, over the three-year period between 1972 and 1975, raised a number of difficult issues. For example, to ensure effective separation between JTCs, each was given a separate frequency. Originally there were seven different frequencies but more recent types have allowed up to eleven. It was necessary also to use different frequencies on parallel tracks to avoid ‘crosstalk’. Getting this to align could be difficult when designing signalling for an area which had track circuits as short as 30m on one track next to a track with a 300m circuit.

It was also realised that, while the need for very tight clearances for track circuits in station areas worked well with fixed block joints, with the early JTC designs there was a zone of up to 10m without detection between each circuit and there was a risk of a train standing in a platform actually causing additional track circuits behind it to remain ‘down’. This was eventually resolved by careful siting of boundaries and refinements to the electronics. The development work also included the need to allow for the transmission of codes for automatic train operation. These and many complex technical issues led to a very long gestation period for the JTC on the Underground. There was at least one operational trial at Brent Cross in 1983 and at some other locations on the Northern Line but it wasn’t until 1988 when it finally went into regular service on the Bakerloo as part of its resignalling programme, where they used the Westinghouse FS2500 circuit.

Aside from the need for a long development period, the delay in getting JTCs accepted was not only because they were originally expensive but also because there was still a commonly held belief that conventional track circuits were essential for the detection of broken rails[10] and that they wouldn’t be detected by JTCs. Although the detection of broken rails by track circuits was actually very rare and it

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5 Carker, T. (2017), Signalling in Japan, IRSE News, Issue 232, April 2017.

6 Hill, R.J. (1996), Electric railway traction, Part 5 Train detection, communications and supervision, Power Engineering Journal, April 1996.

7 Woodbridge, P.J. (2018) A Chronology of UK Railway Signalling 1825-2018, 3rd ed., Private pub. by Author, p. 364.

8 Brown, C. (1985), A Review of Jointless Track Circuits, Proc. IRSE, 1984-85, p.111 et seq.

9 Norton, D.J. & Lawrence, L.S, (1975), ‘Blockjointless Track Circuit – London Transport’, *Proc. Inst. Railway Signal Engineers*, 5 March 1975.

10 Track circuits will only detect broken rails if they are ‘double rail’ circuits with blockjoints in both rails at boundaries. Conventional track circuits on LU have always been single rail where only a break in the section rail would be detected.

was eventually discounted as a reason for not adopting JTCs, the doubts weren't finally dispelled in the minds of many until the occasion of the Hatfield accident on 17 October 2000, when a fractured rail caused a train travelling at 115 mi/h to derail with the loss of the lives of four passengers and with injuries to 70 persons. The fracture did not break the rail all the way through so the signalling circuits remained intact and the train was running under clear signals. Nowadays, JTCs have proved their worth and have the added advantage that long welded rails can be used without the need to cut them for insulated joints.

Although the technical details of electronic systems are way beyond the scope of this journal and incidentally, of my technical competency, the inevitable question must arise in our minds as to how track block sections are separated if there aren't any insulated joints between them, so we must have a brief look at how track circuit separation works for JTCs.

The first thing to understand is that there are a number of different types of JTC. They vary in design, not only between different suppliers but also depending on location, length of circuit and whether the line is electrified or not. There are even main line and metro versions of similar types from the same manufacturer (e.g. Westinghouse – now Siemens), so what you might find that one on a main line railway with 1500m track sections will be different from what might be provided on a 30m section on a metro. Figure 6 shows the basic concept for a JTC.

