# CHARING CROSS EUSTON & HAMPSTEAD RAILWAY: EARLY SIGNALLING PERFORMANCE

**by David Millard, TfL Archives volunteer**

## BACKGROUND

In articles 10 and 11 of his series (January and February 2021) Piers Connor described the new signalling that was introduced on the Metropolitan District Railway and three tube lines in the first decade of the 20th century. This article looks in more detail at the first generation signalling on the Charing Cross, Euston & Hampstead Railway from 1907, and how it changed with experience of operation.

The new signalling was fundamentally different from the manual lock and block then in operation on the City & South and Central London Railways: the task of proving a section of track to be clear was now automated. It was well received. The April 1908 Railway Gazette, in a 'lessons learned' article covering the three recently opened tube railways, included the following:

'The wonderful, the better-than-human, automatic, electro-pneumatic block signalling installation, and the pneumatic power interlocked movement of points and signals …'

'The economic results of this wonderful signalling installation are many. Like the steam shovel, whose reason for existence is that it gets men off the bank and out of the way, it does this more and more, for it reduces the coefficient of human error. It saves something like one-third of the cost of signalling by human power. It increases the capacity of the line by one-third.'

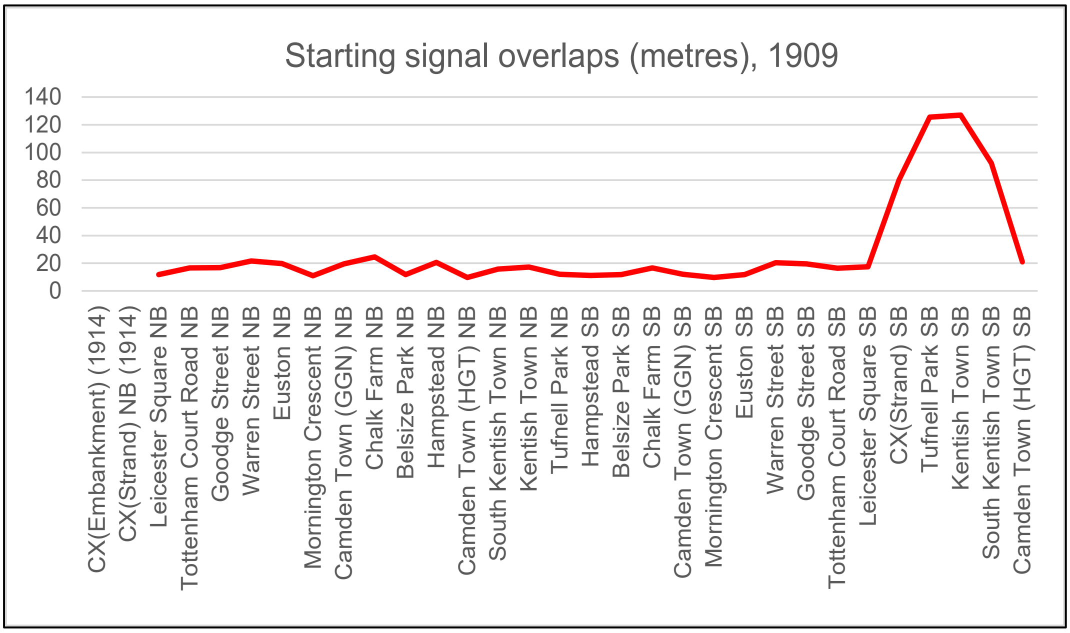
The names of the present-day Northern Line platforms at Charing Cross and Embankment have changed several times over the years. To reduce confusion, I have referred to these locations as CX (Strand) and CX (Embankment), respectively. Original measurements are in feet and inches: I have converted these to metres (1 metre = 3.28 feet)

## SCHEDULED SERVICE FREQUENCIES

The Charing Cross Euston & Hampstead Railway ran from Golders Green and Highgate and merged at Camden Town: from there, the trunk section ran to CX (Strand). This meant that the frequency of trains on the trunk section was twice that on the northern branches. Passenger numbers increased by 50% in the first 18 months of operation, providing an incentive to increase service levels.

| | Railway Gazette 1907 | Railway Times 1909 | |
|---|---|---|---|
| Section and trains per hour | Period not stated* | Off peak | Peak |
| Golders Green and Hampstead | 5 | 7.5 | 10 |
| Hampstead and Camden Town | 15 | 15 | 20 |
| Highgate and Camden Town | 15 | 15 | 20 |
| Camden Town and CX (Strand) | 30 | 30 | 40 |

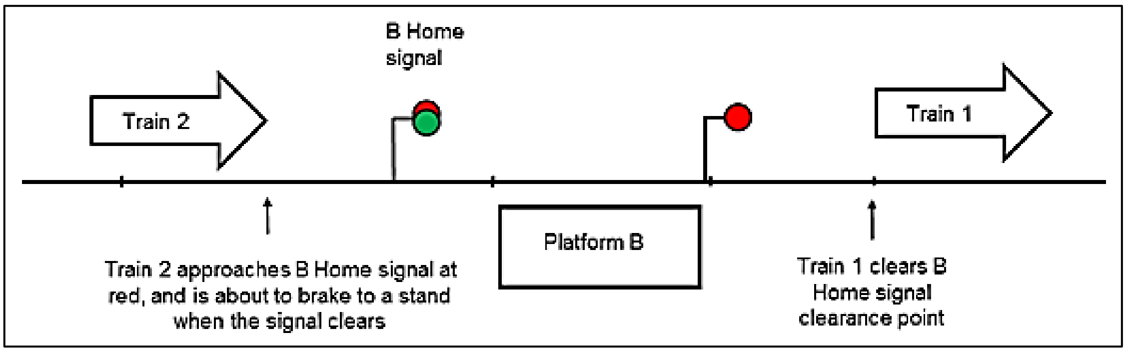
* The article noted that trains were operated as 3 or 5 car sets – the article did not mention peak and off-peak services.




Despite high scheduled service frequencies and growing traffic, the signalling was relatively straightforward. Signal overlaps were around 122 metres for intermediate and home signals. For station starters, overlaps were about 18 metres, except platforms which were regularly non-stopped, as shown below. There was one home signal protecting each platform.

