LONDON TRANSPORT TELECOMMUNICATIONS

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By

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INTRODUCTION

This book had been intended simply to chart the development of London Transport's telephone communications, which is a big enough subject in itself. While tackling the job, it became obvious that at different times other forms of communication had been of equal importance and it seemed perverse to ignore them. They were really part of the same story, and much of the information lay in the same sources: it was also improbable that anyone else was likely to tackle the subject. Nevertheless the majority of the space here is devoted, if not necessarily to the telephone, certainly to fixed two-way communication systems.

Such a work does really need a beginning and an end. This is not a history of telephony, so the story really only begins when the forebears of the London Underground came into existence. The end point is more troublesome. For better or worse it is probably most convenient to draw the line at the end of London Transport itself, which is the point at which London Underground transfers to Transport for London (TfL). TfL is a new and much more diverse body than was London Transport, so it will provide plenty of scope for some writer in the future to chart the telecommunications activities of that organization, and I wish he or she much luck.

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Chapter 1 – Before the Telephone

Telegraphs and Railways

The early railways in the British Isles quickly emerged as the fastest practical means of communication. It is true there were a few long-range optical 'telegraphs' but these were primarily for military and government use and were not material to more general communication requirements. The absence of any means of mass communication meant that the only means of passing messages about urgent adjustments to the planned train service was physically to send them by train. It was, of course, impossible to send messages any faster, and this delay soon proved inconvenient. The worst instances occurred when some mishap delayed or completely stopped a train; typically, the evidence of a problem only emerged when a train failed to arrive whence enquiries would then begin and perhaps a special train would be despatched to investigate. This was immensely limiting and railways had to manage their affairs purely on the basis of what they expected to happen; they were unable to take preventative or mitigating action for want of information, or to offer useful information to passengers.

All this changed when the electric telegraph became available. The electric telegraph (or telegraph for short) was a means of sending messages from one place to another instantaneously. It was particularly suited to the use of a railway company for two reasons. First it meant urgent messages could be transmitted independently of the trains and so quickly that timely adjustments to the service could be planned in advance of any train to which a message related. Secondly, the railways were in the happy position of owning a linear right of way over which the necessary cables could be laid without the need to negotiate with hundreds of landowners in order to establish a route.

Although railways were initially sceptical about adopting the telegraph, owing mainly to expense and reliability, the availability of relatively simple and reliable telegraph equipment from the mid 1840s caused more enthusiasm as the usefulness of the apparatus over significant distances became apparent; even so, it took between five and ten years more before railway managers were generally clamouring for it (and then as much because of its revenue-earning potential as its ability to forecast trains). By the 1870s it was becoming unusual to find a railway that did not make use of the telegraph at all.

For railway purposes the telegraph was to develop along three parallel lines, in all cases relying on an electrical voltage applied to one end of a wire that caused the deflection of a needle indicator at the other—messages were transmitted in code represented by deflections of the needles. Although some early telegraphs used multiple needles the majority had just one, which could be caused to move one way or the other and thus show two different indications as well as 'off'; this was achieved by using polarised needles which responded differently to the direction of the current applied. At first the code used was peculiar to the railway (and may have differed between the different companies), but in the latter part of the nineteenth century these signals were usually coded in the Morse Code, a deflection one way representing a 'dot' while the other way signified a 'dash'. These instruments (known as single needle instruments) all gave transient displays and the equipment required monitoring when messages were being expected, either by dedicated telegraph clerks or by (for example) railway signalmen trained for the purpose. Sometimes bells were used to call attention to instruments to which messages were about to be sent.

The telegraph could equally well be used to convey messages on behalf of the public, for a fee, and this represents its second line of development. Use for sending public messages was easier where the railway had an arrangement with a large telegraph company that could route messages beyond the district covered by the railway, and which had messengers available to deliver the telegrams to their final destination. Many telegraph companies formed alliances with railways because they offered convenient rights of way. The Post Office nationalized the

telegraphs in 1870 (by which is meant the public telegraphs just described), but the railways maintained their own systems for internal use until supplanted by other methods, though complicated arrangements had to be entered into where public and private telegraphs shared wires and equipment, which they often did.[1]

At first it was common for the telegraph to be used for all forms of communication on the railway but inconvenience soon arose over the conflicting priorities afforded to the various types of message and the possible confusion that might arise in transmitting safety-critical messages about train working. The London & North Western Railway appears to have been one of the earliest railways to address this issue when about 1854 they provided duplicate instruments so that one set could be devoted exclusively to train working and the other for more general messages.[2] At this time the instruments used for conveying general messages became known as 'Speaking Instruments' as any message could be send letter by letter.

On the other hand the train working instruments were mainly confined to describing the state of the line by means of a limited set of codes which meant, for example, 'train on line'. The coded messages were still transient and the clerk or signalmen needed to be very careful to record or memorise what had been sent, and this was far from ideal given the risk of serious accident if any mistake were made. It required a small modification to address this, which was simply to provide the means of holding the handles of the sending equipment in one or other of the 'send' positions so that the needle on the receiving unit continued to indicate permanently the state of the line. Initially wooden pegs were provided to hold the levers in position but in many later telegraph indicators more elegant solutions achieved the same ends. The train working telegraphs were essentially 'fail-safe' as a failure of current or broken wire would result in the needle returning to the neutral position thereby indicating some kind of problem.

In the form just described the train working telegraph was ideal for use with the emerging 'block' system which seems to have begun life as a means of preventing collisions in long tunnels where visibility was seriously restricted.* Suffice to say here that the block system became universal by law in 1889 and the telegraph essentially as just described was integral to its operation. In short the railway was divided into 'block' sections with a signalman at either end operating signals controlling entry to that section. No train was permitted to enter a section until the previous one had left it and the telegraph instruments (operated by the signalmen at the 'running off' end of the section) were used to indicate positively to the other signalman either that the intervening line was clear or that there was a train in that section. Any change of state was forecast by bell signals which also conveyed useful additional information such as the type of train being offered. The system is still in use on some parts of the main line railway today.

This third form of the telegraph was not intended to communicate general messages and falls away from the main story of railway communications in favour of its proper place in the history of signalling systems.

The use of the speaking telegraph for general internal communication within the railway network became an essential tool. It took many forms depending on the amount of traffic likely to be carried, the probable skills of the operators, and the money that was available for the apparatus. It was only intended for urgent communications, everything else went by messenger or letter. Vast amounts of communication took place by standardized forms, all transmitted by some sort of regular post (or despatch) system. London Transport, with whom we are concerned here, even had forms to explain that there were no forms to be despatched. Somehow it all worked.

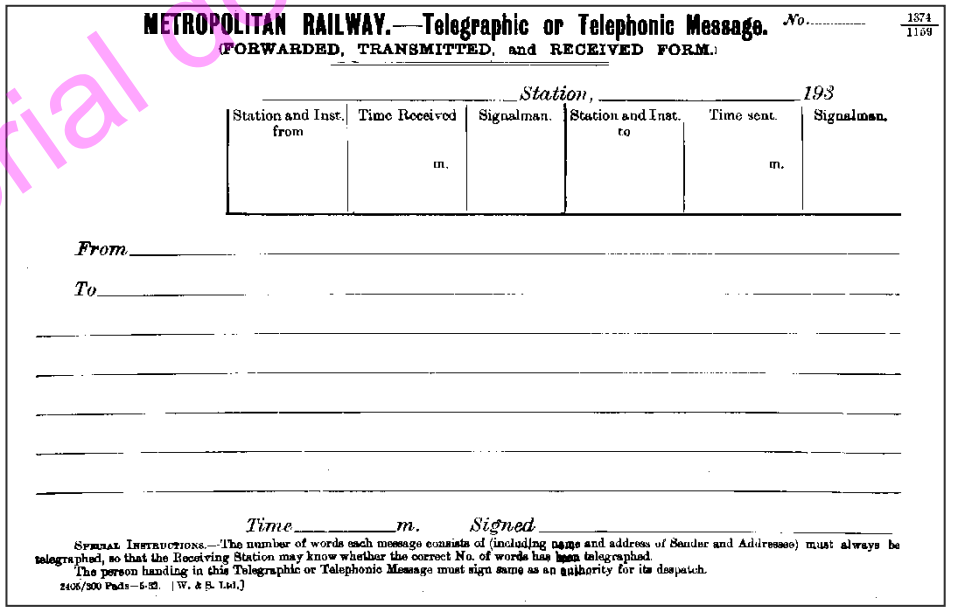
* The Great Western Railway seems to have been the first to install a dedicated block telegraph, in 1847 through Box tunnel.

The Metropolitan Railway

When the first part of the London Underground (the Metropolitan Railway) came into operation in January 1863 it fully exploited telegraphic apparatus to assist with the safe movement of the trains. It was important that a railway operating entirely underground and in conditions of restricted visibility caused by dark and smoky tunnels should have efficient communications. 2-position telegraph instruments were used on each road for regulating the service, supplemented by single-stroke electric bells that transmitted extra information by coded signals. In September 1863 the telegraph pioneer Charles Spagnoletti was appointed as a contractor to 'keep the telegraphs in order' for the sum of £250 a year. At the same board meeting it was noted that the Great Northern Railway (who began running trains over the Metropolitan from October 1863) wanted the use of 'a wire' for its own telegraphic purposes and it was agreed to. A similar telegraphic system was used on the District Railway, opened in 1868, to which the Metropolitan was connected and which for a brief time it also managed.

Although firm evidence has not been found, it is likely that the Metropolitan would also have had speaking instruments from the start. Certainly by 1875 Metropolitan Railway signalling regulations clearly state that stations at each end of the line were equipped with two train signalling instruments (one up and one down), a telegraph bell, and two speaking instruments, one connected to the next station and one 'for communication with all stations'. Intermediate stations had four block instruments, two bells and three speaking instruments (one for connecting to any station and the other two connecting only with stations either side). The dedicated speaking instruments were a means of providing secure communications in the event of failure of the block circuits. It is assumed that the 'all stations' instrument was connected to some sort of omnibus or code circuit, as described later.

During November 1875 the Metropolitan was examining the case to put the company's general offices in Westbourne Terrace into telegraphic communication with its stations. Two options were considered, one involving connection with the six principal stations only, at a price of £123:15s:0d (plus £24 pa maintenance), and the other involved connection with all 19 stations (South Kensington to Bishopsgate) at a cost of £314:10s:0d (plus £80 pa maintenance); it was noted that existing wires would be used although there would be some 'over house' work. An option was also offered to connect the general offices with the solicitor's office at Broad Sanctuary, Westminster, for a cost of £190:2s:9d (maintenance £25 pa) and this would use two spare instruments. The matter was left for the Chairman to decide and the minutes record authority to spend



METROPOLITAN RAILWAY.—Telegraphic or Telephonic Message. No.....

(FORWARDED, TRANSMITTED, and RECEIVED FORM.)

1874
1169

Station, _____ *193*

Station and Inst. from	Time Received	Signalman.	Station and Inst. to	Time sent.	Signalman.
	m.			m.	

From _____

To _____

Time _____ *m.* *Signed* _____

Special Instructions.—The number of words each message consists of (including name and address of Sender and Addressee) must always be telegraphed, so that the Receiving Station may know whether the correct No. of words has been telegraphed.
The person handing in this Telegraphic or Telephonic Message must sign same as an authority for its despatch.

2405/300 Pads—5-82. [W. & S. Ltd.]

£300 to connect to the principle stations and the solicitor's office; the six stations chosen are not stated but one might suppose they included Baker Street, Kings Cross, Moorgate and Farringdon. There are few other

references in the board minutes to expenditure on telegraphs so one might infer that the Metropolitan's network was comparatively stable.

By the start of the twentieth century there was still a substantial telegraph network for the passing of general messages on both the Metropolitan and the District Railways, although some speaking instruments had been supplanted by the telephone. Where they had survived, instruments were still of the two-position 'needle' type with each letter communicated by Morse code using the different needle deflections to represent dots or dashes. In common with other railways, frequently used words and phrases were reduced to a brief code. The practice was that all messages had to be recorded in writing and copies kept. An accident on the Metropolitan in 1901 indicated that the efficiency of the telegraph organization was rather less than perfect and it is discovered that Spagnoletti's staff were still responsible for installation and maintenance work—not a bad contract to have had for some 38 years. To improve efficiency the Metropolitan brought the entire organization of 18 staff and their immediate boss (a Mr E.G. Phillips) in house from 1st January 1902, making Mr Phillips their Telegraph Engineer at a salary of £300. At the time the total annual maintenance expenditure was recorded as £5220. Out of consideration for Spagnoletti's long and loyal service he was appointed, at the age of 70, 'Consulting Engineer for Signalling and Telegraphs' on a retained basis for 100 guineas a year, though by January 1905 it was observed that it had been quite unnecessary to consult him at all and the board was asked if it were possible to stop paying him.

Although more modern methods of communication were substantially in place, even by 1912 the telegraph was the main mode of communication in the remoter parts of the Metropolitan and its joint lines. 'Omnibus' circuits were deployed, where numerous instruments were connected to the same wires, and all operated at once (users had to check each time to see for whom a message was intended). Three omnibus telegraph circuits were still provided: Number 6 served stations and signal boxes Chalfont Road to Verney Junction, Number 7 Quainton Road to Brill, and Number 8 Harrow to Uxbridge. Telegraphic messages were exchanged using predetermined codes from a code book (a standard book of codes was then becoming established throughout all railways in the UK). By 1922 circuits 6 and 7 were operative (8 had apparently been dispensed with), although there is now reference to a telegraph circuit Number 1 which served Marylebone telegraph office and the Great Central Railway north of Quainton Road, but with intermediate instruments at Wendover and Aylesbury North. The telegraph instruments on circuit number 1 went out of use in 1931, the Brill branch closed in 1935 (which would have put paid to circuit No 7) but the fate of circuit 6 is less certain; there is some evidence that the circuit may have been shared with telephone instruments until 1931 when at least some single needle instruments were removed but it is just possible telegraph instruments were retained on the Verney Junction line until its simplification in 1941. Certainly it is very unlikely any speaking instruments survived the war anywhere on the system.

The District Railway and other Underground Lines

In the years leading up to electrification the District Railway had also been an enthusiastic user of the telegraph and its telegraphic history closely followed that of the Metropolitan. In 1901 the telegraph was already used to distribute a daily time signal to stations; at 7:58 am the operative at Westminster station took possession of what was known as the 'through' circuit and indicated a time signal was to be sent—the needle then being held over until precisely the moment he heard Big Ben (over the road) sound the hour. The telegraph clerks at Earl's Court and Mill Hill Park had to retransmit the time signal by releasing the needles on the branch circuits when that on the through circuit was released. The time signals were primarily intended for regulating signal box clocks but the inspectors had instructions to make sure other clocks were properly set as well.

For certain, by 1903 there were six 'omnibus' telegraph circuits that between them served most of the network between East Ham and Ealing Broadway; this included the branch to Putney but excluded the Hounslow line and some of the lesser-used stations. Frivolous messages were discouraged (the instructions expressly prohibited their use for tracing missing luggage, or where a message could be sent by train). Instruments were all of the single needle type and messages were sent in the Morse code. As with the Metropolitan, to reduce the length of messages various commonly used terms were reduced to a small number of letters (for example 'PQ' meant 'end of message').

Whether any of the later constituents of the Underground made use of the telegraph has been impossible to establish to the same level of certainty, although recollections of a former signalman from the City & South London Railway (opened in 1890) suggest that telephones were not originally available between stations and that it was necessary to telegraph using the Morse code (suggesting the use of single needle instruments).[3] It is possible the Central London had telegraphs but by 1900 the telephone was becoming all pervading and it is very unlikely any of the later tubes used the telegraph for internal use.

There were speaking telegraphs still in use just before the Second World War on a rapidly diminishing number of main line sections including the former Great Northern line from Finsbury Park to High Barnet (but abolished when new LT signalling was introduced upon their takeover during 1939/40). The last speaking telegraphs known to have been in regular use on the main lines were on the former Great Northern main line out of Kings Cross where they were withdrawn with resignalling in the 1970s, starting with King's Cross itself in 1971 (though, by coincidence, LT empty stock workings used this line between Kings Cross and Finsbury Park between 1970 and 1975 so a tenuous link between LT and this archaic means of communication might be said to have existed until then).[4]

Public Telegraphs

Although no evidence has been seen to prove that third party telegraphs were provided on the Metropolitan at opening, it is known they were being considered when the line was being built. Wheatstone was proposing to install 'private telegraphs' in the tunnels so that businessmen might have private speaking instruments between their West End residences and City offices; a subscription of 5 guineas was suggested.[5] It is at least possible that with the complications of obtaining wayleaves in the street some third party circuits would have been made available by the Metropolitan.