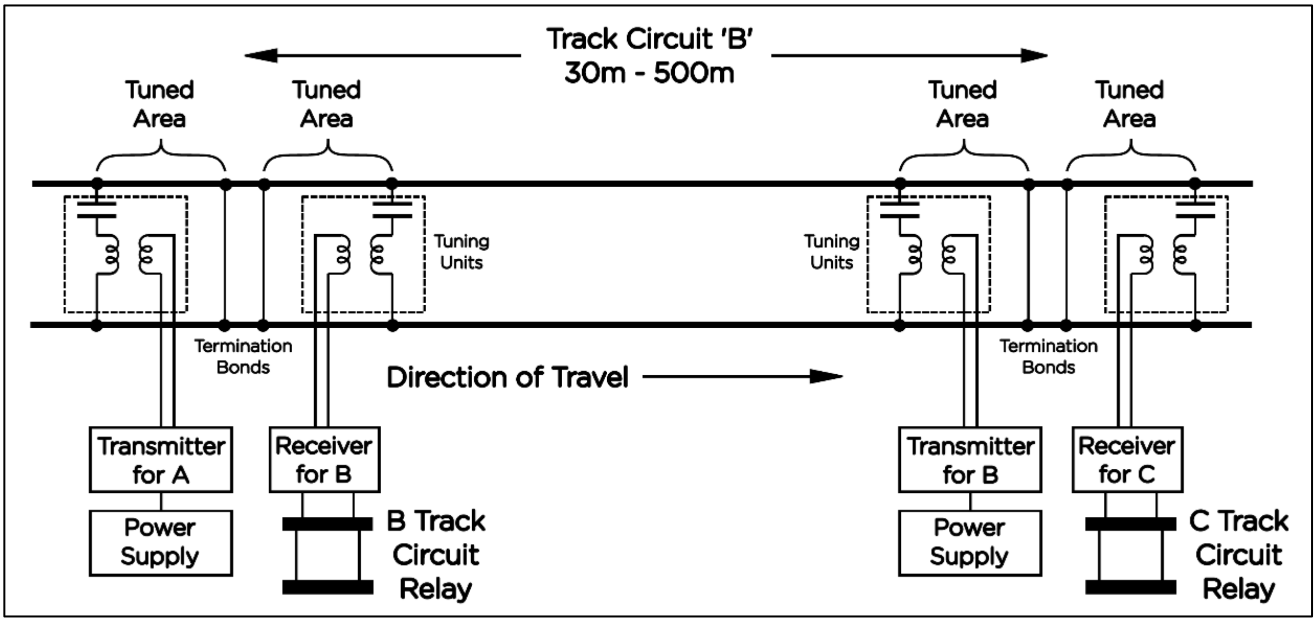

Figure 6: A schematic of a Jointless Track Circuit (JTC), track circuit 'B'. This sketch is based on the Westinghouse design used on the Underground. The transmission of the circuit is fed from the exit end of the section (Transmitter B) to the Receiver B at the entrance. The receiver is connected to a standard signal relay to show the state of the circuit. The so-called 'tuned areas' provide the electronic separation between this track circuit and those on either side (A and C). Separation is provided by using a different frequency on adjacent circuits. The section around the bonds is a 'neutral' or 'dead' zone, where a wheelset wouldn't be detected but the area is too small to present a risk as it is now normally limited to a maximum of 1m in length. Drawing by Thomas Crame.

As shown in Figure 6, the separation between two JTCs is created by tuned areas. Each tuned area begins at the point where a tuning unit is connected across the rails, thus removing the need for insulated joints. This isn't the only design though and there are all sorts of variations, including ones with a centre feed arrangement, which the Underground tried during its experiments in 1972, ones with overlapping tuned areas and many different bonding arrangements.

JTCs are rather limited in their effective length so some, on main line railways, have intermediate capacitors for long sections and, in one design I saw, several JTCs were linked together to form long block sections. In some places, JTC transmitter and receiver units are used with block joints and, in these locations, a tuning unit can't be used. Such tracks are known as 'jointed' when a block joint is used at both ends, or 'hybrid' when one end is jointed and the other uses a tuned area.

A casualty of the new system was the Underground's 10kHz delta rail circuit. It was incompatible with the frequencies used by the JTCs and this forced the re-introduction of treadles as train position detectors. These were provided on the Bakerloo as part of the 1988-91 resignalling programme. This project was the first large scale use of JTCs on the Underground. However, the treadles didn't last too long as they were to be superseded by a new detection system imaginatively known as a ‘position detector’[11].

POSITION DETECTORS

The position detector was a way of detecting train location without needing to put a circuit through the rails. The idea was simple. Like a treadle, if you detect the train’s wheels electrically, you can tell where the train is. They are related to axle counters, which were starting to become popular on British Rail as an alternative to track circuits where track circuit reliability was poor.

So, how does it work? First, we should understand that position detectors are mis-named and would be better described as ‘wheel sensors’. A detector head is mounted on the rail, and this acts as an oscillator at a high frequency around 75kHz, creating a magnetic field around it. As a wheel passes by, the electromagnetic field is altered and the detector registers the change in the circuit’s behaviour (Figure 7). Position detector heads are actually quite sensitive and will detect even quite small metal objects placed on the sensor head.