# CAPACITY

When deciding on the level of service, it is important to assess whether it can be operated in practice. Timetables describe service frequencies, which must be greater than the minimum time separation of trains, or headway. These are often converted to trains per hour (tph). If the headway is 120 seconds, the equivalent tph will be 3,600/120 = 30. All running line signals are uniquely positioned and will therefore have their own individual headway, and hence, tph. The headway for a home signal is illustrated below.




The three components of a home signal headway are:

(1) Running in, from the sighting point of the signal to stopping in the platform.
(2) Platform dwell time (wheel stop to wheel start).
(3) Running out, from wheel start to clearing the limit of control of the home signal, enabling it to clear for the following train.

In addition to any signalling constraints, headways and capacity will depend on train speed, braking and acceleration, driving technique, and platform dwell time. The highest frequency of service that can be operated on a line will be determined by the signal with the longest headway. This is likely to be a home signal, because it includes a platform dwell time.

# ASSESSING THE CAPACITY OF THE ORIGINAL SIGNALLING SYSTEM

I have assessed the capacity of each of the original signals, based on a 1909 signalling diagram and the train performance characteristics given in a 1914 paper by Westinghouse Signal Engineer HG Brown to the Institution of Electrical Engineers. Given the critical dependence of capacity calculations on the assumptions made, it is worth listing them here:

(1) Train length: 91.4 metres.
(2) Train berthed in the middle of 106.7 metre long platforms.
(3) Acceleration: 1.0 mph per second (0.45 metres per sec per sec).
(4) Service brake rate 1.8 mph per second (0.80 metres per sec per sec).
(5) Maximum train speed: 25 miles per hour (11.2 metres per sec).
(6) Sighting time (time between sighting a restrictive signal and a full service brake application being in place). H.G. Brown's calculations are based only on the distance needed for a service brake application, without any sighting time. He stated that although a longer distance was needed in practice this was not included as it was required 'by the personal equation of the driver'. I have used 6 seconds, (the current LUL signalling standard), bearing in mind that the Westinghouse brake was the service brake as well as the emergency brake.
(7) Platform dwell time: H.G. Brown noted 10 seconds as a theoretical minimum, which could not be reliably achieved in practice. Given that there were only two doors per carriage for boarding and alighting, I have used 20 seconds, which is mentioned in 1910 as the permissible dwell at Tottenham Court Road.
(8) Reaction time to the clearance of a starting signal: I have used 5 seconds, bearing in mind the manual train despatch procedure with guard, gatemen and possibly platform staff.
(9) Equipment response time: I have used 2 seconds, covering track relays 'pick up', electro-pneumatic valve operation, flow of air and movement of the signal arm or spectacle.
(10) In areas controlled by signal cabins, I have allowed 2 seconds for each movement of a signal lever and 4 seconds for a points lever.
(11) All calculations have been based on level track: this means that the capacity estimates will be slightly optimistic on significantly uphill sections and slightly pessimistic on large down gradients; this is modest when compared with the difference in capacity of succeeding signals.

I recall that when planning for sustainable tph in the 1990s and 2000s, it was customary to add a recovery allowance of 20 seconds to the signalled headway in order to determine the maximum scheduled service. This was intended to reflect the variability of driving technique and peak dwell times, and enable a reasonable rate of recovery from service disruption. For example, if the longest signalled headway was 130 seconds (equivalent to 27.7 tph), the maximum planned service would be (3,600/(130 + 20) = 24.0 trains per hour. The approach in the early 20th century contained no recovery allowance.