It is quite likely that the head offices of the companies would have been connected up with at least one of the private electric telegraph companies, and, equally, the right of way owned by the Metropolitan (and later the District) would have been an irresistible proposition for any telegraph company wishing to use wayleave rights.

The Metropolitan later made claims that it always appreciated the rights of way it possessed would be exceedingly valuable to the public telegraph business in London in the light of the huge expense and complication involved in the erection of telegraph wires over the house tops. Some indication of the scale of the public telegraph system is offered by the Metropolitan observing that in 1889 it had discovered that 597 telegraph or electric lighting wires crossed its railway (with 4 more on way) and that it had considerable difficulty in establishing who owned them. The company was anxious to ensure that they were indemnified against any accident that might result, and also that they should be entitled to a fee for each one that crossed its land, a shilling per wire per year was proposed. Although all this was eventually sorted out, one can see immediately that from the point of view of a telegraph operator the job of dealing with every landowner and his attitude towards payment was onerous enough before one even begins to consider the problem of erecting masts to houses, and gaining rights of access for maintenance.

The Metropolitan claimed that its underground tunnels would immeasurably assist the development of the telegraph in London.

Whether or not circuits were in place in 1863 it is known that in 1864 the Metropolitan entered into an agreement with the London & District Telegraph Company (later called London & Provincial) to exploit this opportunity, and that company proceeded to lay cables and build telegraph offices at some of the stations, and on the extension to Moorgate. The Metropolitan was entitled to retain 50 per cent of the gross receipts for calls to and from its stations and the rest of the UK (except Ireland where only 25 per cent was retained); not a bad return given the apparent absence of any expenditure by itself. During the period December 1864 to January 1870 (when the telegraphs were nationalized) the 'Metropolitan's portion' rose from just over £403 in 1865 to £658 in 1869. In addition it would appear that the Metropolitan obtained the facility to pass free 'railway telegrams' over the network (in effect giving it a means of internal communication at no cost to itself).

To the Metropolitan's fury, the Post Office took over the telegraph offices at its stations in 1870 and in most cases promptly closed them. Where the offices remained, the Post Office introduced new telegraph offices at adjoining premises; the Metropolitan assumed this to be a sneaky way of abstracting business to reduce any subsequent claim. This led to lengthy correspondence between the parties with the Metropolitan demanding considerable compensation, to which it believed it was entitled under the 1868 Telegraph Act. The railway contended that its system was being expanded and that the future telegraph business (now denied to it) would have been enormous; the Metropolitan claimed that the original three year agreement had been in the process of renegotiation with the telegraph company in 1869 and even more favourable future returns were indicated. This unhappy tale rumbled on until 1878 when arbitration was sought; the Post Office contended that compensation was only payable for rents due from the telegraph offices themselves while the Metropolitan considered the Post Office should compensate on the basis of total revenue lost. As the District, Hammersmith & City and Metropolitan & St John's Wood Railways were in the same boat they proceeded to law jointly (a rare case of the Metropolitan co-operating with the District, it might be noted), the Metropolitan taking the lead. It put forward a persuasive case that evidently swayed the arbitrator who awarded the full £51,907 demanded together with their arbitration costs (a further £5491), which the Post Office had to reimburse (as well as paying its own costs). This was a considerable sum to win in those days. It is instructive to look at the proportions paid to the various railways as it provides a glimmer of illumination about the relative sizes of their public telegraph businesses.

Metropolitan Railway	£22,245
District Railway	£17,796
Metropolitan & St John's Wood Railway	£7417
Great Western & Metropolitan Joint Railway	£4449

This was the first of various disputes between the Underground Railways and the Post Office, the latter usually adopting what might perhaps best be described as an unhelpful attitude.

Fortunately the locations of the telegraph offices are recorded, as below:

Further acrimony arose with the Post Office about Swiss Cottage station (where there also seems to have been an office). The Metropolitan (who worked the station) recorded:

> 'at the request of the Post Office and at great inconvenience alterations were made to provide additional accommodation to enable the authorities to carry on postal and money order business.' 'The Postmaster General agreed to pay an increased rent of £30 per annum but gave six months notice on 17th December 1886 and the Metropolitan lost money which the Post Office declined to pay'.

As 'additional' rent is referred to it might be inferred there was an existing telegraph office there prior to enlargement, and it is likely it was still open as a telegraph office in 1894 when the details were given.[6] The public telegraph lines in the tunnels were largely (if not wholly) owned by the Post Office and in 1878 they wanted to remove them, so they were presumably all redundant; the Metropolitan refused permission until the compensation issue was settled, but gave permission in January 1979 for the cables to be removed at the GPO's cost. It is not known if any cables were shared or not (on some railways cables, lines and poles were shared).

Nor was this quite the end of the matter. The Metropolitan naturally insisted on its rights to continue to make use of the free telegram service which during the Post Office's tenure had risen from 106 a year in 1871 to 3482 in 1890, at least partly resulting from the expansion of goods traffic which often required telegramming other railways. By 1890 the Post Office was grumbling loudly about the unfairness of it all, as the original legislation had not contemplated such a heavy use, they claimed. Although the Metropolitan was not obliged to take action they were concerned about a court decision affecting another railway where it had been decided that the Post Office was not obliged to deliver free telegrams immediately (but merely by following postal delivery). The Metropolitan therefore agreed to the Post Office's request to restrict the number of telegrams to 4500 a year (or 72,000 words a year) in return for immediate delivery, and with the proviso that a shortfall of usage in one year could be carried across to the next. When London Transport was formed in 1933 the Post Office free telegram service was restricted to the Metropolitan and District Lines, but the service was withdrawn from 1st January 1936 after which all telegrams had to be paid for.[7] As LT was in the process of getting out of the management of goods traffic perhaps any hardship was only slight.

The Post Office did occasionally license independent telegraphs, such as the Exchange Telegraph Company, which conveyed news mainly for the benefit of newspapers, and this particular company put some of its wires into the Underground. An agreement dated 1923 authorized a cable between Monument and Aldgate, and a further agreement of 1925 authorized a further cable from Aldgate to the London Midland & Scottish Railway system at Campbell Road, Bow, the latter for an annual wayleave rent of £31.[8] It is entirely possible this company (and conceivably others) had other wires.

Most of the underground railways adopted short forms of address for use when receiving telegrams. Usually telegrams delivered by messenger had to be marked up with the delivery address spelt out in full—with every separate word charged for this was an expensive business. The Post Office did allow short forms of address to be used, usually consisting of a single contrived word unique to the receiving company (followed by the post town). A list of telegraphic addresses known to be used by the underground railways and their associates is given at Appendix 3. These short addresses mainly benefited the railways' customers as railway telegrams went free or were sent over railway wires. For similar reasons of economy, many commercial companies used telegraph code books to compress frequently used expressions into single words; the railways did the same with their own codebooks but this was generally to shorten messages without losing precision. By way of example, from 1939 the code word 'Frog' meant 'Following wagons detained at your station under

load. Get them discharged at once, and send to-day full written explanation of detention.' One can immediately see the utility of such codes for shortening messages but errors could create some interesting results.

Train Messages

It has already been mentioned that telegraphs (and for that matter telephones) were only intended for urgent messages and that ordinary messages and other correspondence had to go by train. This was not a complicated process. Correspondence was simply handed to the guard of a suitable train, though a record had to be kept of which train mail was transmitted. The guard (or all the guards where correspondence passed through the hands of several) had to initial each document and take care to see that it was sent to the right station without delay.[9] Instructions are not forthcoming about delivery arrangements but it seems likely a repository was provided (for example a letter box) at the larger stations. Such arrangements carried on well into London Transport days (though not heavily used), and most stations had small wooden letter boxes near guards' positions. One man operation put paid to this and on the rare occasions correspondence has to be sent by hand station staff are used as messengers.

GENERAL INSTRUCTIONS—*continued.* 53

BRILL BRANCH.

The Engineman must have his Engine and Train **well under control in descending all inclines, especially those on the Quainton straight road, at Blue Bottle, and between Brill and Wotton, and on commencing to descend those inclines he should not require to put on the Engine brake, but sufficient power must be put down by the Guard in the Train to keep the Train back from pressing on the Engine, the Engine brake being reserved for any emergency.**

The speed must not exceed 25 miles per hour, reduced at level crossings to 8 miles per hour, and at Lodge Level Crossing to 4 miles per hour.

RULES AND REGULATIONS FOR THE WORKING OF TELEGRAPHS.

SINGLE NEEDLE ALPHABET.

A ✓	E \	I \\	M //	Q //✓	U \✓	Y /✓//
B /\\\	F \\/\	J ✓///	N /\	R ✓\	V \\✓	Z //\\
C /✓/\	G-//\	K /✓	O ///	S \\\	W \//	
D /\\	H \\\\	L ✓/\\	P //\	T /	X /\✓	

The long strokes are made by pointing the needle to the right, the short strokes by pointing the needle to the left.

The termination of a word is indicated by a pause.

Messages must be transmitted :—

(*a*) In the order of their precedence, according to the following list of prefixes, and

(*b*) Subject to the foregoing, in their turn as received.

PREFIXES.

* (1) **D N G**—Danger Signal, to be used only in cases where the safety of Passengers, Company's Servants, or Trains is concerned.

(2) **G M** —General Manager's message.

(3) **S O** —Superintendent of the Line's message.

(4) **M T** —Train report, to be used only for reporting the running of Trains.

(5) **E T** —Train enquiry message.

(6) **O B** —Ordinary message.

☞ * **D N G** is the most important prefix of all, and messages bearing this prefix must take precedence over all others, and whenever offered, all communication passing with other prefixes must immediately cease.

The employment of this prefix must not interfere with the due observance of the Block Telegraph Regulations re the Obstruction signal and the "stop and examine Train" telephonic message.

In every case where this prefix is used, a report of the circumstances must be made to the Traffic Manager or Superintendent of the Line as early as possible.

Great care must be given to the use and observance of the proper prefixes, and messages must always be dealt with in accordance with their order of precedence and priority.

AFFIXES AND GENERAL SIGNALS.

†**M Q** —Wait, I am engaged.
K Q —Call up when disengaged.
D Q —End of address.
P Q —End of message.
F I —Am going to signal figures.
F F —Figures end.
M M M—Bar of Division (as in ½).
T —I understand.
E —I do not understand.
One of these signals must be given by the receiving station after each word.
G —Go on with message.
S R Q —Repeat message back.
I I I —Full stop or colon.
R D —Right, message received.

†A station on receiving **M Q** ("wait") must quote the prefix of the message about to be sent, in order that the station called may, when ready, accept the message in its order of precedence.

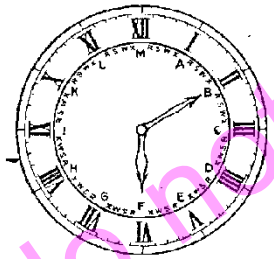
Met. & G.C.—6a.

54 GENERAL INSTRUCTIONS—*continued.*

RULES AND REGULATIONS FOR THE WORKING OF TELEGRAPHS—*continued.*

Affixes and General Signals.—*Continued.*

Order of Code Timing.—A Code for the time a message is given in for transmission is obtained by marking the letters from A to M (not including J) opposite the hours, and the letters R, S, W, X, opposite the four minutes intermediate between each interval of five minutes as shown in the following diagram :—



The Code is to consist of two or three of these letters—the first denoting the hour, the second the minutes (to the nearest five minutes under the number of minutes required), and the third the exact minute.

Thus, for a message handed in at 4.54, the Code would be D, K, X, and for one handed in at 2.12, B, B, S.

The time should be marked by this Code on each message as it is received at the sending Station, and the Code signalled immediately after the prefix.

Any alteration of the Code time for the purpose of facilitating the dispatch of a message out of turn, or the giving of a false Code to obtain possession of an instrument is strictly forbidden.

When the prefix has been omitted by sender, the Telegraphist must insert it and the Code time, and carefully count the number of words to be signalled.

Counting of Words, Initials, Figures, &c.—Each word is to be counted as one, but combinations of two or more words must not be counted as one, whether conjoined by the sender or not unless coming under the following exceptions :—

The abbreviations a.m. and p.m.

Compound words such as :—Mid-day, mid-night, noon-day, to-day, to-night, to-morrow, and amounts in pence, beginning with two pence and ending with eleven-pence.

Names of places, however, whether in the address or the message itself, should be counted according to the number of words of which they are composed.

The words "from" and "to" in the addresses are not to be counted, nor the signal D Q at the end of the address or P Q at the completion of the message.

Forwarded messages with multiple addresses must have the total number of words, including all the addresses, counted and signalled to the Station which has to deliver or re-transmit them, and it will be for that Station to re-arrange the number of words in sending them forward.

All initial letters must be written thus :—A, B, C, and the Full Stop Signal (\ \ \ \ ) given after each initial.

When figures occur in messages they are to be signalled as such and each figure counted as one word.

Whole numbers and fractions as 1½ would be signalled thus :—

\\ /\ \\	✓	✓/\ /\\ ✓	// // //	/\\\	\\ /\ \\ /\
Affix F I	one	and one	bar of division	two	affix R F

The word "and" separating the whole number from the fraction must not be written or counted.

The finals "st," "nd," "rd," or "th" after a date count one word each.

A bar of division also counts one word.

Particular care should be exercised in signalling and receiving figures, and whenever a repetition of figures is required, such as the number of a wagon, it should be commenced from the first figure.

The Colon must be carefully observed both in signalling and writing.

The diagrams show four pages from instructions issued by the Metropolitan & Great Central Joint Committee in 1922 relating to the operation of the 'speaking' telegraph. The single needle alphabet describes the combinations of the two positions of the telegraph needle, and it might be noted this corresponds to the Morse code.

RULES AND REGULATIONS FOR THE WORKING OF TELEGRAPHS—*continued.*

Affixes and General Signals.—*Continued.*

The object of counting the words in a message is to check the correctness of its transmission; if the number received does not correspond with that signalled, the Telegraphist at the Receiving Station must notify the fact to the Sending Station who must then recount and signal the correct number, and if the difference is not discovered the Telegraphist at the Receiving Station must repeat the initial letter of each word from the commencement of the message.

Should a doubt raise as to the correctness of a word after several other words have been taken, stop the communication by holding the needle over, then signal the word "after," and the word in the message preceding that required.

Method of Telegraphing.—The code time, which must be the time the message is handed in, must be signalled after the prefix, and before the number of words.

GENERAL RULES.

The telegraph must only be used when absolutely necessary.

Messages should be as clear and concise as possible, all useless words and complimentary expressions (including the word "please") being omitted.

Telegrams, sent or received, should be written out in duplicate on the proper form, duly signed, and the time of receipt or despatch noted thereon. In taking off messages, each word should be written down as received and the memory not relied upon—otherwise mistakes and misunderstandings, often causing much inconvenience, are liable to arise.

Violent working is useless, makes no difference to the signals, frequently causes damage or deranges the instrument, and is forbidden.

Calling should be performed steadily and distinctly. Fast calling is indistinct and does not gain attention more readily, but usually the reverse.

Strict attention must be paid to the instruments at all times.

Stations must not answer any call but their own.

In the event of two stations having messages for each other with the same prefix, the station having first possession of the instrument must proceed with his message first.

If "A" has commenced calling "B," and "C" also has a message, "C" should immediately signal the prefix of his message. If "A" thereupon finds that "C" has a prior prefix, he should give up possession of the circuit to "C." If however "A" has a prior prefix to that of "C," he should signal it and proceed to call "B."

A message is commenced when the attention of a station has been obtained, signals exchanged, and the prefix signalled.

Should any station interrupt and insist on having possession of the Circuit, he may be allowed to proceed, but the circumstances should be reported at once to the Traffic Manager or Superintendent of the Line.

A Station when called must answer as soon as possible, and note the station he is called by, and the prefix signalled.

If **D N C** is signalled, the message must be taken at once. If not bearing prefixes 1, 2, or 3, the station called may, if engaged, give **M Q** ("wait"), but as soon as disengaged, must call up the Station wishing to speak and take the message.

If a Station gives **M Q** and does not call within 10 minutes, that Station must be called again, but on receiving **M Q**, the prefix must be given.

If prompt attention cannot be obtained and other messages are waiting to be sent on the same Circuit, the Station calling should not insist upon retaining possession of the Circuit an unusual time unless the message is a very important one.