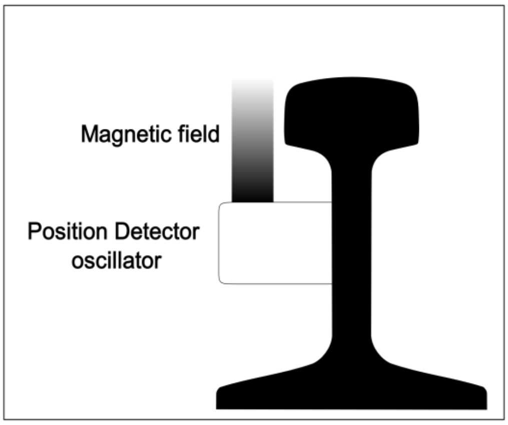

Figure 7: A schematic showing the principle of the detection process of a position detector. An oscillator circuit inside the unit mounted on the rail produces a magnetic field. As a wheel passes through the field, it collapses, which is detected electronically in the equipment room. Drawing supplied by Thomas Crame.

Position Detectors (PDs) first appeared on the Underground as part of the Central Line resignalling, staring at West Ruislip in 1991. From the mid-1990s, Siemens PDs were installed as replacements for 10kHz Delta circuits for both new installations and to replace rail circuits when new rolling stock was introduced on the Northern and Jubilee lines. A newer design, consisting of two sensor heads in a single unit, was used on the Sub Surface Lines in readiness for S Stock, though only one of the heads was used.

Figure 8: A Siemens position detector as seen mounted on a rail. Photo: Thomas Crame.

AXLE COUNTERS

The position detector was originally designed as part of a system to replace the track circuit. It became known as the ‘Axle Counter’. Indeed, the first position detectors used on the Underground were actually proprietary axle counter systems where the counting feature wasn’t used.

The idea was that you have two position detectors or wheel sensors, one at the start of a section and one at the end, together with another piece of electronics to do some counting, you can tell when the section is occupied or unoccupied. In a reversal of the manner of BBC war reporter Brian Hanrahan[12], you count them all in and count them all out. All you have to do is make sure that the count is accurate at both ends.

The first true application of axle counters on the Underground was in 1994 on the Chesham branch, where the track circuits on the branch were removed and replaced from 20 May by an axle counter system, supplied by Standard Elektrik Lorenz of Germany. However, my research suggests that they had already been around for at least 40 years before that. They are recorded as being used in Germany

[11] The treadles on the Bakerloo Line were replaced by position detectors in 1999-2000 at all sites except Queen’s Park which, together with Bank (W&C), are the only two sites left with them. *Note from Thomas Crame 22 April 2022*.

[12] Brian Hanrahan was a BBC reporter on the aircraft carrier HMS Hermes during the 1982 Falkland Islands war who was monitoring RAF fighter planes setting out for and returning from a combat mission over the islands and who famously coined the phrase, “I counted them all out and I counted them all back in” to reassure viewers that there had been no losses that day.

in the early 1950s in places where they had installed steel sleepers[13] and the Railway Magazine of March 1953 reported that axle counters were installed at the end of Platform 5 at Euston main line station for the resignalling scheme completed there that year. They were also installed in the Severn Tunnel from 1987, where the damp conditions made conventional track circuits very unreliable.

Axle counters use two sets of two detector heads at each end of a section. Pairs of heads are provided next to each other so as to determine the direction of movement. This is particularly important where trains can move through a section in either direction, as you would find at a terminus. Each head is connected to a counter, known as an Axle Counter Evaluator, often abbreviated to ACE. This does the counting of the number of wheels detected by each wheel sensor head. As the wheels pass the 'entry' sensor head, the count increases and, when the wheels pass the 'exit' one at the far end of the section, the count decreases. When the count is at zero, the section is unoccupied. When the Jubilee and Northern lines were being equipped with the SELtrac automatic train control system, axle counters similar to those on the Chesham branch became used for backup train detection in place of track circuits, as we will see in a future article.

Axle counters did have their critics. They were originally regarded with suspicion by some operators and engineers because they don't provide continuous detection and because of the persistence of the idea about not detecting broken rails. They are more expensive than track circuits and tend to require more equipment trackside, which has more sensitive electronic circuit boards than traditionally. Around points and crossings, they need careful configuration to ensure that the right heads are being used to generate the in and out counts, so that there isn't a false 'out' count from a sensor on an adjacent track. There were problems with counting reliability in their early days but, in reality, if the counters are mounted in pairs and the counting is duplicated, it will be resilient enough to permit minor mistakes in counts by a single unit.