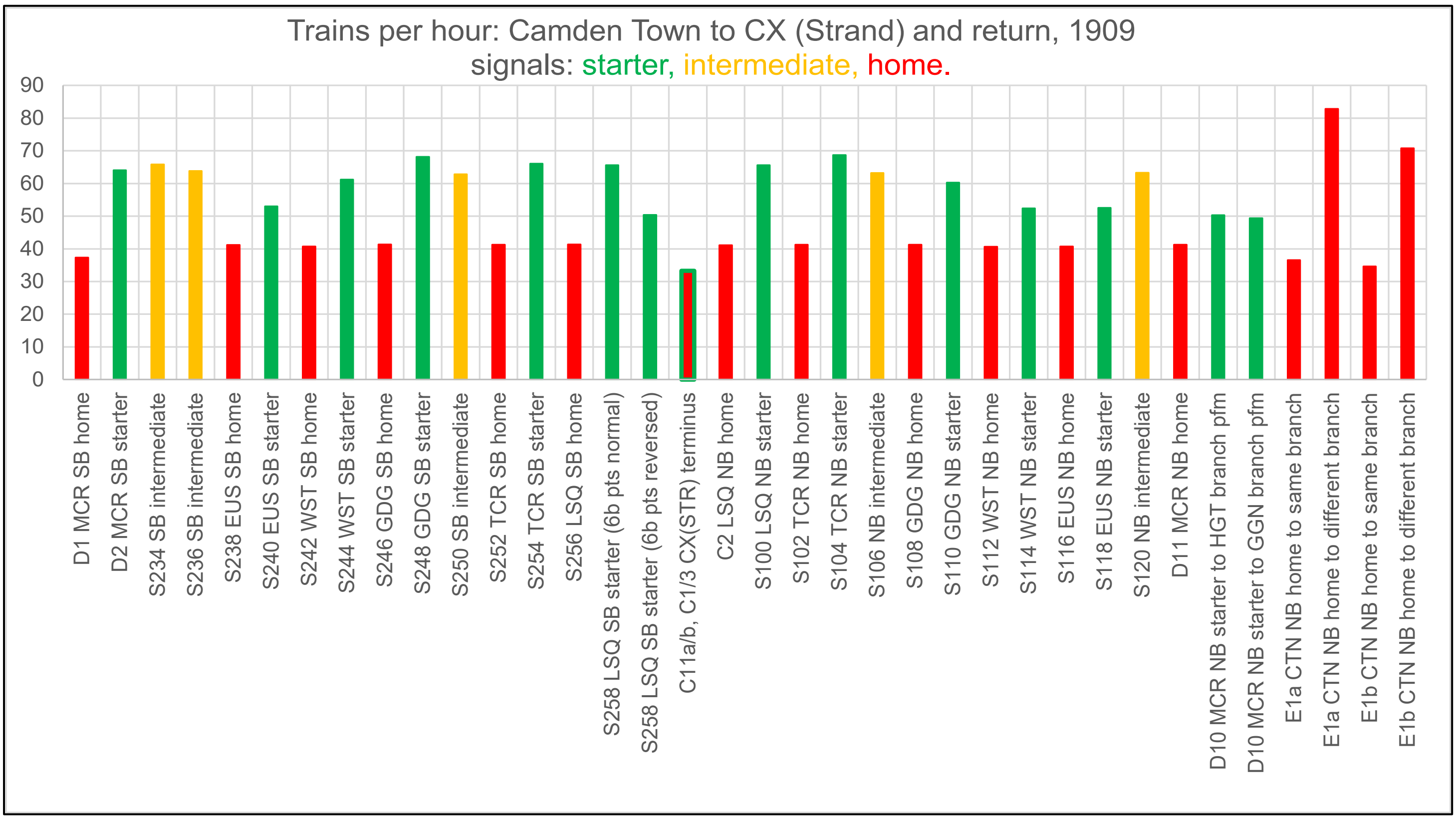
## CAPACITY ON TRUNK SECTION

It did not take long for the service level to be increased sufficiently to identify pinch points on the trunk section. On 30 November 1908, Arthur Cooper, Engineer of the Underground Electric Railway Company of London, wrote to the Board of Trade stating:

"The new service starting to-day on the Hampstead Tube Railway, is being somewhat hampered at our Charing Cross Terminus, and the bringing ahead of the Home Signal would materially facilitate the working at this place. Perhaps you would kindly assist us by considering this one Signal alone; leaving the several others mentioned in my letter to you of 21st instant, to a time more convenient to yourself".

The proposed change was to reduce the overlap of the junction home signal(s) from 124 to 80 metres. The safety justification consisted of tripping a train at 20 mph at the signals and noting that it stopped in 38 metres, 53 metres short of the crossover. This was approved, and improved the capacity at Charing Cross from 31.8 to 33.5 tph. This figure is sensitive to the speed of trains over the crossover: if this rises from 10 to 15 mph, the capacity increases to 36.8 tph. However, the latter is still below the peak schedule of 40 tph, and suggests that speeds may have been higher than 15 mph in practice.

The graph below shows the estimated capacity at each signal on the trunk section, colour coded by type.




As expected, the lowest capacities (just above 40 trains per hour) are associated with home signals.

In March 1909, Arthur Cooper wrote again to the Board of Trade with a request for a list of signal alterations 'to facilitate traffic working'. The changes requested on the CCE&H included:

(1) Moving home signals at Charing Cross [already implemented], Tottenham Court Road northbound, Euston and Highgate closer to the platforms.
(2) Providing an inner home signal at Tottenham Court Road southbound.

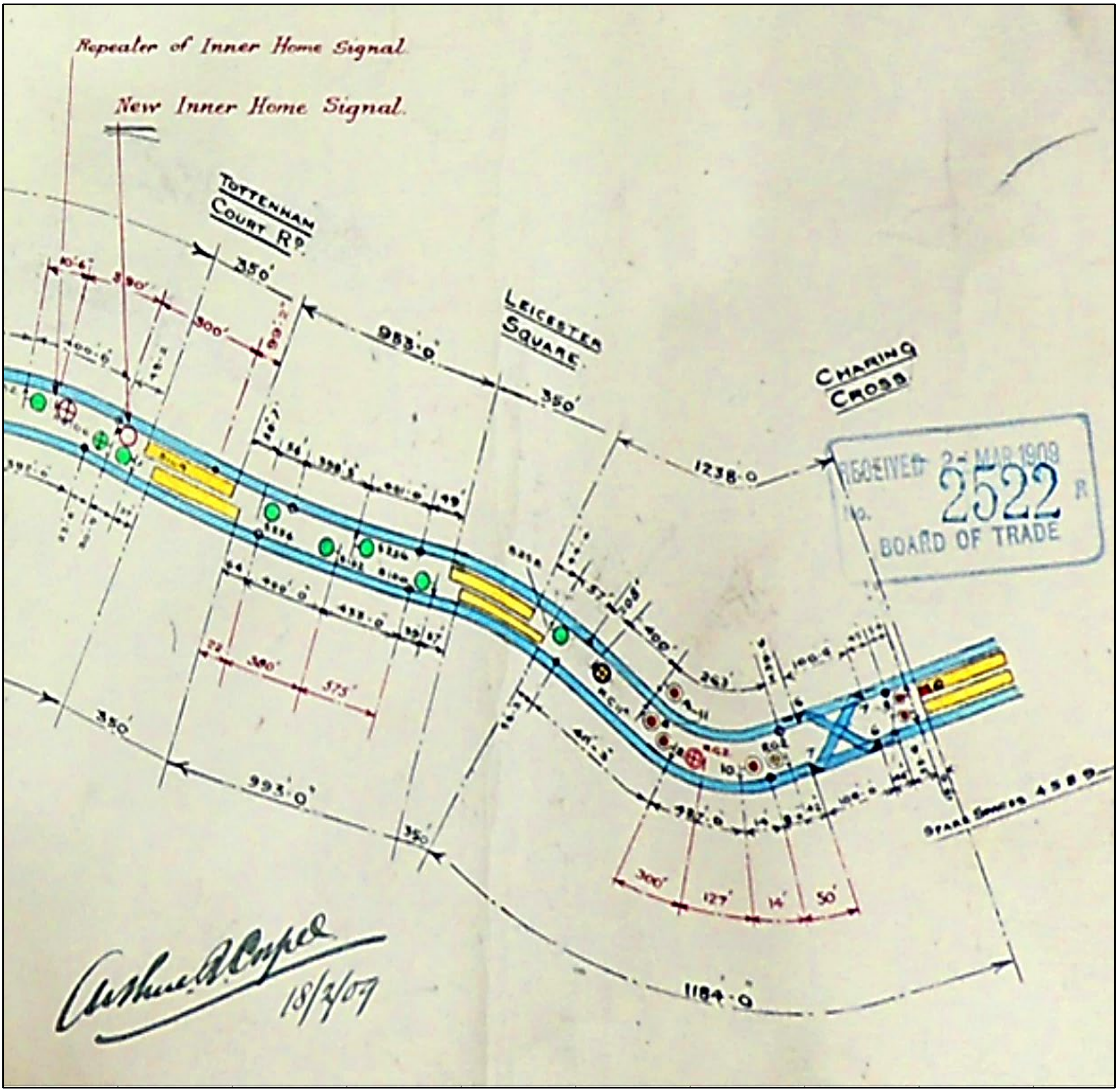
The Railway Engineer of February 1910 noted:

"To obtain this latter rapid service only a station stop of 20 seconds is permissible, but the traffic requirements at Tottenham Court Road Station call for 35 seconds".