METHOD OF TELEGRAPHING.

To call a Station, indicate the Station you require by the code call, continuing to do so until that Station acknowledges the call by repeating it.

Then indicate your own Station in the same way. This also should be acknowledged by repetition.

Next give the prefix to show the nature of your communication, which the receiving Station must acknowledge by the "understand" Signal, **T**.

The number of words contained in the message (address included) should then be given.

Then should follow the name and code address of Sender, and that of Addressee.

Then signal **D Q**, indicating completion of the Addresses.

The message itself should then be sent, and

Finally, the **P Q** signal, indicating "end of message."

RAILWAY TELEGRAPHIC CODE BOOK.

This Code must in future be made use of for all messages whenever possible. In sending or receiving messages in code, the code word must always be shown on a separate line by itself.

This Code must not be used for communicating with the following Companies, viz.:—

Caledonian | North Staffordshire
and

Railways in Ireland, excepting the Cork, Bandon and South Coast, Great Northern (Ireland), Great Southern and Western and Midland (Northern Counties Committee), which adopt the Code.

DIAGRAM OF TELEGRAPH CIRCUITS AND LIST OF CODE CALLS.

TELEGRAPH CODE CALL.	STATION OR SIGNAL BOX.	Telegraph Circuit No. 6	7	1
M B	Marylebone Telegraph Office			■
F N	Chalfont and Latimer Station Box	■		
M	Amersham Station Box	■		
M W	Mantles Wood Box	■		
G D	Great Missenden Station Box	■		
D	Dutchlands Box	■		
W R	Wendover Station Box	■		■
S	Stoke Mandeville Station Box	■		
A Y	Aylesbury South Box	■		
A J	,, North Box	■		■
W M	Waddesdon Manor Station Box	■		
Q N	Quainton Road Station Box	■	■	
W G	Waddesdon Station Box		■	
W O	Wotton Booking Office		■	
B L	Brill Booking Office		■	
G O	Granboro' Road Station Box	■		
L D	Winslow Road Station Box	■		
V J	Verney Junction Station Box	■		
C T	Calvert			■
F N	Finmere			■
B	Brackley			■
H M	Helmdon			■
C H	Culworth			■
O D	Woodford			■

The thin black lines represent the Circuits, and the black dots indicate that the Stations or Signal Box against which they are shown is on the Circuit indicated.

Chapter 2 – Manual Telephony Days

From telegraphs to telephones (Met and District Railways)

The date of the first practical telephone is surely open to debate, but certainly 1876 might be suggested as the year during which the instrument started to develop from a purely experimental device to something that stood some chance of commercial application. The telephone's supposed inventor, Alexander Bell, secured his first British patent at the end of 1876, and in the summer of 1878 the first British company (called The Telephone Company) was established to exploit Bell's patents. From that point onward telephone systems were available to anyone prepared to pay the price. However, there were at first no telephone exchanges so in essence telephone systems were restricted initially to private lines within or between premises, with a telephone at each end. The first London public exchange (at Coleman Street) opened in August 1879, after which, of course, the development of an intercommunicating public system became possible and several companies emerged to provide such services. Even so, entirely private systems were popular for many years more.[10] The Telephone Company became the United Telephone Company in 1880.

The date of the first use of the telephone on what is now the Underground cannot really be known with certainty. The first telephone may have been at Earl's Court, where it linked the telegraph office on the westbound platform with the 'east' signal cabin, which was beyond the station. But this was in 1881 and it was not an electric instrument. It comprised a taut wire on which a metal disk was mounted at each end; the disks acted as diaphragms for speaking and listening and it was the practice to rap them sharply in order to call attention. Over short distances such 'mechanical' telephones could be quite efficient and for several years during that decade there was a thriving industry in such equipment as it offered a means of getting around the patents that covered the electrical apparatus. The description of the District's device fits something called the 'pulsion' telephone (though this does not seem to have been in vogue until 1889 so it is possibly a fore-runner, or possibly the commentator simply got the date wrong).[11]

It would seem that the District might have acquired its first electric telephones in 1885, in the General Manager's office at Parliament Mansions.* The exchange equipment, provided by the National Telephone Company (or 'NTC', into which the 'United' had transmogrified), consisted of an 8-indicator board with lines to the NTC's exchange at Westminster, the workshops at Lillie Bridge, three departments in the general offices and the Chairman's office at Victoria Station (on the London, Chatham & Dover Railway—Mr Forbes was chairman of both concerns). The equipment was typical of the period: local battery, magneto ringing and single wire with earth return, and considerable crosstalk was sometimes experienced.† The operator was a District Railway man and later recalled that the protocol of the day was to write down all messages and to keep a carbon copy on file.[12] This of course echoed telegraph practice but it was carried on with variations until at least the first decade of the twentieth century. Another former District Railway employee states that the District had its first telephone at Earl's Court in 1896.[13] Clearly it was not the District's very first telephone, but it may well have been the first provided in connection with the operation of services at station level.

The early adoption of the telephone by the District Railway may be no accident. Its Chairman, the enterprising James Staats Forbes, was one of the first subscribers to the Coleman Street telephone exchange in 1879 and was evidently so keen on the idea of the telephone that he became a director (and vice-chairman) of the United Telephone Company upon its formation the following year. It must be appreciated that the utility of the telephone network was entirely dependent on the ability to convey the necessary wires between premises, and the private companies, having no

* The District offices were at Parliament Mansions in Victoria Street from 1883 to 1898

† The main office was on extension 3026 and there was a line to Victoria on 3192, which were both on the Westminster exchange.

statutory powers whatever, had to endure the painful experience of negotiating wayleave rights with perhaps some hundreds of landlords in order to get their cables in place. Furthermore the cables were overhead, subject to frequent damage, and the landlords of the properties over which they passed demanded wayleave rents, which together could amount to a tidy sum. Forbes, being a railway director, had access to lengthy and comparatively secure rights of way over both of his railways, and these rights were a natural partner for a telephone company. His enthusiasm undaunted he later became Chairman of the National Telephone Company (into which the United was amalgamated) whilst still retaining his railway chairmanships. It is perhaps of interest to note that prior to having offices at Parliament Mansions the District had previously been at 6 Victoria Street from where they moved in 1883; it may be coincidence that this premises accommodated the NTC's enlarged Westminster telephone exchange in 1888. The previous location of the Westminster exchange was at 3 Palace Chambers, which was the freehold of the District Railway, next door to its Westminster Bridge station. Each of these premises was close to the District's tunnels and wayleave opportunities.

By 1903 the District was very well provided with telephones. There were by this time no less than 31 separate 'omnibus' telephone circuits in use, all connected at least at one point to a small number of 'junction' stations which could put calls through to a further circuit. There were additional telephone circuits between the various head office officials at Earl's Court, Lillie Bridge and St James's Park. 'Omnibus' circuits were circuits running between two points with some or all intermediate stations or signal boxes connected to the same wires. Such an arrangement lacked privacy and stations were called by sounding the telephone bells (all of them) using a code sequence, so that only the staff at the station intended to receive the call would pick up the instrument. It had the merit of being cheap though. At the 'junction' stations two or more omnibus circuits came together; the person receiving the call could be asked to connect through to another circuit if the caller needed to speak to anyone not on his own circuit (but generally the circuits overlapped to reduce this inconvenience). However, while there were telephones at and between stations, an accident report for 25th June 1903 positively states there were (in general) no telephones between signal cabins, telegraphs still being relied on.

The opening of the Ealing & South Harrow line in 1903 caused the inspecting officer to comment that each station could only contact another via an 'exchange' at Mill Hill Park, which he thought would unduly slow down the transmission of messages (there was no direct communication between stations because with experimental automatic signals there were, except at South Harrow, no signal boxes or, apparently, telegraphs). The inspecting officer may not quite have understood how the telephones worked as the District had employed an omnibus circuit along the line—in any event they were not persuaded any change was needed.

Diagrams of the District tunnels at the time of its electrification in 1905 clearly show the cabling arrangements, with signal cables at the bottom, power cables next, and 'foreign' cables uppermost. That these were felt especially worth providing for implies 'foreign' cables—telegraph and telephone —were by no means then uncommon, and were doubtless a useful source of income to the railway. Certainly in 1904 the Board of Trade were complaining about the obstruction of the station platform safety overhangs because of cabling which the District explained were all the NTC's property. An unfortunate mishap in 1905 again reinforces the view that the NTC's presence was not insignificant. During some alterations caused by electrification works some NTC lead-covered telephone cables were lowered temporarily along the trackside of the District Railway near Westminster. Somehow a piece of iron cable troughing, which it is thought might have fallen down, landed on the cables and also touched the newly laid but still dead current rails. This, unfortunately, was not noticed by anyone until the District decided to run an electric test train one night. As soon as the current was turned on a fireworks display erupted on some overhead telephone gantries in Queen Victoria Street and shortly after-

wards serious fires broke out at both the Bank and Cannon Street NTC exchanges that deprived over 2000 subscribers of a telephone service. The subsequent Inquest* found that heavy currents originating from the District's electrified current rails had flowed through the lead cable sheath and eventually caused all the trouble (there was some debate about the possibility of telephone subscribers being electrocuted but this was finally felt unlikely). In any event it was reported that the NTC's cables had been using the District's tunnels for some years and looked likely to do so for the foreseeable future. From 1912 the 'foreign cables' became less evident as the Post Office took charge of all public communications and (having statutory powers) created its own network using purpose built under-street ducts. The subject of 'foreign' or 'third party' cables will be returned to later.

The electrification of the District Railway from 1905 was recognised as an opportunity to install the most modern telephone equipment. Each station, signal cabin, substation and each of the various offices were to be connected to a main exchange situated in the ground floor of the signal cabin at the west end of Earls Court station. A 300-line switchboard was provided and a distribution frame equipped with test jacks and fuses. In addition to the extension lines, 'trunk' lines were provided to the telephone exchange at Lots Road power house (using the railway's own under-street power ducts) and to other railway exchanges to which communication was thought important.[14] Lots Road had direct line connections to all of its substations quite separate from the Earl's Court exchange lines.

It was upon electrification that the District created a central control function to co-ordinate on a minute-by-minute basis its more intensive train services. It is reported[15] that to avoid the traffic controller having constantly to communicate to key staff via the exchange operator, certain important points could be contacted by means of telephones connected to the telegraph omnibus circuits. This operation required the recipients first being telegraphed to alert them to an imminent call as the telegraphs had no bells; for the duration of such a telephone call the circuit would be rendered otherwise unusable. This may be apocryphal, but it comes from an Underground officer (J.P. Thomas) who was there at the time, and he claims this arrangement remained in use until 1912. It is all quite plausible. The District had just received a new telephone system based on a switchboard at Earl's Court with exchange lines to nearly all locations. In reality the old telegraph circuits may have fallen out of use quite quickly. It probably represents the earliest use of so-called 'direct' lines between a controller and key railway operating facilities. The District's traffic controller at Earl's Court also had an extension telephone on the District's National Telephone Company external line.†

The Metropolitan Railway seems not to have been too far behind the District in its introduction of telephones. It seems that it was in September 1888 that the Metropolitan's Chairman, Sir Edward Watkin, suggested to his general manager (appropriately called Bell) that the Metropolitan's offices be connected to the main stations. A scheme was prepared to lay a single gutta percha covered copper wire from Westbourne Terrace offices to the stations at: Edgware Road, Baker Street, Kings Cross, Farringdon Street, Moorgate Street, Bishopsgate and Aldgate. Including the necessary fittings and batteries the cost was estimated as £210. The eight telephone instruments were to be purchased from The Telephone Company and would cost a further £8 each. The board was advised that it was intended to place the instruments in the station booking offices as they would be a distraction in the signal boxes and in any case the noise would make conversation difficult.[16] As these circuits would ordinarily be used for administrative purposes the booking office would seem the better place for these telephones, but the fact it needed to be mentioned at all might perhaps imply that it was more usual at that time for telephones to be put

* The City of London Coroner – perhaps uniquely – was able to hold inquests into fires.

† This was *Gerrard 5820*, the District's main private branch exchange number at St James's Park (which had nine lines by 1910), although the *Gerrard* exchange was near Leicester Square (the District may have taken over the number from the Hamilton House offices, on the Embankment, which was slightly nearer to *Gerrard*). It is possible that any District telephone extension could be connected from the NTC line.

in signal boxes. A month later it was evidently decided to extend the circuit to South Kensington ('B' signal box, not the booking office) in order to meet some unspecified need—it must have been important in order to justify the £103 cost.

Also in October 1888 the general manager was complaining about the efficiency of the old single needle telegraph instruments; messages were being misunderstood (or not taken at all) where signalmen were slow or otherwise lacked the necessary proficiency, especially at the Circle Line cabins where train intervals were so short that the busy staff didn't have the time necessary to take messages correctly. He asked that the instruments be replaced by telephones where no experience was necessary.[17] This must have been agreed to with some vigour. Instructions dated February 1889 explain that telephones had been provided 'at each station and intermediate signal box' between Aldgate and Notting Hill Gate and between Baker Street and Rickmansworth with the intention of improving communication about the working of trains; these had evidently entirely superseded the use of 'speaking instruments' which had been removed on these sections. The instructions stated that each station had two telephone instruments, one connecting to the station or signalbox ahead and the other to that on the other side. Each telephone was equipped with two separate receivers, both of which were to be used (implying the use of Gower Bell instruments) and a single push button that rang the bell on the telephone at the other end of that circuit.[18] There was no exchange system or other interconnection between the instruments at that time. Annoyingly the notice is stated to supersede instructions dated December 1885, opening the distinct possibility that the telephones were installed then, with some modification in 1889, perhaps the removal of the telegraphs.

Electrification generated the need for a telephone system by which the Metropolitan's various substations could communicate with the power house at Neasden; the electrified network stretched from South Kensington to Aldgate via the north side of the circle, and from Baker Street to Uxbridge. The Metropolitan authorized in January 1904 the enormous expenditure of £1071 for the installation of a network of telephones that appear to have been dedicated entirely to the use of its electrical staff and was based on a switchboard at the power house. A further £173 was later required at both the power house and Neasden substation to provide 'telephone chambers' in which staff could communicate despite the tremendous noise.

During the same sort of period widespread changes were also made to the existing telephone system, though the records are less than specific about the detail. In January 1904 it is reported that it was 'advisable to repair and complete the present private telephone system and fix a telephone exchange system at Neasden which switches to different departments'. Later in 1904 instructions were given to link the Neasden exchange to the general offices in Westbourne Terrace. The Neasden Works exchange is known subsequently to have had a capacity for at least 43 lines and was still a going concern in 1936 when the building department at Wembley Park was put onto it in preference to the omnibus circuit in Wembley Park signal box. It may have lasted until the system was converted to automatic. What 'repair and complete' means is anybody's guess, though conversion of earth return circuits to metallic would suit the context for part of the job. In 1905 and 1906 further modest sums were made available in order to improve the telephonic arrangements between Edgware Road, Baker Street and stations to Chesham (and intermediately), and as a second phase to install 'a similar system' around the Circle Line. At a combined cost of £411 these works cannot have been extensive. In 1906 Neasden Works was also linked directly to the carriage sidings at Farringdon.

In any event, the combined effects of these changes meant that by 1912 the Metropolitan Railway had made considerable changes to the original system. A telephone exchange at Edgware Road connected to its stations along the north side of the Circle Line and to various head office officials (including Neasden Works). Edgware Road was also linked to the District's exchange at Earl's Court. The Metropolitan's offices at West-

bourne Terrace, Paddington might have had a small switchboard of its own, although Edgware Road was sufficiently close to service a small number of extensions.* The Edgware Road exchange was evidently shut at night and the operator closing the exchange was required to 'switch through' to the key signal boxes along the north side of the Circle (such that they were all interconnected). By this means all the signal boxes were linked together, and by using coded calling signals one could call another. The Traffic Controller at Edgware Road also had an external line on Paddington 5724, though other officials probably had lines too.

The Hammersmith & City Railway was jointly owned by the Metropolitan and the Great Western Railways. When the line was electrified in 1905 the GWR was responsible for the electrification system and provided substations at Royal Oak, Shepherds Bush and Hammersmith, all fed from its own power station at Park Royal. Each was equipped with its own telephone switchboard to facilitate communication between these four key points. At each location three telephone instruments were provided at the generating station and one (apparently) at each substation to facilitate communication between staff at the high tension feeders. Other telephone instruments were installed around the H&C Railway at signalboxes, stations and switch pillars and each of these was connected with one of the switchboards just provided. Installation of the system was in the hands of the Westminster Engineering Company.[19] The Metropolitan Railway took over the day to day management of the H&C in 1912 after which the telephone arrangements were slowly harmonized with those of the Metropolitan, though interconnection both with the Met and the GWR was doubtless available from the start.