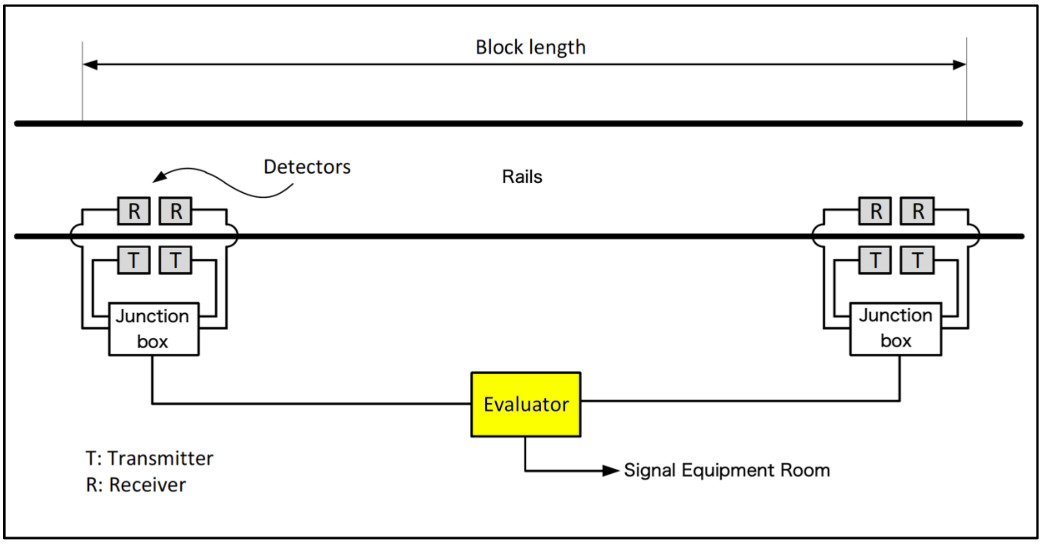

Figure 9: A schematic of a section of track using axle counters. The data gathered by the detectors includes the number of wheels passing between each transmitter and receiver at each end of the section. The evaluator checks the data and determines the direction of running. Drawing from Scalise, J. (2014), How Track Circuits detect and protect trains, railwaysignalling.eu modified by P. Connor.

Perhaps the most difficult issue is 'resetting'. After a possession or any failure where the counting has been interrupted, the axle counters have to be reset. They can be disturbed by, for example, an engineer's road rail vehicle going into a section from the trackside, by the system being switched off for maintenance, or by a power loss. If there's any sort of disturbance, once it's resolved, they need to be set up correctly. Trying to do this in a way which is accepted as 'vital', in order to prove the integrity of the system before trains can use it, needs strict procedures. One common way is to send a sweeper train through the section so that the indication shown by the ACE is proved by the train entering, occupying and then leaving the section.

Axle counters are not necessarily suitable for every location. For some reason, during a recent upgrade programme, it was decided that axle counters should be installed in Neasden Depot rather than track circuits. With shunting moves, short vehicles and a range of ways in which a train could be 'lost', it really doesn't seem to me to be appropriate. Nevertheless, it is generally accepted that axle counters are better than track circuits. We've already seen that the broken rail detection facility in track circuits is much overrated and in many analyses of the two systems, axle counters come out on top. They don't

13 Resuhch, G. (1954), Signal Engineering in Germany Today, Proc. IRSE, 1954, p.184.

12 The axle counter on the Chesham branch used the same head for both 'entry' and 'exit' counts, counting up as a train entered the single line section and counting down as it returned to Chalfont & Latimer.

rely on the wheel/rail contact for operation. They are easier to immunise from other electrical systems, like traction supplies, and they don't restrict block lengths because of voltage drop. They do show better reliability, once they have bedded in, although Network Rail had a lot of trouble with them in their first installations. If you are replacing signalling, they can easily be overlaid on the existing system and they have reduced commissioning times. I am sure that now people have got used to them, they have asked, "Why did we wait so long?" Finally, my thanks to Thomas Crame for his contributions with detailed updates, historical notes and advice on technical issues.

To be continued …