My analysis suggests that neither of the improvements at Tottenham Court Road would enable a 15 second increase in the dwell time without loss of capacity:

| | Headway reduction | Trains per hour increase |
|---|---|---|
| Northbound: home signal moved 100 foot north | 3.9 seconds | 1.9 |
| Southbound: new inner home signal | 6.7 seconds | 3.4 |

Below is an extract of a plan, submitted to the Board of Trade, showing proposed alterations at Tottenham Court Road in dark red.



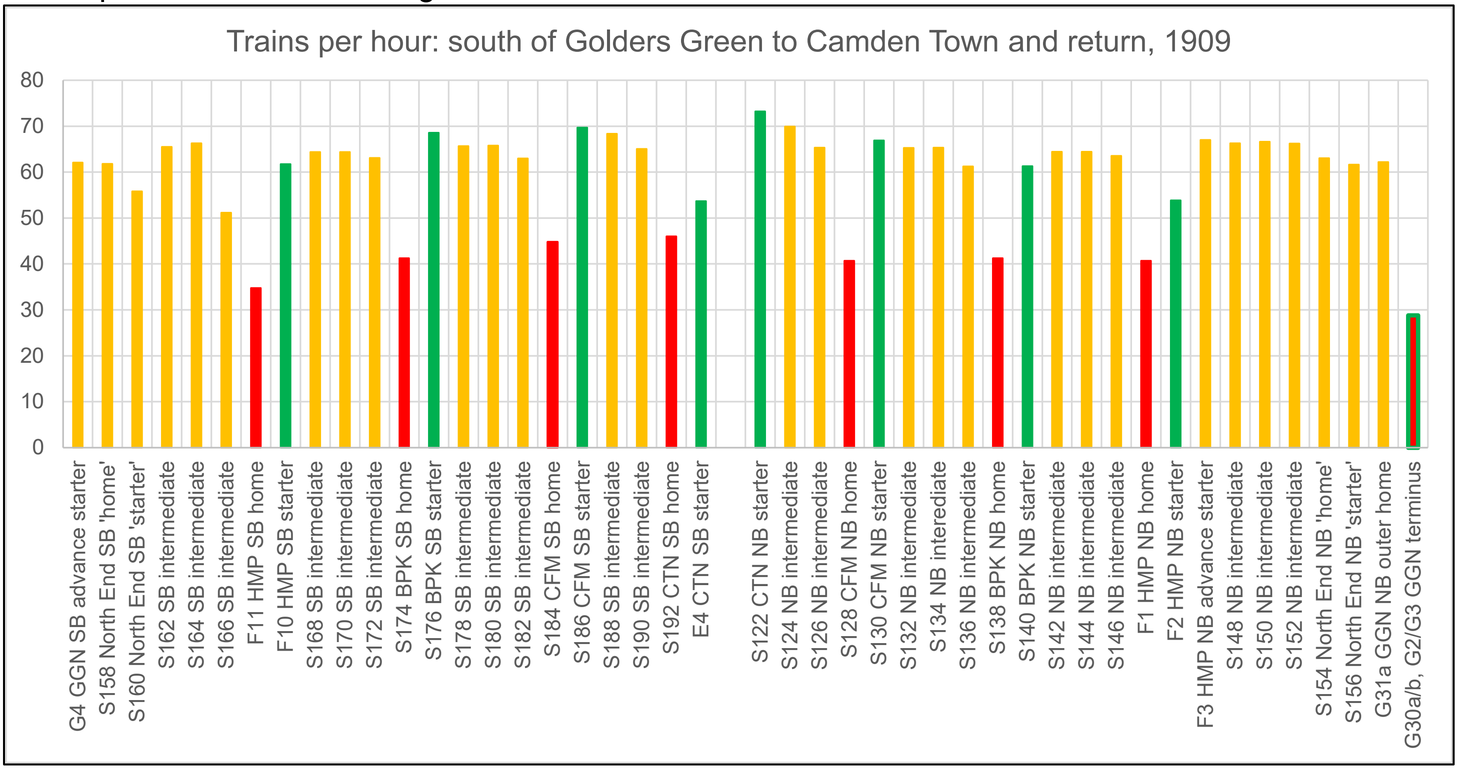

## CAPACITY ON NORTHERN BRANCHES

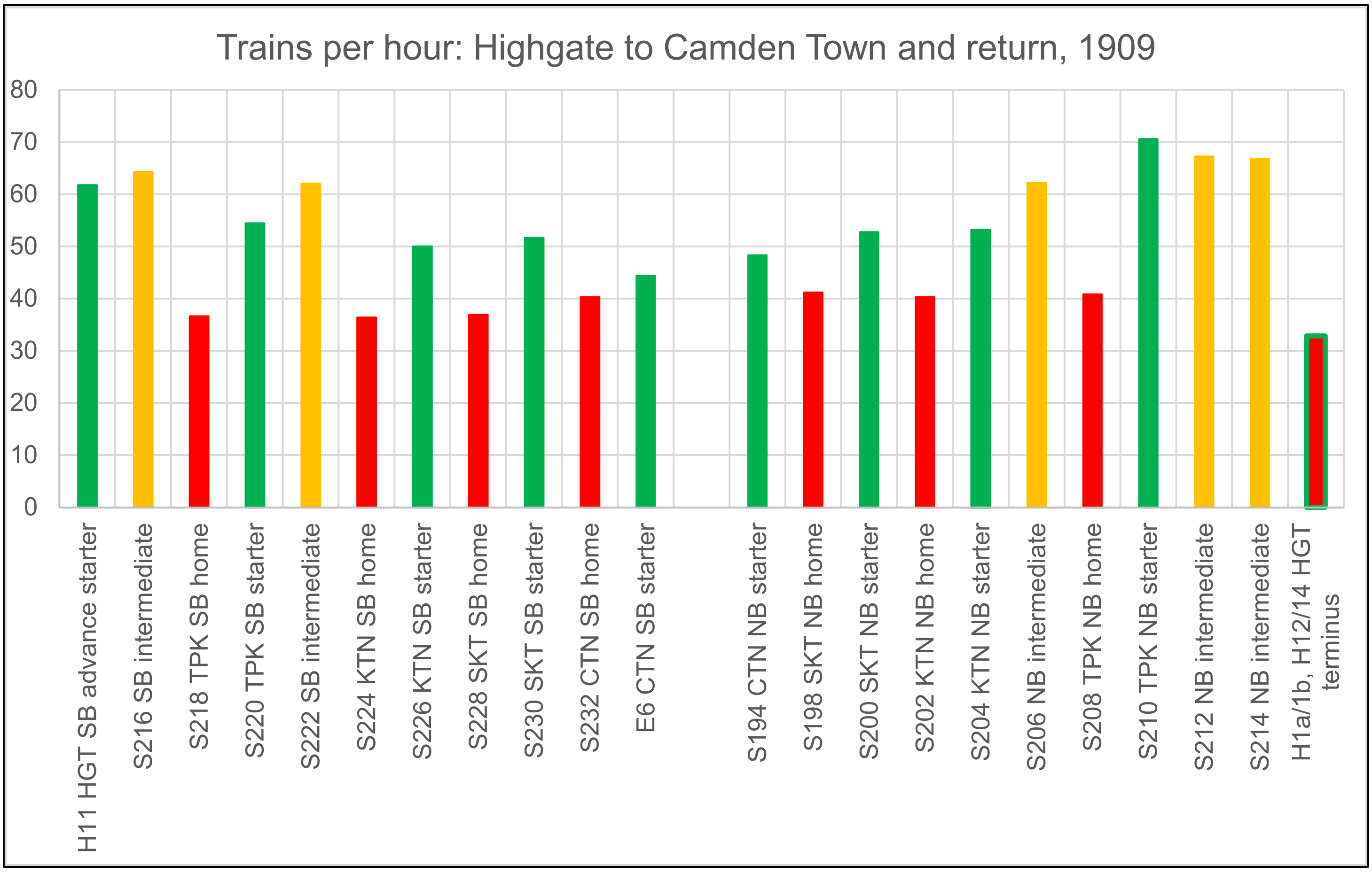
Although each northern branch saw half the service on the trunk section, the signalling was little different to that south of Camden Town. This would have assisted in reducing disruption in the event of a long delay, as either branch could cope with most of the other's traffic in addition to its own. The capacity at platform home signals was above generally above 40 tph, except:

(1) At Hampstead southbound, where the signal home signal was 425 metres from the stopping point, protecting movements over the crossover as well as trains in the platform.