Between 1910 and 1911 the increasing traffic on the Metropolitan resulted in the installation of automatic signalling between Baker Street and Neasden. Since this resulted in the permanent closure of some of the signalboxes, and opening of some of the others for shunting work only, it was discovered by May 1911 that considerable inconvenience was being caused in passing messages to stations. To answer this problem it was decided to install what was described as a '15-way switch' at the signalbox at Willesden Green, which at that time was open continuously. To the switch were wired a through line (possibly more) to the telephone exchange at Edgware Road and what appear to have been individual lines to telephones at Baker Street East signal box, St John's Wood Road, Marlborough Road, Swiss Cottage, Finchley Road signal box, West Hampstead, Kilburn, Dollis Hill, Neasden station signalbox and Neasden South Lodge (at the entrance to the works). The work was to cost £80 and use existing block wires. It is likely that some and perhaps all of the stations already had telephones, and if practice further north is to be any guide these telephones were previously short extension lines from the local signal box (an arrangement probably retained at Baker Street, Finchley Road and Neasden). It is quite possible that prior to these changes omnibus code circuits were still in use. The nature of the 'switch' at Willesden is quite unknown, but it could apparently connect any pair of local stations with each other, or any one of them with Edgware Road.[20]

North of Neasden and on the Met & Great Central section telephones were provided on a number of omnibus circuits. Circuit number 14 served Baker Street platform, Baker Street East, Finchley Road, Neasden, Harrow and Chalfont Road; number 16 served stations Neasden to Harrow (including Harrow South Junction cabin); number 18 served stations Harrow to Rickmansworth, and No 24 served stations Rickmansworth to Chesham. As mentioned earlier omnibus circuits reduced the number of wires needed between locations; this was useful in far flung parts of the system where distances were long, traffic was light, and the telegraphs still in evidence. Communication with stations north of Chalfont was still only available by telegraph. It is clear that if a call had to be made from (say) Kings Cross to Wendover it required a telephone call to the Edgware Road Exchange who would probably forward it to the Willesden Exchange where the operator would relay the message on the omnibus line to

* In either event the National Telephone Company number was *Paddington 5340*.

Harrow, who would then telegraph to Wendover. And so on. Of course at that time trains would still have conveyed most non-urgent messages.

Overall, the instructions for the use of the telephone system on the Metropolitan have a flavour of novelty about them, and it is clear that the network in 1912 was nothing like as comprehensive as that of the District. The primitiveness of the Metropolitan's communications is highlighted by a particular public complaint received in 1914. This gentlemanly protest concerned the indifferent reliability of the westbound Circle Line at Baker Street, a problem compounded by the frequency with which Circle Line trains (in particular) were wrongly described by the hand-operated apparatus provided to inform the public. Investigation revealed that the successful routeing of trains at Baker Street depended on a man at (what was then) Portland Road telephoning the signalman at Baker Street who (in order to enlighten the waiting passengers) then rang the eastbound platform where a man shouted the information across the tracks to the indicator operator on the westbound platform, presumably in between trains. The precariousness of this arrangement was immediately apparent.

Helpfully, the ensuing correspondence throws light on the telephone arrangements at the time. It is clear that the exchange at Edgware Road (and almost certainly 'the switch' at Willesden) had already been replaced by a single telephone exchange at Baker Street, in the new General Offices that had opened in 1914. However only the exchange had been altered, there seems to have been no change to the disposition of telephones around the system, and the traffic controller (also at Baker Street) had to make and receive calls via the exchange operator. In addition to the exchange lines there were local circuits between adjacent signal boxes and sometimes other points, but these do not seem to have had provision for through connection, hence the special arrangements in force at night when the exchange was closed. The discovery by the general manager (Robert Selbie) of the inadequacy of the telephone arrangements prompted lengthy discussion about what could be done within the bounds of economy. The suggestion was made that if the station-to-station circuits were coupled together in two groups then it would aid considerably the passing of information about train running, and the hapless indicator-operator at Baker Street could also be given his very own telephone on the same circuit so he stood at least some chance of putting up the correct train description. This 'omnibus' arrangement meant the use of bell codes to call attention to the intended recipients, and the traffic department wanted loud bells to be installed so that staff could hear them wherever they were. Selbie's apprehension about the annoyance that might be caused prompted the engineer to volunteer an illuminated sign (showing the letter 'T') which was tested at Kings Cross during 1915. However the idea of having signs on omnibus circuits proved too complicated and bells were finally settled upon. After some confusion with the engineer about what was wanted Selbie acceded to the use of 'loud' bells 'but a bell less noisy than the usual loud sounding bell'! The outcome was that the local circuits were coupled in two groups, which met at Farringdon signal box where the circuits were divided; a total of sixteen telephones were put on the circuits and it is rather implied that these were in addition to the existing exchange lines where the instruments previously seem to have been capable of switching either to an exchange line or to a local circuit.[21]

By 1923 there had been some slight development and the instructions for use of telephones implied that local telephone circuits also now existed between various adjacent locations, and these were to be used in preference to omnibus telephones. The instruments were of the pattern requiring closure of a local handset switch whilst speaking, and ringing was evidently by means of magnetos. The telephone omnibus circuits had now been slightly rearranged, and there were more of them. All in all, the system was still quite primitive compared with that of the District.

The Metropolitan's relationship with the Great Central Railway was not without incident (the company ran over the Metropolitan's tracks between Quainton Road and a point near Finchley Road). Prior to opening in 1899 the latter wanted to run four telegraph lines along the Metropolitan's existing poles. It would seem these were for telephone purposes, but one

or more circuits might have been used for telegraphy or, in places, the 'lock and block' signalling. The correspondence is as lengthy as it is bad tempered, and there were arguments at every stage of the way, but the job was eventually done (though very late). It emerged, to the Met's irritation, that the telephone circuit would be on the omnibus principle, which was thought likely to disturb their sensitive signalmen at Quainton Road. The relationship was clearly not very good at that time, though the main line company readily agreed to the charges—installation was at £14:10s per wire per mile with annual wayleave and maintenance costs of a further £2 per wire per mile per year. In later years (by the 1930s) Marylebone had quite an extensive manual telephone exchange with some of the Metropolitan signal boxes apparently having a direct extension line, although the technical arrangements have yet to emerge.

The coming of the Tubes and centralization of switchboards

At first all the tube lines were separate companies. The earliest tubes were the City & South London Railway (opened in 1890), the Waterloo & City Railway, opened in 1898, and Central London Railway opened in 1900. All had at least one signal box at each station and used telegraph instruments for train signalling. The latter railway certainly had telephones between the power station at Wood Lane and various key points, and it had station-to-station telephones between signal boxes. It is implied by the instructions[22] that there was a central exchange with one or more lines to each station. Although the CLR later came to establish a control office at Wood Lane, its main offices were above Oxford Circus station, so there may have been switchboards at both locations.*

The Waterloo & City had used telephones even during construction, with telephone lines connecting the tunnel working faces with the contractor's depot on the staging in the river; this is probably a 'first'. Little definite is known about the telephone arrangements at the time of opening, but by 1924 there were a number of telephones in use, including instruments on the platforms at City and Waterloo and several in the tunnel between the two, and in the depot. These were connected on one circuit and used coded calling signals, except there was a special key used to call the Waterloo switchboard (the main Southern Railway switchboard). The tunnel instruments were mounted in iron boxes with sliding doors[23]. It is at least probable that the telephones were there from the line's opening, though they may have connected originally through to a local switchboard, perhaps in the power station, which closed in 1915 (though it was retained as a standby). By 1936 the omnibus circuit was still very much operating and was coded 'XB' on the Southern Railway switchboard.

Whether the City & South London Railway had any telephones when it opened is not known for certain, but T.S. Lascelles records that signalbox to signalbox telephones were 'soon' added after the opening, to supplement the telegraph[24]. The NTC is also known to have used this railway for its wayleaves so one might suspect some help from that quarter. Telephones were very much in evidence by 1900 when extensions opened at each end of the line and the power supply was replaced. Certainly, at about the time of the extension to Moorgate, bare tunnel telephone conductors were being installed to allow drivers of trains in difficulty to communicate with the signalmen from telephone instruments (fixed) on the locomotives.[25] It is recorded that a control office was opened at about the time of the line's extension to Euston in 1907, and this was established at Moorgate.[26] This was also the railway's new head office and there would undoubtedly have been a concentration of telephone facilities there.† It is known that in 1923 there was a central exchange at Stockwell Depot, but this might have been provided or adapted in connection with reconstruction work;‡ not being a large depot the need for an exchange earlier can hardly have been compelling.[27]

* The NTC telephone number at Oxford Circus was Gerrard 260, but no evidence has been found for a separate external line to Wood Lane.

† The NTC telephone number was London Wall 1675.

‡ The exchange was connected to Leicester Square (see later) on lines 59, 81 and 81.

There was also the tiny Great Northern & City Railway that opened in 1904. The 1906 GNCR rule book reveals that there were telephones at each station (and at the power station) which evidently connected to the railway's offices at Highbury, as well as signalbox-signalbox telephones.[28] The latter were certainly there from the start, and it is worth noting that for some years each station had a signalbox even though those at Old Street, Essex Road and Highbury merely booked trains.[29] Tunnel telephone lines were (perhaps surprisingly) not provided at the outset and nor was their absence commented on by the Inspecting Officer; however they had certainly appeared by 1921 and were connected to the signalbox switchboards at each station. The tunnel telephone system was entirely replaced from 17th March 1935 with equipment of standard LT pattern. The line had been taken over by the Metropolitan Railway in 1914, and they may well have made improvements to the communications system at around that time, as well as linking it into their own. The GNCR offices at Highbury were on the NTC system and probably had a small exchange switchboard.*

The three lines built by the American, Charles Yerkes, and which opened in the period 1906-07, were built to a common formula. They comprised the Baker Street & Waterloo Railway, the Great Northern, Piccadilly & Brompton Railway, and the Charing Cross, Euston & Hampstead Railway. The description of the Baker Street & Waterloo system would be typical:

> The general scheme provides for telephone instruments at every passenger station, booking office, basement lift machinery room, repair shop, office and sub-station on the system, these being connected through the telephone cables running to the exchange located in the London Road office building. The 50 pair telephone switchboard is installed at this point and to it is connected the lines from all places together with the trunk lines from the other exchanges. There are three sub-stations and each of these is provided with two sets of instruments, one set for direct communication with the generating station without the necessity of having to call through the London Road exchange and the other set to be connected to the London Road exchange in the usual way. In all other cases connection with the generating station is obtained through the London Road exchange. For convenience in distribution, all lines, sub-stations excluded, are brought to a distributing frame fitted with fuses, test jacks and terminals, with facilities for cross connecting, this distributing frame being located in the London Road exchange.[30]

All three railways each had a central telephone exchange with (generally) two lines to each station. The stations were equipped with an 'annunciator' panel (generally in the Station Master's office, or that of the senior official where there was no Station Master on site), and from these panels extension phones around the station could be connected through. The panels consisted of (typically eight) indicator flaps. An incoming call would cause one of these to drop, indicating from where the call originated, and would make a contact that sounded at least one electric bell (many stations seem at first to have had bells on both platforms). Resetting the flap would silence the bell and by plugging in the telephone to the appropriate jack socket the call could be taken. By using bridging cords (or jumpers) a call could be forwarded to an extension. Extensions seem to have been located on at least one platform of a pair (generally the opposite platform from which access to the SM's office could be gained, or on both platforms where platforms were not adjacent), the booking office, and panels at adjacent stations via a pair of bare phosphor bronze conductors in the tunnel. It is not clear how the booking office telephone (or any other extension telephone) would have selected the main station switchboard as alternative to its own direct exchange line, but descriptions imply this was possible so presumably a small annunciator or a simple switch was provided. At signal boxes (generally) three-drop switchboards were fitted with jacks connecting to an exchange line and to the signal boxes either

* The NTC telephone number was North 853.

side; at Charing Cross signal cabin there were also lines to Highgate and Golders Green.[31]

These bare tunnel telephone lines could be accessed by train drivers using fly leads connected to an instrument permanently mounted in the driving cab, and also by night maintenance staff using portable handsets. The drivers' instruments comprised a metal box with a door opening along its bottom edge to reveal a fixed microphone and a 'watch' receiver on a fly lead and a magneto generator. Drivers in trouble between stations could therefore summon help (it seems that such a call would normally sound the bell at the station in rear, and it can only be surmised that at the station in advance the operation of the line somehow did not actuate the drop flap). In case of direct exchange line failure at a station, calls could be routed via the tunnel telephone line and the annunciator at the next station. It should be noted that in providing a continuous tunnel telephone line the Yerkes tubes were merely complying with the 1903 Board of Trade requirements for new railways, and in putting it in their requirements the Board had probably held the City & South London's use of such wires as 'good practice'; that is not to say the Yerkes lines would not have followed good practice anyway, of course, since they did in most other respects. It is recorded that where stations had two lines they were on adjacent numbers, and that towards the end of 1908 the odd numbers were connected permanently through to the booking offices. There was also a number of other staff having their own telephone lines including a large number of assorted repairmen.

In addition to the various central exchanges there were also small local exchanges at other locations, including the UERL headquarters at Hamilton House on the Embankment (the HQ moved to St James's Park in 1910), and the Power House at Lots Road; this latter also had direct extension lines to each of the 24 substations, which could also be reached through their own local exchange. The exchanges were also linked to the large District Railway exchange at Earls Court. It is conceivable there were other similar links, and perhaps even other small exchanges that were part of the system, but evidence is sparse.

The Bakerloo's 50-line exchange was at London Road depot, the Hampstead's and the Piccadilly's were at Leicester Square (these two 100 line switchboards seem to have been quite separate); at each location there was an associated traffic control function. The UERL exchanges were also linked to the District's exchange at Earls Court. There is a reference to the London Road and Leicester Square exchanges also being connected with the Post Office and National Telephone Company's systems but it is not clear whether through communication was possible (though it is implied that it was). The system on the Piccadilly was provided with instruments from the Sterling* Company with British Insulated & Helsby cables; it is likely the other Yerkes lines had identical equipment and it is known Sterling supplied all three. The Bakerloo, incidentally, had been asked by the NTC in 1901 to accommodate their cables in the tubes, then under construction, but the Bakerloo declined (probably with their incomplete tunnels in mind and no immediate prospect of completing them). It is likely the NTC approached other tubes but any such outcome is as yet unknown.[32]

Both the CSLR and CLR were acquired by the UERL from 1st January 1913, and gradually their telephonic arrangements were harmonised with the former Yerkes companies. The Central London Railway had certainly been equipped with tunnel telephone lines by 1914 as they are visible in photographs of the new automatic signalling apparatus installed from 1912; they may well have been installed as part of the same project, but were not there when the line opened.[33] Of course the Liverpool Street extension, opened in 1912, would have required these lines on the extended portion anyway, as, in theory, would that to Wood Lane in 1908.

The first major improvement to the telephone system on the Yerkes tubes was when a combined 'control' office for the three tubes was established at Leicester Square in 1909, requiring improved exchange

* The spelling in the article in Tramway & Railway World is, incorrectly, 'Stirling'.

equipment. Probably between 1909 and the beginning of the First World War the number of separate telephone exchanges was reduced by concentrating the lines in one place; this improved efficiency, especially reducing the number of calls requiring routeing through more than one exchange. Certainly by the early 1920s internal calls on the tube lines were all being dealt with at Leicester Square (on a 450-line board[34]) and this included facilities for the Central London and City & South London Railways, which had by then been absorbed. The District continued to have its own telephone exchange at Earls Court.

The mode of operation of the controllers' equipment during the 1920s is not at clear beyond all doubt, but such descriptions as there are have the merit of being consistent. The evidence suggests that additional telephone lines direct between the control offices and control points were not provided, at least on any scale. Instead it seems that a number of ordinary exchange lines serving key staff were simply rerouted through the controllers' switchboards at either Earl's Court or Leicester Square. Normally the telephone operators would service these lines in the normal way. However, if a controller wanted to speak to a control point he could do so by plugging into the jack on his own switchboard and ringing the line himself without troubling the exchange operator; if a normal call were already in progress it would be interrupted, thus giving the controller priority of access. In the reverse direction (at least on the Earl's Court exchange) it is stated that the person at the control point would operate a push button next to the telephone that would drop the relevant red 'flag' on the controller's board. Whilst one cannot be absolutely certain that this description was not referring to some additional telephone, the implication is that it was the normal exchange line and that the exchange operator would answer upon operation of the magneto in the normal way. Technical descriptions show that the push button applied a direct voltage from a 24 volt local battery to the line that operated only the controller's equipment.[35] For many years the District control board had a capacity of 45 lines and the tube lines board 60 lines. Each of the controller's switchboards included lines to the powerhouse, various repairmen, and other control offices. The bus controller was also located at Leicester Square; in those days the services were highly co-ordinated.

In the early 1930s the extension of the Piccadilly Line westwards over the District Railway made it convenient to group these two lines for organizational and control purposes. In consequence, from 18th September 1932, all Piccadilly Line telephone extensions were transferred from the Leicester Square exchange to Earls Court, and the direct lines were transferred from the Leicester Square controllers to those at Earls Court.*

Separation of the Tunnel Telephones

It was during this period that the tunnel telephone lines were rearranged and became segregated from the rest of the telephone network. The first rumblings of this have been found in correspondence between the Board of Trade and the London Electric Railway (as the three Yerkes tubes had become in 1910). The correspondence dates back to January 1914 where the ler explains to the Board of Trade that they have complied with their requirements for telephonic communication to be possible from trains to local stations (on the LER and the CLR), but that in practice this form of operation is not entirely satisfactory; there had already been some worrying incidents where delay had been occasioned in getting the current off. In short, it was now proposed to connect the tunnel telephone lines directly to the substations, and in addition to provide switches at signals which would discharge traction current automatically. The Board of Trade[36] supported the idea notwithstanding that it was not what the regulations stated, but it is evident that the matter of substation connection was not quickly addressed, and the idea of the switches seems to have been dropped.

* The traffic circular entry **says** all the transferred telephones were renumbered but it is to be observed that the vast majority of 'new' numbers all fall into convenient gaps in the Leicester Square series and the inference to be drawn is that existing numbers were retained on the new exchange where possible and renumbered where not possible.

Rearranging the tunnel telephones appears to have been undertaken over several years, one railway at a time. The first difficulty to present itself was that the existing tunnel lines ran between passenger stations, but they now needed to run between substations, which were much longer distances and whose locations by no means coincided. The second problem (which one might suspect emerged from experience), was to determine to which of the two or more substations on a section a call should go, and the third was that this system was only with some inconvenience amenable to the existing method of operation using local batteries and magneto ringing, and that it was desired to introduce central battery (CB) operation which was not compatible with the existing telephone network.

The outcome was that lines were converted in two stages. Stage one involved the connecting together of the tunnel telephone wires on each road to conform to the substation sections. The wires were connected to the substation telephone at the forward end of the section while the station switchboards were rearranged so that one socket outlet was connected to the wires on each road, giving them the ability to speak to the substations direct. A substation call would be received by the attendant who would then notify as necessary other substations of the need for current to be removed or restored. The second stage involved the alteration of the circuits from local battery (LB) operation to central battery (CB) operation,* and this required the separation of the tunnel telephone lines from the station switchboards and their direct connection to additional instruments; it also rendered the telephone equipment in the driving cabs of the motor cars redundant and required the issue to all motormen on duty of portable handsets which they had to keep with them in small wooden boxes provided for the purpose.

The first line to be converted was the Bakerloo, which appears to have been altered in 1915 or 1916 with work completed in April 1917. In this case the additional station instruments were fixed in similar positions to the existing telephone panels. Work on the Hampstead Line evidently began in 1916 and was completed in October 1917, but this time the additional station instruments were fixed to the station headwalls. Work on the Piccadilly Line began in December 1919 and appears to have been completed in April 1920, again with the new instruments at headwalls. In January 1920 it is recorded the Central London Railway's arrangements were changed, with headwall instruments being introduced which connected with forward substations, but no reference to reorganisation of the tunnel lines has been discovered. It may be that on this railway (which did not have tunnel lines from the beginning), they always ran between substations. As a reference has also been seen in 1919 to driver's handsets it may also be that the CLR by then used CB operation on the tunnel telephone lines, and may have done so from their erection.

1919 instructions to LER substation staff[37] indicate that Chelsea exchange should be used for ordinary interconnection between substations (rather than Leicester Square), but that for communication between adjacent substations the tunnel telephone line may be used, where installed; regular such use would act as a test for this safety-critical circuit.

During 1921 it became evident that at some stations on the Hampstead and Piccadilly Lines there were second sets of headwall instruments that related to adjacent current rail sections at locations where the gaps were intermediate between stations. These were evidently a source of confusion and were removed, with all remaining headwall instruments now placed on the leading headwalls. From May 1922 the locations of tunnel telephone instruments at Bakerloo stations were standardized at the leading headwall positions, the move taking a year to complete. The hijacking of the tunnel telephone lines for emergency communication with substations meant the loss of direct communication between stations. In consequence the direct magneto telephone lines between stations were in due course replaced by

* As perhaps the terminology implies, LB (local battery) operation requires batteries to be located near each telephone instrument, a considerable maintenance liability given they needed to be kept reasonably charged. On a CB (central battery system) the electricity was supplied down the line from a common battery at the exchange. Broadly speaking CB and LB systems needed to be kept separate though interconnection at exchange level was possible.

new lines in order that station-to-station working could be put in operation without going through the telephone exchange.

As mentioned earlier the CSLR had had tunnel telephone lines from around 1900, and there is little reason to suppose that over the years the means of operation changed much. In October 1920 each of the locomotives was equipped with a telephone handset and a push button, together with leads that would connect with the telephone line. Stations could be called up by connecting the leads and pressing the button (so at that date it looks as though CB operation was not in use) and separate lines were placed at certain locations so the instruments could be tested. The lines at that time connected with the signal boxes in advance and in rear. From September 1921 new regulations were implemented which clearly state that the drivers were now provided with individual telephone handsets and that merely clipping them onto the wires would connect them to the station in advance (rather than signal boxes as hitherto); it may be presumed that CB operation came into use from this date.

The advantage of CB working of the tunnel telephone lines was that any significant load on the line would cause the substation equipment to detect a call and ring the alarm bell, whether such a load were a telephone handset or a short circuit. It was therefore no great mental leap to cause the substation equipment to operate automatically to take off current, whether it be by attaching a telephone handset, operating the tunnel telephone instrument at a station, or just by pinching the wires together. The Piccadilly was converted to this mode of operation from June 1924, the Bakerloo in April 1925, the Hampstead & City Lines in June 1925 and the Central London Railway in January 1926. The City & South London Railway appears to have retained tunnel line connections to each station until it closed for reconstruction in 1923/4. Upon re-opening its operating practices were thoroughly harmonised with the 'Hampstead' line, initially with the tunnel telephone line connected to substations and from June 1925 working automatically.

Tunnel telephone lines were not at first provided on the District Railway or the Metropolitan Railway and it has to be doubted whether they originally had any sort of direct lines between stations, which may therefore mean they did not need annunciator panels at the smaller stations. The utility of tunnel telephone lines was obvious to the UERL, and the District was eventually equipped with such a system, commissioned on 14th July 1930. It operated in precisely the same manner as that on tube lines. The Metropolitan followed suit, but not until 26th January 1936 which was well within the London Transport era. The universal provision of this system around the Circle Line avoided the highly inconvenient arrangement where from 1930 drivers of Metropolitan Line trains running along the south side of the Circle (over the District) had to collect a telephone handset at Mark Lane and return it at Sloane Square, or vice versa. The East London Line was equipped with tunnel telephone lines from 4th September 1938, completing the installation across the network.

The driver's handsets were specially wired with their receivers and transmitters in parallel with each other, reducing operating resistance. In fact electrically similar types of handset were also used within the substations (and at station headwalls) as these, too, had to operate on the telephone lines. When the tunnel telephone lines were converted to automatic operation the means of giving an indication in the substation relied on the relay apparatus not resetting itself when the short circuit was removed, and this was achieved by feeding the supply current through the detection relay at the forward substation, which, when dropped, took the supply away until the circuit was reset by applying a temporary supply from the substation in rear, which also proved the telephone line to be intact. This being the case, there would have been no current available to operate the telephone and it was necessary to introduce a 4½ volt battery in series with the telephone instrument at the substation in order for speech to be communicated. With this special circuitry it was no longer possible for the tunnel telephone instruments to be linked with the general telephone system in any way.

Location of Station Telephones

After some years operation on the tube lines it became evident that having the station annunciator panel in the Station Master's office was not necessarily very convenient, the incumbent finding himself used as a telephone operator and great inconvenience being caused if the office were unmanned (and perhaps locked). From no later than 1913 new installations were centred on platform kiosks as the location for the annunciator and over the next twenty years the older installations were largely altered to conform. At the busier stations the supervisor often received a direct line in compensation, sometimes on a new number but sometimes by transfer of a little used line elsewhere. At other stations he would often receive an extension line off what was now the platform telephone. This was always less than ideal although it reduced the number of different numbers to be tried when attempting to contact a station urgently.

Lift Telephones

All the tube lines originally used lifts to connect the upper and lower stations, and the ubiquitous Otis lift became almost universal, many other types being replaced by Otis equipment displaced by the arrival of escalators. However the Otis lift was for many years normally operated by an attendant within the lift car. In the event of failure he had to attract—by means of a whistle, or just by shouting—the attention of other staff who could extricate the trapped passengers and staff. By the end of the First World War some stations that were very lightly used lost staff, at least during certain times of the day, so that only the booking clerk was left at the top station. He was not permitted to touch the lifts but he could still summon help from an adjacent station. As a final economy measure the clerk, too, was dispensed with and the lift operator was provided with a mini-ticket office in the lift.* Now on his own, the lift operator had no means of summoning help.

During this de-staffing process the Underground Group decided to introduce a form of 'tunnel telephone' line running vertically within the lift shaft and to which an operator in distress could clip a telephone handset. The exact history of these is obscure, but such installations seem to have been fitted in the early 1920s† at a small number of the quieter stations and the telephone lines themselves seem always to have been terminated in the traffic controller's offices.‡ The installations at Regents Park and Mornington Crescent lasted until the lifts were withdrawn from service in the 1980s. At Aldwych the equipment was replaced in around 1990 by telephones in the lift cars that connected to the supervisor's office (though the station closed in 1994); this probably coincided with the introduction of ticket gates and withdrawal of the ticket issuing equipment in the lift.[38] The lifts at Lancaster Gate were fitted with automatic phones (intended only for emergency use) from 28th October 1966, and these lasted until the lifts were replaced.

Station-to-Station working

In case of major signal failure a special form of working was introduced called 'station-to-station' working whereby supervisory staff were authorized by telephone to allow individual trains to proceed to the next station. This procedure was immensely inconvenient to operate if the platform telephone were remote from the leading headwall where the driver needed to be instructed what to do. As already stated, the tunnel

* In 1928 there were nine such stations (Borough, Regents Park, York Road, Aldwych, Hyde Park Corner, Down Street, Brompton Road, Gloucester Road and Mornington Crescent), reduced to six by 1934 following station closures.

† The shafts at Aldwych were fitted in March 1922. No date has been found for any other installations (except that Borough was equipped on re-opening) but it is at least likely the other stations with lift ticket offices were equipped; the regulations are certainly written in the plural.

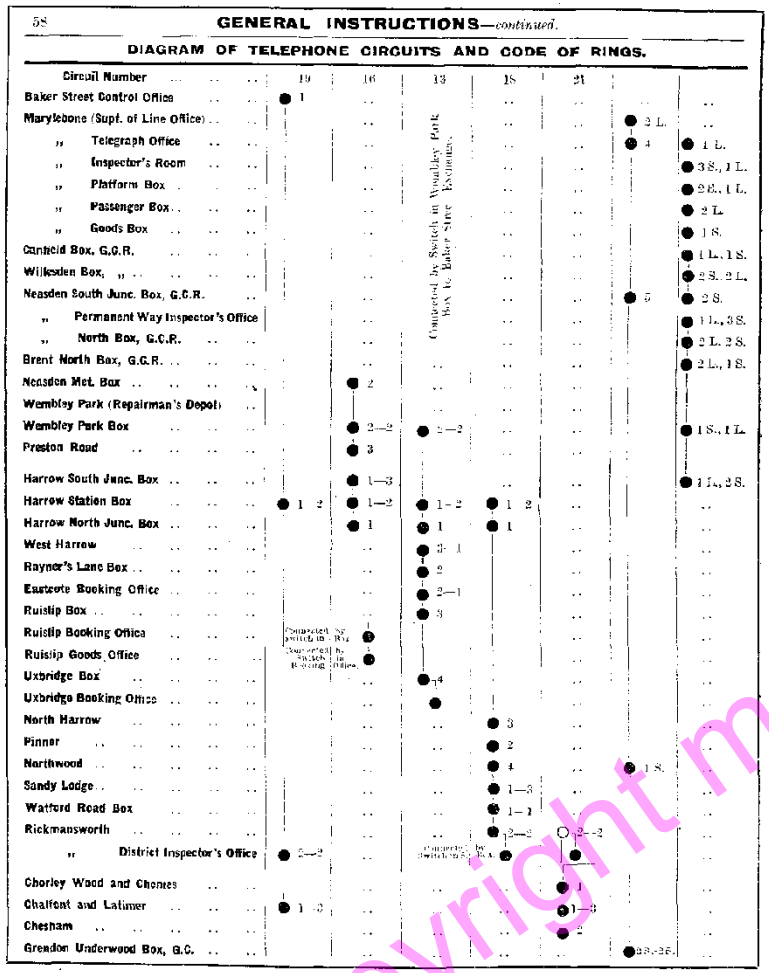
‡ Since the stations were lightly manned it seems a sensible decision not to terminate them on the station itself, though they could have been terminated at adjacent stations. It is not obvious why permanent telephones could not have been installed in the lifts, but it is not thought ever to have been done prior to the introduction of modern lifts.

telephone lines originally provided direct connection between stations which could be used for this purpose and when the use of these lines was altered new circuits had to be installed.

To facilitate station-to-station working on tube lines nearly all tunnel stations were equipped with extension telephones installed at each leading headwall, often in a wooden cabinet to help reduce dust problems (though these instruments were always filthy). It is thought that this work took place mainly during the 1930s and 40s. By means of interconnecting plugs at the annunciator panels, the 'headwall' telephones at adjacent stations could be connected together through the station-to-station wires. No doubt following accidental meddling with these temporarily safety-critical circuits, in later years the bridging cords at the annunciators were duplicated with bright yellow leads prominently marked 'When Connected DO NOT REMOVE', for use exclusively during station-to-station working. For some reason, stations on the busy south end of Northern Line were never fitted with station-to-station telephones at the headwall and staff had to make do with the ordinary platform instrument simply plugged through to the next station.*

Station-to-Station working was not in fact used in the open air sections of line until a change of policy in 1957; this resulted in a huge number of new station-to-station extension telephones being fitted at platform ends, and consequential changes to platform telephone arrangements (this probably resulted in widespread provision of annunciator panels where previously there had not been any).

* This was immensely inconvenient as the rules failed to address such a situation and the phone kiosk wasn't even on the platform. Having had to implement station to station working in this area myself I can vouch for this. Additional supervisors and an improved system of whistles had to do the job.



58 GENERAL INSTRUCTIONS—*continued.*

DIAGRAM OF TELEPHONE CIRCUITS AND CODE OF RINGS.