(2) At Tufnell Park, Kentish Town and South Kentish Town southbound, where the starting signal overlaps had been extended in order to enable scheduled non-stopping of some trains.

The capacities of individual signals are shown overleaf.

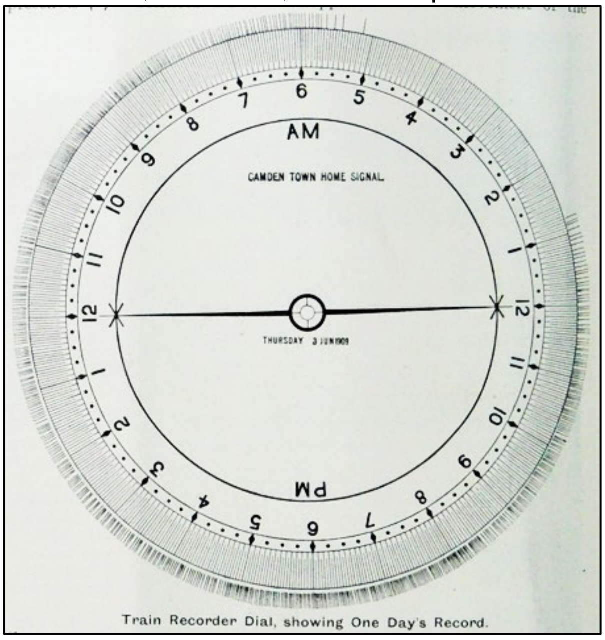


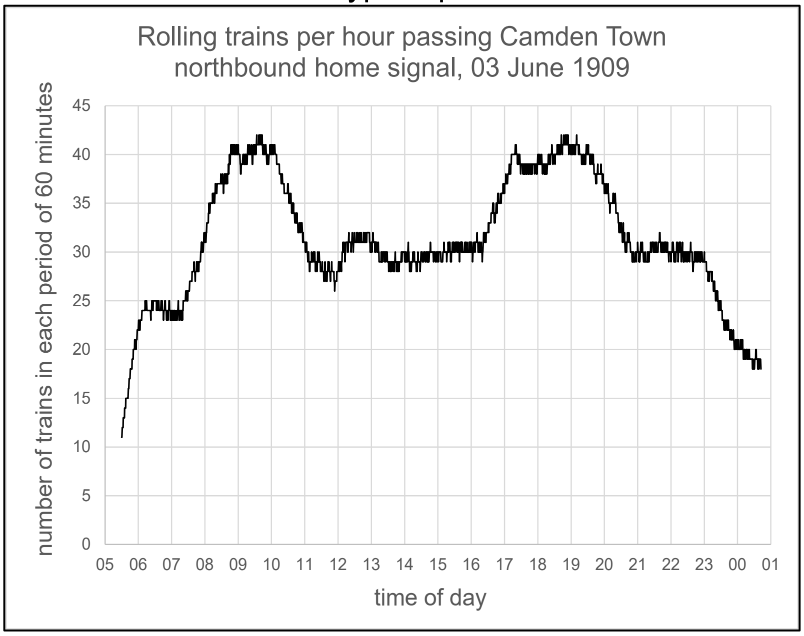

## ACTUAL PERFORMANCE

Given the constraint of reversing at CX (Strand), how many trains per hour were achieved in practice? An article in the Railway Times included a Train Recorder Dial, linked to Camden Town northbound home signal. A line was marked on a circular paper disc each time a train passed. The dial for Thursday 03 June 1909 is reproduced opposite *(Top Left).*

Conversion to a rolling total of trains in each 60 minutes gives the following graph, which shows that 40 and 30 tph were achieved in the peak and off peak on that day. The graph *(Opposite, Top Right)* also suggests minor delays around 1130 and 1730hrs, resulting in slight backlogs of trains. There is no indication, however, of how representative the 03 June 1909 was of typical performance.