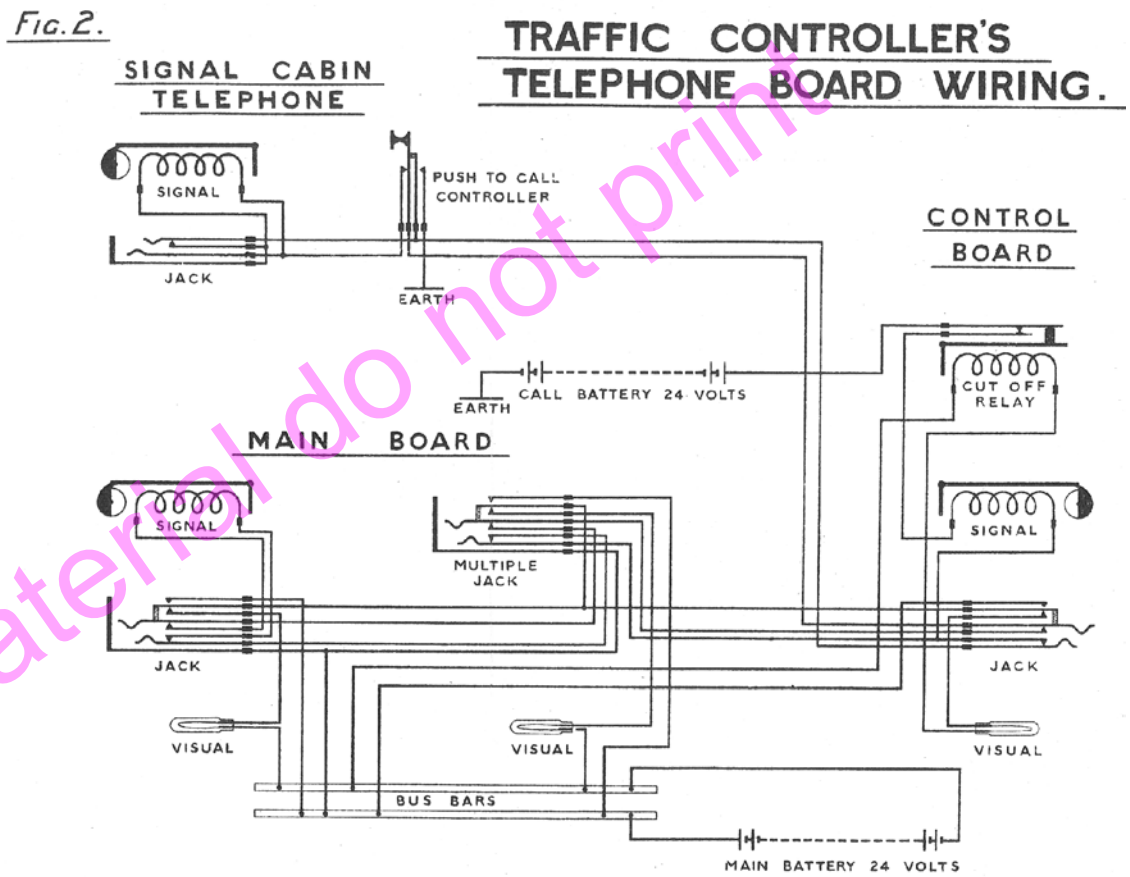
Circuit Number	19	16	13	18	21		
Baker Street Control Office	1						
Marylebone (Supt. of Line Office)						2 L.	
,, Telegraph Office						4	1 L.
,, Inspector's Room							3 S., 1 L.
,, Platform Box							2 S., 1 L.
,, Passenger Box							2 L.
,, Goods Box							1 S.
Canfield Box, G.C.R.							1 L., 1 S.
Willesden Box, ,,							2 S., 2 L.
Neasden South Junc. Box, G.C.R.						5	2 S.
,, Permanent Way Inspector's Office							1 L., 3 S.
,, North Box, G.C.R.							2 L. 2 S.
Brent North Box, G.C.R.							2 L., 1 S.
Neasden Met. Box		2					
Wembley Park (Repairman's Depot)							
Wembley Park Box		2—2	2—2				1 S., 1 L.
Preston Road		3					
Harrow South Junc. Box		1—3					1 L., 2 S.
Harrow Station Box	1 2	1—2	1—2	1 2			
Harrow North Junc. Box		1	1	1			
West Harrow			3—1				
Rayner's Lane Box			2				
Eastcote Booking Office			2—1				
Ruislip Box			3				
Ruislip Booking Office							
Ruislip Goods Office							
Uxbridge Box			4				
Uxbridge Booking Office							
North Harrow				3			
Pinner				2			
Northwood				4		1 S.	
Sandy Lodge				1—3			
Watford Road Box				1—1			
Rickmansworth				2—3	2—2		
,, District Inspector's Office	2—2						
Chorley Wood and Chenies					1		
Chalfont and Latimer	1 2				1—3		
Chesham					2		
Grendon Underwood Box, G.C.						33–36	

Connected by Switch in Wembley Park Box to Baker Street Exchange.

Connected by Switch in Ruislip Box to Ruislip Booking Office.

Connected by Switch in Ruislip Box to Ruislip Goods Office.

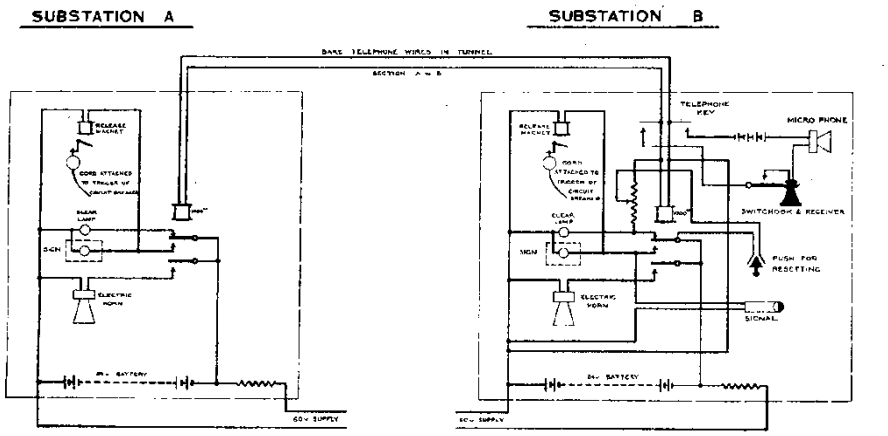
Connected by Switch in Rickmansworth Box to Chorley Wood and Chenies.



Example of Omnibus Circuits in use on Metropolitan Railway in 1922

Traffic Controller's telephone circuit in early 1920s showing how traffic controller had priority control over the normal telephone switchboard operator.

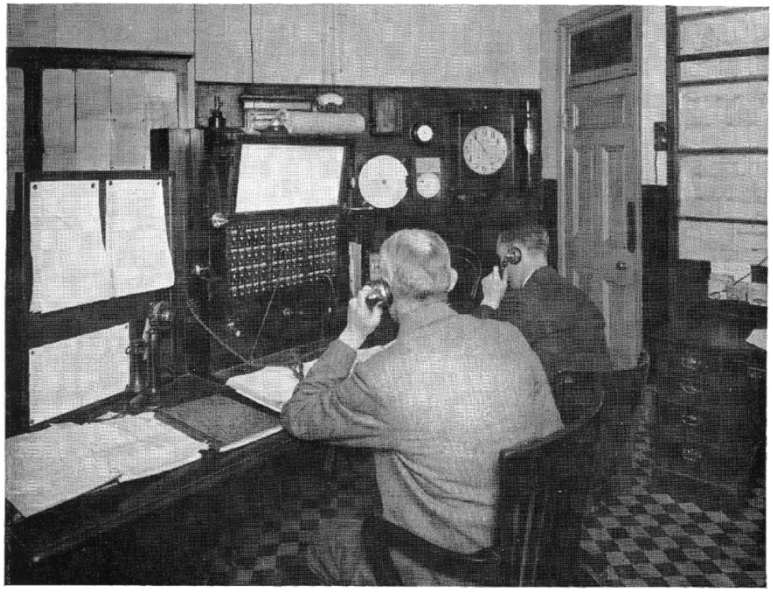
EMERGENCY CUTTING OFF OF CURRENT.
TUNNEL TELEPHONE WIRING.

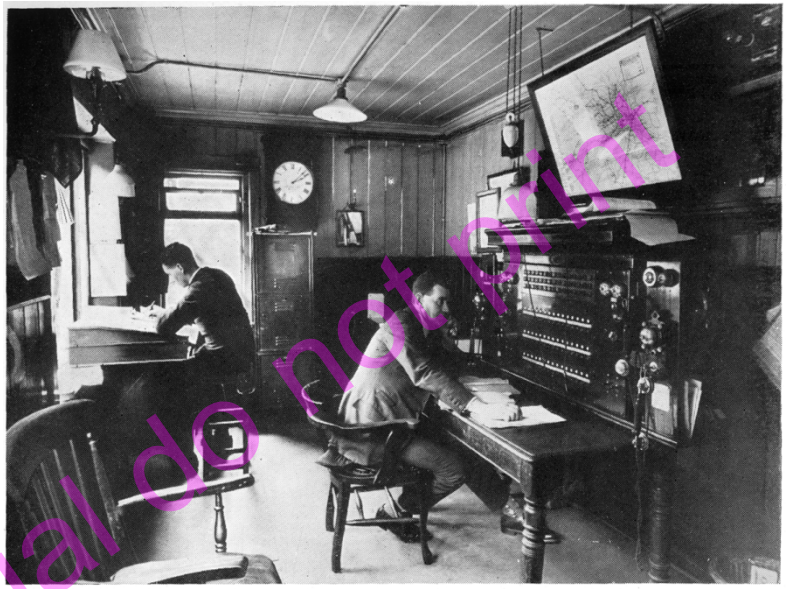


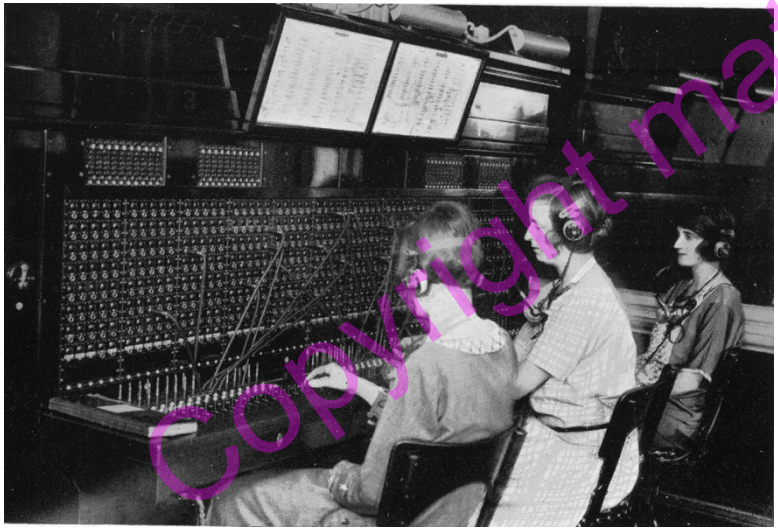
The diagram above shows the experimental circuit in use on Piccadilly Line to allow traction current to be discharged automatically when the tunnel telephone line was operated (see pictures on right to show phone clips in use and the wires being short circuited). In the above diagram the tunnel line is supplied by current from Substation B, but equipment in both substations operates simultaneously to provide a warning and discharge current. The tunnel line can only be reset from Substation B (the only one to have a telephone connected), but each must recharge current independently.

Fig. 49. A driver using his portable telephone set. By hooking the terminals to the bare wires in the tunnels he is enabled to communicate with the sub-station.

Fig. 50. The action of pinching the wires in the tunnel, as shown, enables the train-man, in emergency, automatically to operate the sub-station cut-out.







These pictures show the 400-line Telephone Exchange at Leicester Square (**lower left**) which carried most ordinary communication between stations, signal boxes and offices.

At **top left** is the control office for the tube lines, also at Leicester Square, showing the small telephone board connected with key points on the network and where calls took priority over exchange calls.

The **upper right** photo shows the equivalent control office at Earls Court on the District Railway. All photos represent position in mid 1920s.

Chapter 3 - The Automatic Era

Automation and Head Offices

It can be no surprise that LT looked to automation to speed up communication, improve reliability and reduce costs, and its decision to introduce such a system in the 1930s, during a period of great expansion, seems eminently logical. That it did not do so earlier may be open to question, perhaps in 1932 when the network previously expanded, but much of the manual equipment then in use was really quite new and the cost of re-equipment would have been harder to justify. It is worth noting the Southern Railway had introduced a 50-line automatic system at Waterloo as long previously as 1921, followed by several other automatic exchanges at major centres. These were so successful that in October 1925 an extendible 1000-line system was installed throughout the inner London area, and these served several stations at which Underground trains called. When the Underground's own automatic system was eventually commissioned there was 2-way direct-dialled interconnection between these systems.

Initially the automation of the LT system was focused upon the head office buildings at 55 Broadway (and, so it seems, the establishments at Acton and Chiswick works, and the office complex at Baker Street). The new Head Office automatic exchange was of 500 line capacity and used 3-digit numbers; it was certainly in use by July 1938 but is thought likely to have entered service the previous year;[39] the other exchanges were much smaller (under 100 lines) and introduction dates are not known other than they are pre-War.

More significant was the commissioning of a second exchange within the head office complex, known variously as the head office tandem, or Tandem 'X'. In telecommunications jargon a 'tandem' is essentially an exchange that connects other exchanges together, rather than serving individual end users. In this instance the tandem was to be the hub of a substantial internal telephone network consisting of the four new automatic exchanges just mentioned, a large new automatic system serving the

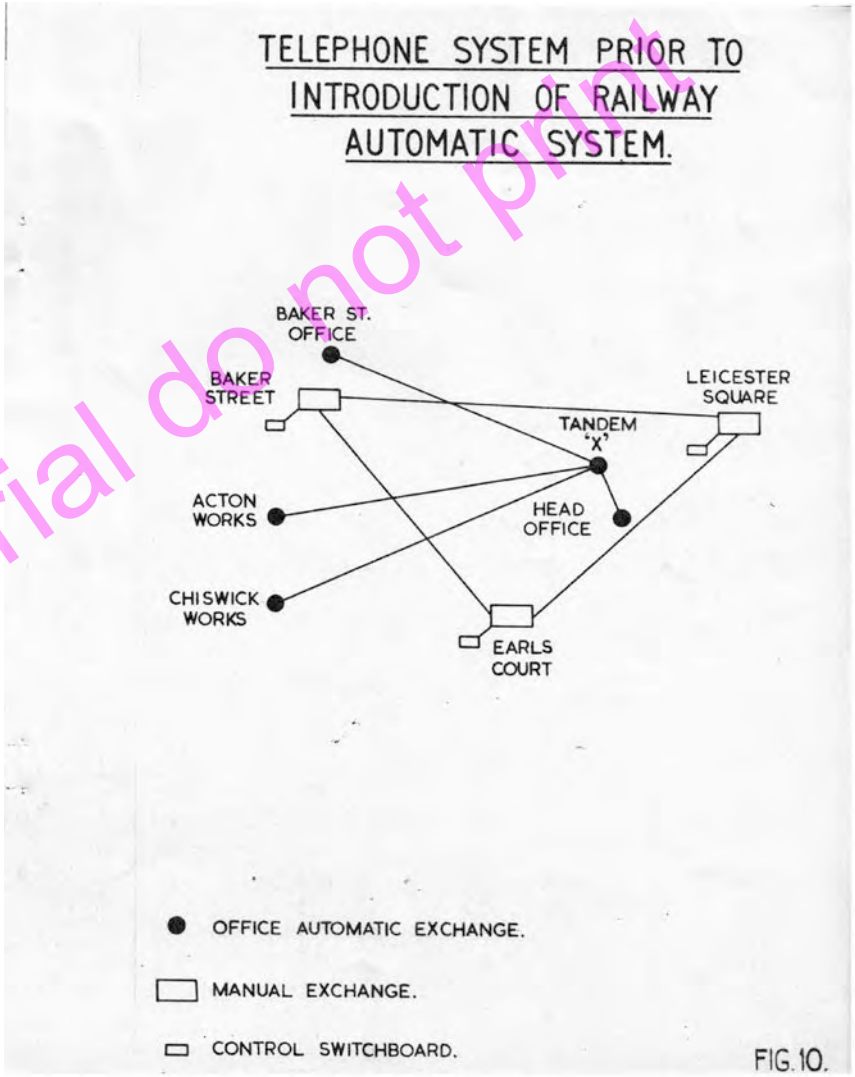


Diagram of the railway network exchange system, after the Tandem exchange was opened.

railways, and a number of manual exchanges dotted around the huge LT organization.

The interconnection between these various exchanges was achieved when a user dialled a three-letter code, consisting of an X (or level 9, not then used to begin any telephone extension numbers) followed by two letters unique to the exchange required; the 'X' seized a line to the head office tandem (hence the name tandem 'X') and the remaining two letters identified the next exchange required, following which an operator answered (if a manual exchange) or the remaining digits were dialled (if an automatic). Exchanges connected to the Head Office tandem appear initially[40] to have been shown by the following table.

Location	Access numbers	Number of lines	Type
Camberwell Trams	XHO 540-543	200	Manual (CB)
Greenwich (Generating stn)	XHO 548-549	75	Manual (LB)
Manor House Trams	XHO 473/544	100	Manual
Shoreditch Trams	XHO 545-547	100	Manual (CB)

Within a few years (but by the time the February 1942 directory was issued) these manual exchanges were connected to the Tandem 'X' exchange and allocated the following codes, apparently in substitution of the number blocks given above:

Location	Code
Camberwell Trams	XCL
Greenwich (Power House)	XGH
Manor House Trams	XMH
Shoreditch Trams	XSH

These were accompanied by other LT manual exchanges (that did appear to have had special numbers previously) as follows:

Location	Code	Number of lines	Type	Connection date
Lots Road Power House	XPR	100	Manual	1940
Oval Bus Control	XOB	300	Manual (CB)	1946

'Tandem X' exchange was built by Siemens Brothers Ltd and is believed to have entered service in or about January 1937* (it would be plausible to suppose it came into use at the same time as 'XHO').

The existing head office manual board (known as the general offices switchboard, or the GPO switchboard) was unaffected by the introduction of the automatic equipment and remained in use, with its own extensions, to put calls through from the GPO network.† The systems were interconnected in that 'XHO' extensions could dial the GPO switchboard‡ and be put through to any extension, and vice versa, though the 'XHO' lines could not be connected to a GPO outgoing line (or 'junction') because of the attitude of the GPO authorities to interconnection between automatic systems.

At this time the GPO switchboard was described as comprising 'nine switchboards with access to 25 outgoing and 21 incoming lines, four direct lines to Earls Court, three to Leicester Square, one each to Baker Street, Lots Road and Green Line coach control, and 435 indoor extensions'.[41] The introduction of the 'XHO' automatic network would have relieved the operators of much of the routine inter-office traffic, giving them more time to deal with the general increase in traffic volume, a significant amount of which related to travel enquiries. In addition to the set of exchanges already referred to there were others which could be accessed

* Trams and Trolleybuses traffic circular entry 1309 refers to code XSO being available on automatic telephones to contact Southern Railway.
† The LT main (GPO) switchboard number was altered from VICtoria 6800 to ABBey 1234 on 2nd April 1938.
‡ The GPO switchboard number was 'XHO' 371

through the Head Office ('XHO') exchange itself. These were as are set out in the table below:

Camberwell, Manor House, Oval and Shoreditch exchanges are not considered here further as they fall into the ambit of bus and tram communications discussed later. It should also be noted there were a number of other manual exchanges on the network, not apparently connected directly to the above and possibly only accessible through direct extension lines or junctions, or via the coded (ie 'X' prefixed) manual exchanges already referred to. One of these was the exchange used to service the residential flats and offices known as Chiltern Court, above Baker Street station.* In addition the Baker Street manual exchange must have remained in use until 1939 to service former Metropolitan Railway stations, notwithstanding loss of the head office lines to XBS.

The Railway ('XRL') Network

By far the largest of the LT automatic exchange systems belonged to the railway, and was known as the 'XRL' exchange. The automatic switching of railway telephone traffic was 'distributed' to reduce the cabling required. It comprised eleven local exchanges that were based around a core tandem exchange at Leicester Square through which the majority of inter-exchange railway traffic passed. The network was designed to operate using a common 4-digit series of numbers the first one (or sometimes two) digits directing the call to the exchange required; there is no obvious pattern to the number allocation. The exchanges were initially located as follows:

Location (initial)	Prefix	Number of lines
Acton	0	140
Aldgate	5	140
Baker Street	7	180
Clapham North	42	50
Earls Court	8	200
East Finchley	62	60
Finsbury Park	61	80
Golders Green	43	50
Harrow	3	180
Leicester Square	44/5/6	280
Loughton	52	100
Leicester Square	X (or 9)	Connection to Tandem 'X' equipment

The first part of the automation of the railway network was the subject of a contract let on 14th June 1938 for the supply of £32,000 worth of telephone equipment, although the complete scheme was expected to cost £150,000 during the 18-month installation period. A contemporary report states that the number of telephones was to be increased from 670 to 1795, which at least partly reflects the vast increase in the size of the Underground network and the new or rebuilt stations which needed to be served (including the Metropolitan Line part of which was still using omnibus circuits). However, since the total number of telephones quoted far exceeds the railway exchange capacity it must be supposed that it includes the equipping of at least some head office buildings as well. The costs also include relocation of the various line traffic controllers to new accommodation at Cranbourn Chambers (Leicester Square), and the expansion of the direct line network may account for a few telephones in the overall total.

The 'XRL' exchange equipment was ordered from Ericsson and was mainly of the 'PO 2000' pattern (a form of Strowger electro-mechanical step-by-step apparatus used by the British Post Office). The sites selected for the equipment were influenced by the pre-existing cabling for the

* The Chiltern Court exchange and telephone system dates back to 1930-31 in Metropolitan Railway days; irritatingly the Met Railway file on the subject (at London Metropolitan Archives) is listed as missing.

manual system, as major changes in cabling within the difficult environment of the Underground would have been onerous. Finding space was inevitably a problem in central London but fortunately a number of disused lift shafts were available and it was possible to find space there. In such spaces the high levels of metallic dust had to be considered and efficient dust sealing, coupled with positive air pressure blown in through dust precipitation plant, largely overcame the problem, though frequent cleaning still proved necessary. Power was selected by changeover switch from either the signal main (emergency) or local supply (normal) which charged 50V nickel-cadmium batteries for operation of the equipment, the batteries having an 8-hour operating capacity from full charge in the event of power failure. The largest exchange, at Leicester Square, was built on three floors but was still exceedingly cramped and hot.

The exchanges were all linked to the Leicester Square tandem as well as having junctions directly to neighbouring exchanges. This called for the equipment to operate in a novel way. Picking up a handset would seize a junction to Leicester Square and simultaneously seize a selector at the local exchange. On dialling the leading digit the first selectors at both Leicester Square and the local exchange would step to the required level. If the local exchange determined the call were local (that is to the same exchange) the Leicester Square junction would be released, as it was not needed. Equally, if the call were for an exchange to which a direct junction were available then the local switch would seize that junction (in readiness for the remaining three digits) and the Leicester Square junction would also be released. If neither of these two eventualities occurred then the remaining three digits would be sent to Leicester Square for onward routeing of the final digits, the selectors were already standing on the leading digit, and the first selectors at the local exchange would now be released. If an 'X' (ie a 9) were dialled then the Leicester Square tandem would route the call to the Head Office tandem for onward processing.

Where two-digit discrimination was used between exchanges then one or more local exchanges acted as satellites to a 'parent' exchange and this

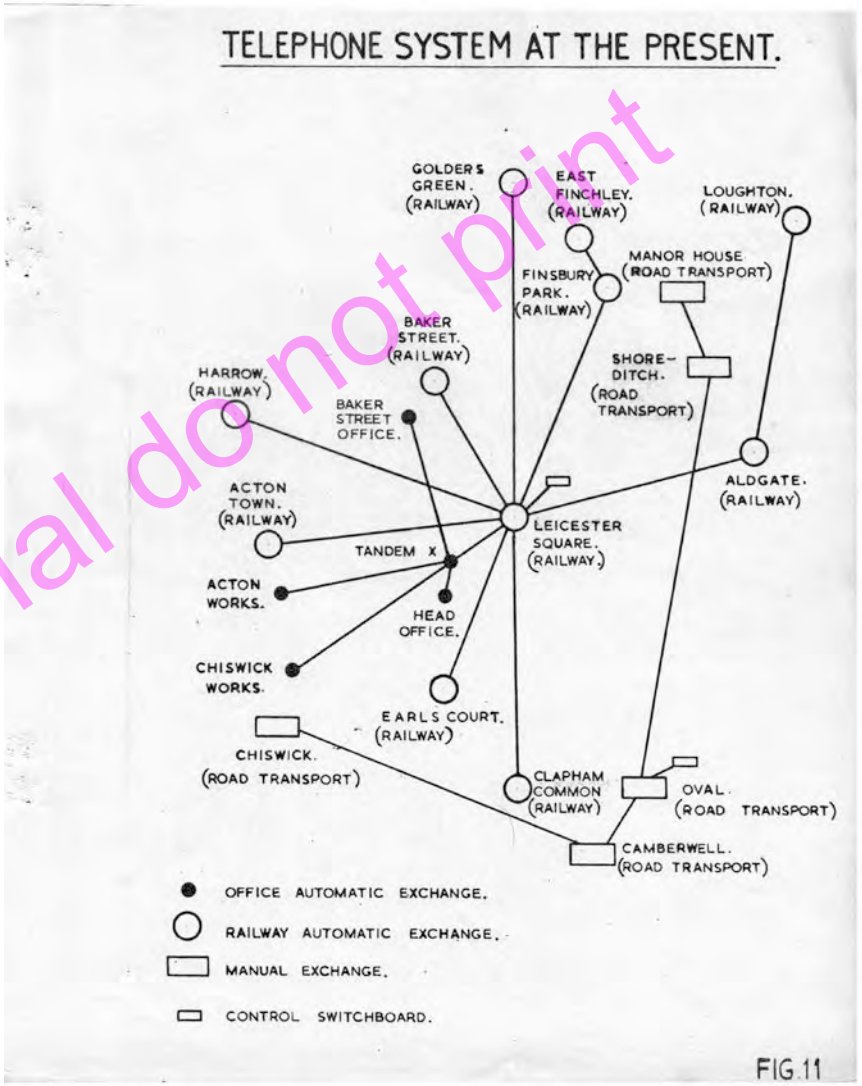


Diagram showing the main telephone exchange connections after the railway 'auto' network was introduced. The road transport network was substantially separate but was connected to the Tandem X exchange (not on this diagram).

second digit selected the satellite. In other words they were merely separate 'hundreds' groups in a separate building, connected to the parent by 2-wire junctions and relay sets. This was cunningly arranged. The satellites only had 2-motion final selectors, but these monitored the first two digits sent to the parent. If the first two digits were recognised as being for the same satellite the circuit to the parent was dropped, the 2-motion selector reset to await the final two digits, and then the selector would step to the right outlet to complete the call. If not for the local exchange then the call would be processed through the parent as previously described.

As part of the new control function a central information desk was provided at Leicester Square, contrived to be dialled by the letters 'INF'. This of course represents the numbers 463 that happily coincided with the Leicester Square exchange, although taking out ten other numbers for the privilege. Perhaps Leicester Square exchange was deliberately allocated the '46' range so this could be done.

Each exchange was linked to Leicester Square tandem by means of 19 both-way junctions, and connected to neighbouring exchanges by (usually) five both-way junctions. This was intended to provide sufficient capacity in times of stress. Local cables were, where possible, arranged in pairs to each station with some of the telephones fed from each pair to avoid total loss of communications in the event of cable fault. For reasons of history most local cables contained direct line and other circuits as well as those servicing the new automatic equipment. The equipment was designed for 15 per cent utilization (ie fifteen simultaneous calls per 100 lines).

Although the new automatic telephone network provided an opportunity to install new 'subscriber's' equipment a very large proportion of the existing equipment remained in use initially, with only the telephone instruments themselves replaced (or adapted) to permit automatic operation. New equipment was, however, designed and installed at the considerable number of new and rebuilt stations, and then fitted to existing stations later as occasion allowed. Nevertheless, even at the end of the life of the electro-mechanical exchanges in the 1980s some quite primitive subscriber's apparatus could still be found. Most of the new telephones provided were either of the latest PO 300 pattern if they were desk telephones or were one of a number of proprietary wall telephone designs not exactly following the po pattern, although in later years 300-style wall phones did make an appearance. In new platform kiosks neat integral panels were provided. These had drop flaps and connecting sockets at the top (one of which was the auto line), the 'wall' dial instrument below, retractable bridging cords to one side, with the retractable telephone lead on the other, a magneto handle under the telephone itself and a shelf at the bottom. Usually directory panels were in a frame on another wall or disposed either side, depending on space. Dial labels were yellow and marked 'London Transport' [at the top] and 'Private Telephone System' [at the bottom], with the extension number stamped or written in the middle (a simpler design may have been used initially) The number of extension lines at existing stations was not vastly increased and many lines were operated with two telephones connected in parallel with one another. Typically a station office telephone shared a line with a platform but a variety of arrangements pertained, sometimes with the potential for much confusion. Party Line operation (using an earth conductor) and extension working with a trembler bell were not unknown.

Phasing in the Equipment

Phasing in the new system was not without its difficulties—for a start it could not realistically be achieved overnight. Another very significant factor was the need to co-ordinate the changes with parallel alterations being made to the location of the traffic controllers (who were going to be centralized in a new combined control office at Leicester Square). It must be recalled that hitherto the controllers gained priority access to key locations either by means of a direct line, or by interrupting the normal telephone circuits that were also run through their switchboard. Since it was not practicable to shift these circuits temporarily it follows that the controllers could not move before the lines were transferred to automatic.

Following transfer, the controllers were given special priority facilities to cut into any automatic telephone call on finding it engaged, requiring the equipment to be arranged accordingly.* In the reverse direction it was now possible for anyone to telephone their own line controller by dialling 'C' (ie 2, as this was not then used for the initial digit of extension numbers) which required complex special arrangements to be made as telephone extension numbers were not allocated by railway line.† The practical effect of all this was that any changes to the various controllers had either to be made at the same time as automatic working was introduced in that area or otherwise co-ordinated closely where the line changeovers were split (large numbers of direct lines would need shifting at the same time).

It was intended that the work be undertaken in seven phases, as detailed below, in each case from start of traffic. An eighth phase followed somewhat later to complete the operation, war having got in the way.

Phase 1 – Tuesday 12th December 1939

The existing manual switchboards were given temporary numbers for the first three stages to allow interconnection from converted stations on the automatic system. Leicester Square was 4642, Earls Court 4612 and Baker Street 4601.

Automatic telephones introduced Aldgate – Paddington Praed Street, Baker Street – Dollis Hill, East London Line (all) and Greenwich Generating station. Traffic controller moved from Baker Street to Leicester Square. Manual exchange at Baker Street retained to deal with remaining Metropolitan Line stations with temporary number (4601) to allow connection from automatic system.

Phase 2 – Sunday 17th December 1939

Automatic telephones introduced Mansion House – Bow Road.

Phase 3 – Sunday 7th January 1940

Automatic telephones introduced Queens Park – Elephant & Castle, Finsbury Park – Moorgate, Hammersmith – Royal Oak, and High Street Kensington – Bayswater.

[In practice the Bakerloo ticket offices were transferred early on Friday 5th January. The Northern City Line telephones did not have the facility to call the line controller by dialling 'C' and such calls had to be routed via Leicester Square exchange].

Phase 4 – Sunday 14th January 1940

The manual switchboards were given temporary numbers for the final stages to allow interconnection from converted stations on the auto system. Leicester Square remained on 4642, Earls Court became 8256 and Baker Street 8261.

Northern Line converted, with that line's traffic controller moved from old to new office at Leicester Square. [This was postponed until Sunday 21st January]

Phase 5 – Wednesday 17th January 1940

Central Line converted, with that line's Traffic Controller moved from old to new office at Leicester Square. Manual telephone exchange at Leicester Square abolished at the same time. [This was postponed until Sunday 28th January]

Phase 6 – 21st January 1940

Piccadilly Line (Cockfosters – Earls Court) converted with Piccadilly Line controller moved from Earls Court to Leicester Square.

* Of course, this merely replicated with the automatic equipment a useful facility that had been available from the controller's manual switchboards. When the Victoria Line opened in 1968 the Victoria Line regulator and line controller were each given a 'priority' key on their control desk; this had to be operated prior to dialling the number. In addition it appears that (at least in 1966) substation control operators also had priority facilities. (TC 786/66)

† Despite some effort to find out how dialling 'C' worked, some puzzles remain. At Leicester Square, for example, the Northern Line and Piccadilly Line platforms were in the same number range but dialling 'C' on either platform phone would need to connect to different controllers (and, until following March in different locations); and what happened on telephones in common areas?

[In practice this phase was postponed until 24th February, except for Lots Road numbers which were postponed indefinitely]

Phase 7 – Sunday 28th January 1940

District & Piccadilly Line – All remaining stations converted (and Chiswick tram depot) and with District Line controller moved from Earls Court to Leicester Square. Manual telephone exchange at Earls Court abolished at the same time.