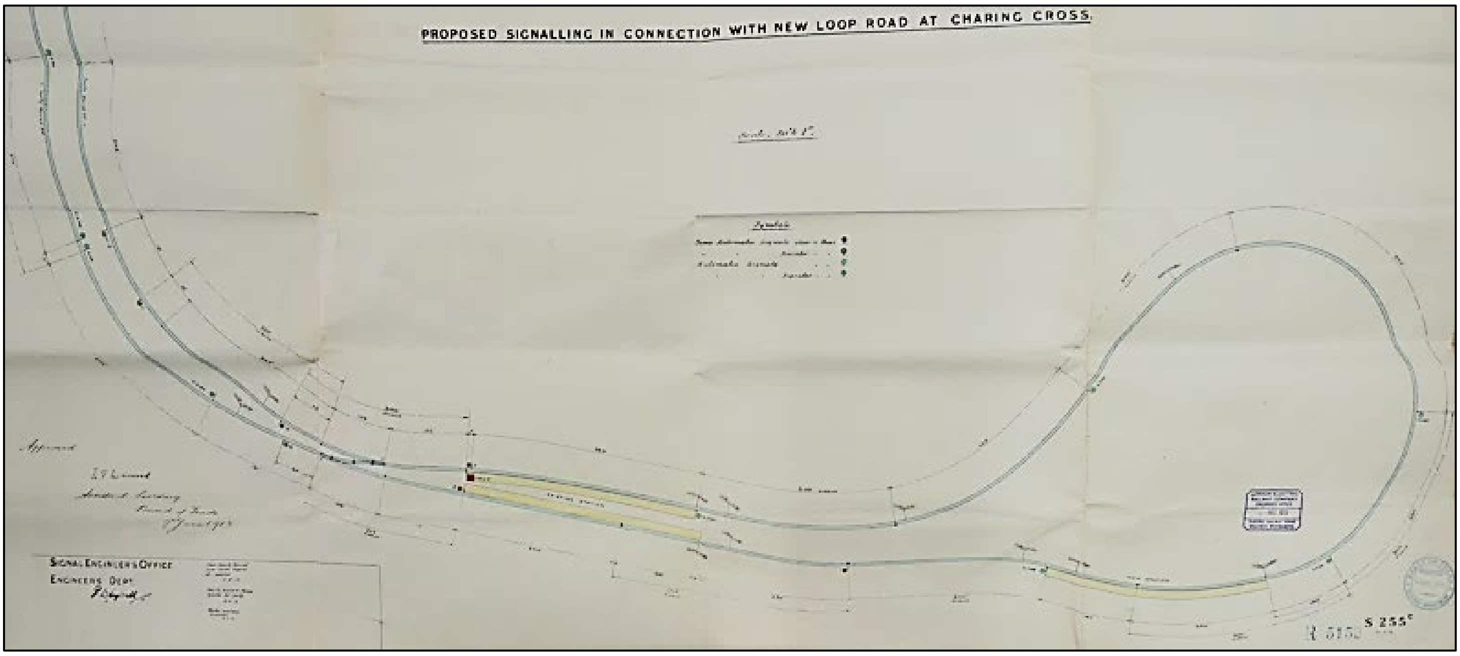
Train Recorder Dial, showing One Day's Record.



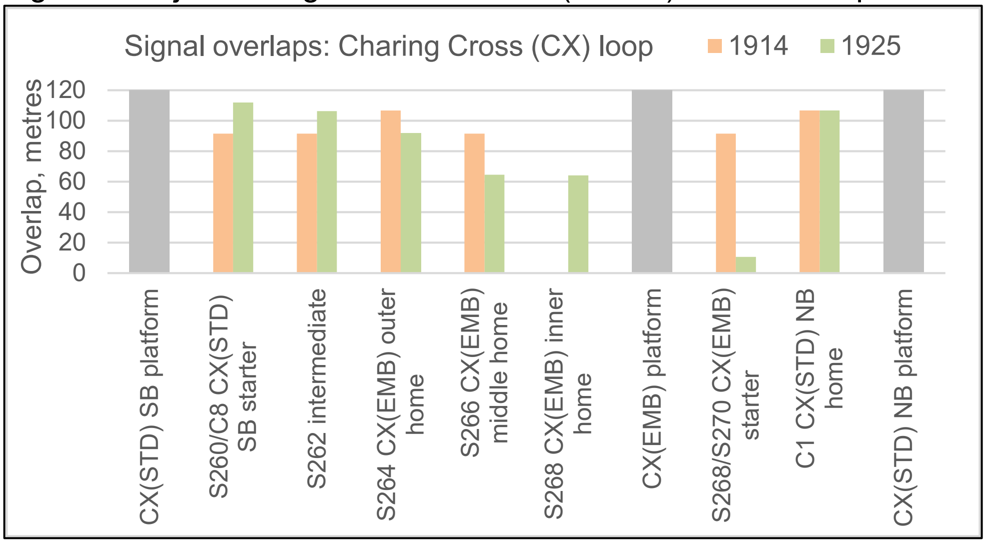

The Railway Times of 16 October 1909 noted that services were being increased from 40 to 42 trains per hour. A year later, the Railway Gazette noted that the number of trains worked south of Camden Town rose from 455 in 1907 to 621 in 1910, a rise of 36%. This suggests continuing traffic growth, and upward pressure on peak dwell times.

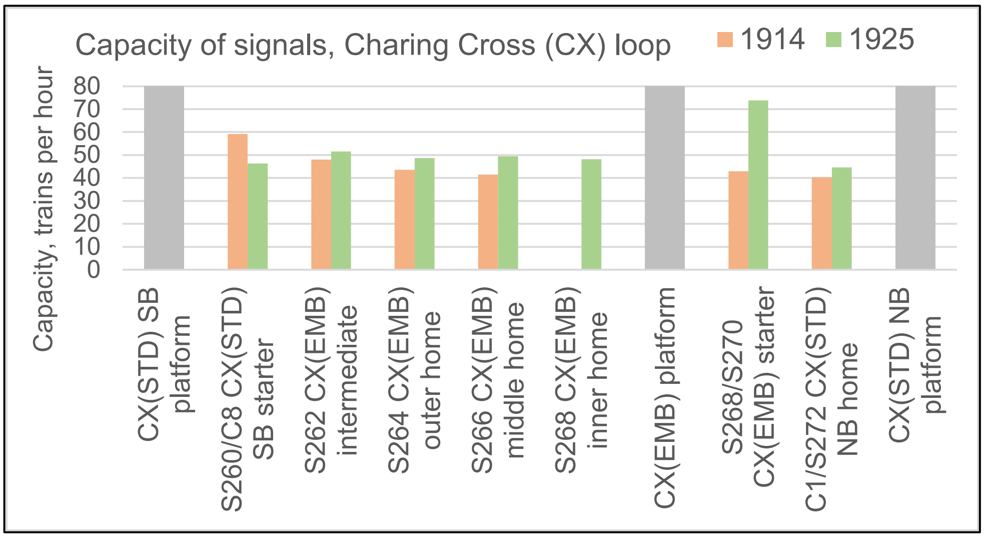
## EXTENSION FROM STRAND TO CHARING CROSS

The lack of headroom between scheduled number of trains and practical capacity at CX (Strand) and Tottenham Court Road may well have resulted in queues of peak trains approaching these locations, and slow recovery from service disruption. In April 1914 an extension was opened from CX (Strand) via a 'tear drop' shaped loop to a single platform at CX (Embankment), as shown below.

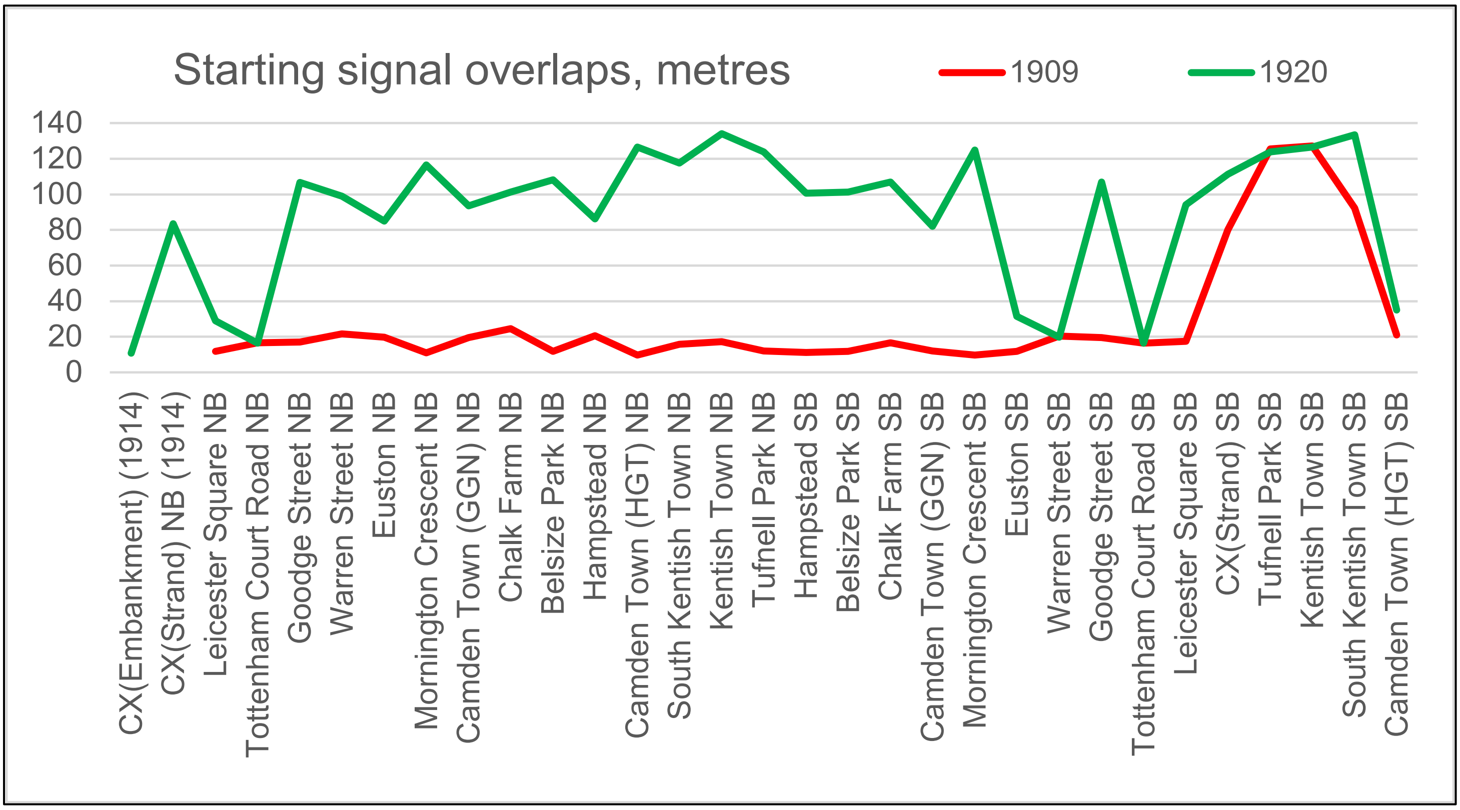



The loop curved sharply (70 metres radius, compared with 101 metres of Kennington loop), and speed was limited to 15 mph. The key advantage of this type of terminal arrangement was simplicity – avoidance of point work (and therefore a signal cabin), and the need to reverse each train. The signalling, approved by the Board of Trade in June 1913, had been significantly improved by 1925. The key changes were the addition of a third home signal and shortening of overlaps at CX (Embankment), particularly the starter overlap (from 91 to 11 metres), increasing capacity by 4 tph. This suggests there was continuing pressure on capacity from long dwell times at CX (Embankment). This is understandable, given that the loop platform became today's sharply curved platform at Embankment northbound: This single platform coped with boarding and alighting, on trains with only two doors per carriage. The substantial increase in capacity of CX (Embankment) starting signal was due to the home signal blockjoint being moved from CX (Strand) northbound platform to slightly south of it.




Files held by Transport for London Archives Section shed some light on how overlaps were amended. As mentioned, the original signalling overlaps were broadly either 122 metres, or 18 metres for station starting signals (except for platforms which were scheduled to be non-stopped). The operator was keen to reduce advertised journey times by increasing the number of stations that were non-stopped. This required the starter overlap to be increased (see graph below): the non-stopping speed was 20 mph. This increased home signal headways and put more pressure on keeping peak dwell times down. As traffic built up, proposals were introduced to add inner home signals, starting at Tottenham Court Road southbound.




There needed to be a rationale for moving away from fixed overlaps, if they were to be reduced with safety. Overlaps began to be related to the observed speed of trains passing the signal, and how far the train travelled after being tripped. This enabled an understanding of the rate at which trains decelerated after tripping, and the adoption of a brake rate of 10% (percentage of the acceleration due to the earth's gravity (0.98 metres per sec per sec), adjusted for track gradient). A 10% brake rate was applied to the observed speed of trains passing each signal, and 30% added to the result 'to provide a margin of safety'.

The following examples give a flavour of early memos.

From the Engineer to the Mechanical Engineer on 07 Nov 1917:

**CHARING CROSS (LOOP) STN**

Trains are being checked badly entering the Loop Station at Charing Cross, that is to say, during the heavy service.

Mr Whysall [Signal Engineer] has looked into this question, and recommends that the overlap on Signal S266 [middle home signal] should be reduced by 84 feet. There is a speed restriction round this Loop of 15 miles per hour, but from records taken this speed is at times well exceeded.

In view of the 3½ chains curve, the overlap installed, I think, is excessive, and shall be glad to hear whether you see any objection to its being reduced to an overlap of 216 ft. On the straight this apparently is good for 25 miles per hour, but on this curve it would be good for a speed considerably higher.

The Mechanical Engineer responded on 12 Nov 1917:

In reply to your memo of 7th November, I see no objection to the overlap of S266 being reduced to 216 feet, having regard to the existence of the speed restriction of 15 miles per hour and the sharpness of the curve.

A stopping distance of 216 feet for trains travelling at 25 mph corresponds to an average brake rate of 0.95 metres per sec per sec, or a braking efficiency of 9.7%.

The Engineer further responded on 26 Nov 1917:

**CHARING CROSS (LOOP) STATION SIGNALLING**

Further to my memorandum of 7th instant: the alteration has improved the clearance of the signal in question, but it has (as might have been supposed) thrown it ahead to the following signals. Please say if you agree with the reduced overlaps as shown on the plan herewith sent you. Kindly return early.

From the Mechanical Engineer to the Engineer on 08 Jan 1918:

**SIGNALLING AT CHARING CROSS – HAMPSTEAD LINE.**

I note in Traffic Notice 2/18 that the over-lap on the starting signal at Charing Cross Station has been reduced from 289 feet to 35 feet. I have apparently no memo from you on the subject. I rather think that at 35 feet an overlap on a 1/50 down gradient is rather a fine margin even for a starting signal.

From the Engineer to the Mechanical Engineer on 11 Jan 1918:

**SIGNALLING AT CHARING CROSS – HAMPSTEAD LINE.**

In reply to your memorandum of the 8th inst, I have had a drawing showing these alterations turned out and find that you signed this drawing on November 28th last. There may have been some little confusion in your mind as this drawing shows three separate alterations, one to signal S266, which you approved in the memorandum dated November 12th, also to S268, as well as the starting signal. My memorandum to you of November 26th refers to alterations to S268 as well as the starting signal it being shown on the plan sent you. Apparently you overlooked the fact that the starting signal alteration was included as well as S268. My memorandum of 26th November refers to overlaps in the plural.

With reference to your remark relative to down gradient you must I think have in mind some other station. The gradient leaving the loop station is 1/50 Up and not 1/50 Down and on a seven chain curve. My recent memorandum (copy of) to you has some bearing on the particular feature you mention of short overlaps at stations.

The Mechanical Engineer replied on 15 Jan 1918:

**SIGNALLING AT CHARING CROSS – HAMPSTEAD LINE.**

Your memo of 11th January, and note that I signed the drawing, but find that my memo of 27th November approved only S.268.

My copy of "Overlaps of Signals" 13th April 1915 gives 1/50 <u>down</u> but I note it is incorrect.

Your memo of 11th January to Mr Blake suggests 100 ft for starting signals rather emphasises this overlap as being short.

From the Engineer to the Mechanical Engineer on 24 Nov 1919:

**OVERLAPS**

Owing to a good deal of checking of trains during the busy service on the Hampstead Line, I arranged with Mr Thornton for Divisional Inspector Hodge and Mr Proud of the Signal Office to study the matter on the site. As an outcome they prepared a scheme for rearrangement of the Signals at Leicester Square, which is shown on diagram A.S.1337, dated 11th Nov 1919. This rearrangement involves reducing the overlap on the Starting Signal from 309 to 100 feet. This I think is in accordance with the arrangement we came to and is covered by memorandum dated 31st January 1918. Before, however, having the alterations put in hand I shall be glad to hear that you agree to this change in the Overlap.

From the Mechanical Engineer to the Engineer on 26 Nov 1919:

**OVERLAPS**

In reply to your memo of 24th November, I note that the overlap of the inner home S.257 has been reduced to 319 feet and its position has been altered so that with 3-car train working it becomes the home signal.

In these circumstances I do not think that the overlap proposed provides the customary margin of safety.

The Engineer to the Mechanical Engineer on 09 December 1919:

**SIGNAL OVERLAPS**

Referring to your memorandum of the 26th ultimo, the reduction in the overlap of Signal S.257 from 354ft to 319ft was made as presumably the overlap was in excess of that required by the agreement we came to. The agreement, as I understand it, is that an overlap shall be provided based upon the observed speed at signals as supplied by you, and that for this observed speed the overlap shall be calculated according to your diagram at 10% on the level corrected as required for gradients, giving also allowance of 30% as a margin of safety. The observed speeds were supplied by you in January, 1913, and attached thereto is a memorandum detailing the arrangement. The observed speed at Signal No 257 is shown as 27 miles, and 319 ft gives the requisite overlap on this basis. Maybe, there is some misunderstanding on this matter, but, if so, I should like to clear the matter up, and make the memorandum or data upon which we are now working perfectly clear.

Many further discussions took place with the introduction of faster trains, changes in braking material, and in the light of operational experience. The extracts are a small fraction of the information available; they illustrate the early development of a pioneering system of metro signalling, descendants of which continue to safeguard customers and staff on the Bakerloo and Piccadilly lines over a century later.

The information in this article has been taken from National Archives, Kew, and Transport for London records.

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