[In practice, stations Blackfriars to St James Park were converted from 18th February and the remaining stations from 9th March. The District & Piccadilly controllers moved 2nd March. The manual exchange was not finally abolished until close of traffic on 2nd June owing at least in part to non-conversion of Lots Road numbers]

Phase 8 – 14th May 1940

Metropolitan Line – Harrow exchange brought into operation, covering all stations from Neasden to Uxbridge and the Stanmore branch. This exchange was mounted in the signal box tower above the uncompleted Harrow station, delayed by the War. It had been intended to commission the section from North Harrow to Watford and Rickmansworth from the same date but no doubt owing to wartime conditions it was postponed. This part appears to have come into use from Sunday 8th June 1940 whereupon Baker Street manual exchange closed.

Stations north of Rickmansworth did have some manual direct extension line telephones but for one reason or another this unelectrified region was not thought worthy of conversion (the cost of cabling would perhaps have been unwarranted until the much mooted electrification was in hand). For stations Chorleywood to Chesham one had to ask the signalman at Rickmansworth to patch the call through while for Amersham and stations to the north Marylebone LNER exchange (which was on the 'XRL' network) was expected to put calls through (this arrangement, which may only have been viewed as temporary, went on for years and was an evident cause of irritation); details are scarce but probably existing omnibus circuits were converted. Call in the reverse direction required the converse process. All this must have been transparently inconvenient as Chesham signalbox received a direct 'XRL' line in 1945 replacing an extension on the omnibus circuit.

When the Earl's Court manual exchange was abolished there were still some extension lines to Lots Road generating station that had not yet been converted to automatic. The outcome was the installation of two junction lines to the existing switchboard there (which was probably still the manual board). The junctions were accessed using the code XPR.[*42] One cannot be certain it was a new code but the generating station was well served with direct lines, as well as a few manual and later automatic lines, so it is doubtful there was a need for additional interconnection previously. The switchboard was of 100 lines capacity still on the magneto (or LB) system.

East of Bow Road the District Line stations to Upminster were owned by the LMS railway, and they were disinclined to spend money on lavish communications facilities. These stations were all on omnibus circuits, a pair of which was connected to the switchboard at Earls Court; they were redirected to Leicester Square when the control office moved. When automatic working was introduced, nine 'XRL' lines were installed at key points to reduce the pressure on the omnibus circuits. The Loughton exchange was not commissioned until 19th October 1947 when the Central Line extensions had reached a suitable stage. As the extension to Leytonstone had already been opened before the exchange was ready, temporary numbers based on Aldgate had to be used at Leytonstone itself until the 19th (it had been the intention that Leyton be on the Loughton exchange but in the event it was given permanent Aldgate numbers). The remaining eastern extension stations were given Loughton numbers as they were brought into use.

[*] XPR already listed in 1939 Telephone directory with implication it was small automatic exchange, but this seems very doubtful. It may have been planned as such but not implemented. The exchange had a planned Auto line 8137.

Shortly before the introduction of the new railway automatic system it was necessary to consider the matter of telephone directories. As far as it has been possible to tell, the pre-automatic styles were retained. There were two types of directory in use on the operational railway, one in sheet form in telephone kiosks and the other a small booklet for use mainly in station and divisional offices. The proofs of the sheet directories for the new Auto system included all stations, depots and signal boxes that were expected to be in use upon completion of the 1935-40 New Works Programme. The sheets (and the booklets) as actually printed included only those locations already in use or expected to be opened within the next few months. Thus the Central Line extensions as far as West Ruislip and Loughton (but not beyond), the Northern Line from Archway to High Barnet (but not Bushey), and the Bakerloo from Baker Street to Finchley Road, were the only new sections to be included (nb; the Central Line extensions did not in fact open until the late 1940s). A curious exception was the inclusion of Muswell Hill (with three lines and two extension lines to the substation).

During October 1948, recording apparatus was installed at the Leicester Square information desk which, by means of a continuous tape, made available important messages concerning breakdowns or significant delays. This was accessible through the 'XRL' system by dialling '48', which occupied an as yet unused level at the Leicester Square exchange. The apparatus was capable of handling multiple calls which, of course, were connected into the tape loop wherever it happened to be in its cycle, frequently requiring callers to listen to the remaining end of the message until it began again. The recorder went out of use from 7th May 1949 having evidently not been free of problems. The device was again brought into use during April 1951, still based at the control office at Leicester Square. This time the number allocated was '19'* on what was described as the railway telephone system. The device came to be called the Breakdown Message Recorder, or BMR. In its revised form on '19' the BMR message was continuously broadcast to each 'XRL' telephone exchange where it was connected through when the number was dialled. It is stated that if dialling from any of the other automatic telephone exchanges the number was 'XHO' 19, so it seems to have been broadcast to that exchange as well. It has been suggested that by dialling a leading '1' the junction to Leicester Square was dropped and the call was assumed to be local on the exchange concerned, implying that level 9 on each second selector was entirely devoted to the BMR messages.†[43]

In 1948 it is worth mentioning that telephone provision in the head office buildings was nothing like as lavish as it was even thirty years later and many offices only had a handful of telephones, and one was made to feel extravagant if even they were used. In Appendix One a former member of staff recalls the early days post Second World War.

Consequences of Automation

To summarise the position reached in 1940 the initial 'integrated' railway telephone system had now developed into a number of separate systems that to varying extents could sometimes be interconnected but in all essential elements were now entirely separate networks. These were:

(1) The railway automatic telephone network interconnecting all railway locations and providing access to a number of remaining manual exchanges and other networks.
(2) Direct lines from traffic controllers to major control points and between those control points.
(3) Station-to-Station direct lines (primarily for station-to-station working but capable of interconnection elsewhere, although headwall telephones never had dials).
(4) The Tunnel Telephone lines, used to turn off current and allow drivers to talk to substation controllers.

* The number '19' had previously been used during the War as the number for calling the LT emergency engineering headquarters at South Kensington.

† This raises a problem (later) on the Barking exchange where numbers were in the 59xx series.

The introduction of automation had effectively severed any general interconnection with the Post Office network (who demonstrated a level of concern about interconnection bordering on paranoia). However, under the exceptional conditions of war, limited interconnection 'for the duration' was at least discussed; this followed a spate of serious bombing that seriously damaged parts of the GPO network that served some of the lt departmental offices and caused severe difficulties (for example the loss of Primrose Hill exchange for several weeks denied the permanent way staff of much needed gpo lines). In November 1940, with the blitz at its height, the Chief Engineer was planning links from his South Kensington wartime headquarters to Abbey, Frobisher, Kensington, Sloane and Grosvenor GPO exchanges, as well as lines to the emergency gpo switchboard at the wartime facilities at Holborn station. By this means a new switchboard could provide (manual) interconnection with the 'XRL' network (15 junctions) and the 'XHO' network (10 junctions). Some discussion with the GPO must already have taken place or the proposal would not have reached such a detailed state. It cannot be proved all this was done but it is known some sort of switchboard was certainly installed at South Kensington, 'for the duration'.

The remainder of this chapter will concentrate on the further development of the new automatic network, but developments relating to the direct lines, station-to-station and tunnel telephones will be covered somewhat later (and the road service network, which was connected to the railway system, will be covered in the next chapter).

More widespread development curtailed

We shall investigate shortly the history of private telephony on London Transport's buses and tramway systems, but suffice to say here that in the early 1950s the trams and trolleybuses had private telephone systems taking advantage of their private below-street power ducts and the bus network made extensive use of the GPO system including the use of private wires and (it is suspected) some connections using convenient

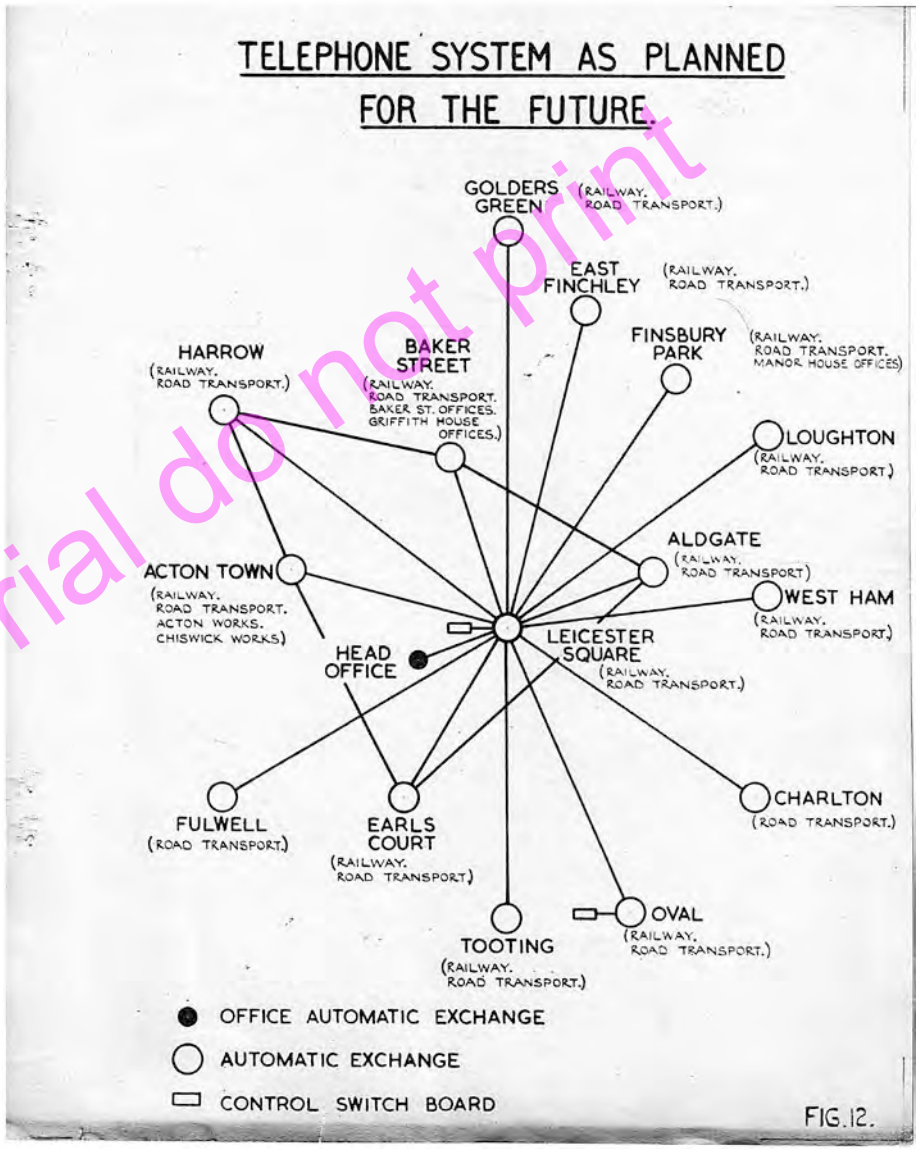
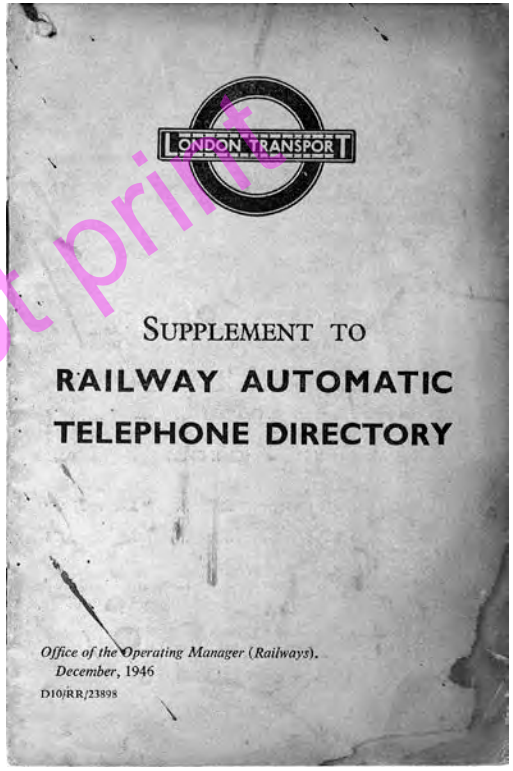


Diagram indicating how Dell proposed to combine the railway and road transport telephone networks.

Top Left *is illustration of part of a telephone directory sheet of the type posted within platform telephone kiosks, this one dating from 1932, just after Piccadilly Line extensions were moved onto the Earls Court exchange. These were about 19 inches wide by 21½ inches deep.*

Top Right *is the first directory sheet produced for the new Automatic system, dated 1939 and anticipating the final equipment changeover in 1940. This includes numbers for stations whose opening was then thought imminent (Northern Line to High Barnet, but not Finchley-Edgware, and Central Line except north of Chigwell Lane).*



Underground tunnels and rights of way. There was interconnection of a sort via the Broadway tandem exchange, but this was of very limited capacity and calls had to by dialled through via the road transport exchange operator.

A review around 1955 by London Transport's Chief Signal Engineer observed that the road transport telephone network was of indifferent quality, the more doubtful where calls had to be routed through several switchboards. Some of it was quite old, and a great deal of it virtually duplicated the railway system. By way of example of wastefulness he noted the existence of four exchanges within a mile of Acton Town (Acton XRL, Acton Works and two at Chiswick Works); calls between most combinations of these involved a lossy route via Broadway and Leicester Square.

Dell described what he would like to see developed next, which was effectively a further development of the railway telephone network to accommodate all road transport needs, making all calls automatic and optimizing line length. His proposed plan is shown on the foregoing chart, but as we shall see the road transport people preferred to switch to additional GPO lines in the short term and radios in the longer term.

Migration of the small exchanges

During the late 1950s the existing equipment at the Baker Street (XBS), Acton Works (XAW) and Chiswick Works (XCH) exchanges was becoming life expired. The Acton Works exchange used 2-digit numbers and the lines were transferred to the Acton Town 'XRL' exchange from 5th February 1958. The existing extension lines were converted to 4-digit numbers by prefixing with '07', though access to line controllers and the Breakdown Message Recorder were not immediately available. The 'XBS' exchange also used 2-digit numbers* and the lines were transferred to the

* These numbers were different from the GPO extension numbers (on WELbeck 6688), which were also 2-digit. Griffith House was also allocated 20 lines from the XBS exchange in 1940 (in addition to a number of 'XRL' lines).

Baker Street 'XRL' exchange (which was extended) with effect from Monday 12th March 1962, the existing extensions being prefixed by the numbers '74'. At Chiswick Works some new telephone lines (in the 06xx series) came into use from 7th March 1960, although the 'XCH' exchange remained in use until 5th November 1961 when the extensions were placed on the Acton 'XRL' exchange; details are scant but it appears extension lines were given entirely new 'XRL' numbers. Oddly, the notification for this explains that anyone wanting Chiswick numbers from another exchange could dial either 'XRL' or 'XA'; this is the only reference to 'XA' ever found and it is to be presumed this facility was not long lived.* Chiswick is reported as having two automatic lines in the telephone exchange in 1964, but this was probably a GPO exchange.

Closure of remaining non-'XRL' exchanges

By 1962 the Head Office automatic exchange needed replacement and it was decided to migrate the lines into the 'XRL' network, a complicated process undertaken in several stages. The extensions were notionally allocated numbers in the 9xxx series so the first problem was to get rid of the remaining inter-tandem dialling codes which began with the letter 'X' (or 9) and so free up that number range (releasing nearly 1000 numbers). The XPR code (Lots Road switchboard) had already been abandoned in early 1960; Lots Road already had a number of direct 'XRL' lines but a few more may have been added when the switchboard went. The XGH (Greenwich Generating Station) and XMH (Manor House Offices) codes were abandoned with effect from 7th April 1963. Both switchboards remained in use but were now accessible from replacement 4-digit 'XRL' numbers;† these switchboards were also accessible from the GPO network.

From 28th April 1963 the remaining codes 'XHO', 'XSO' and 'XRC' were abandoned. The Southern Region Switchboard ('XSO') was given a direct 'XRL' number (4646), as was the Railway Clearing House switchboard ('XRC'), which was allocated 4690. Both these connected to manual switchboards where the operator would forward calls (during mid 1964 the other three regional switchboards were also given 'XRL' numbers). In the case of the 'XHO' exchange itself it was arranged that by dialling '9' on an 'XRL' exchange access was gained to the Head Office exchange equipment whence the final three digits could be dialled. In the opposite direction anyone wanting an 'XRL' number simply dialled a zero, followed by the 4-digit number. In practice what appears to have happened is that the Head Office tandem exchange was taken out of use and the junctions from Leicester Square simply wired straight into the 'XHO' exchange.

The 'XHO' exchange finally closed on Sunday 29th September 1963 and from 5pm the extension lines were connected directly into the 'XRL' system. The only practical effect was that Head Office users now had 4-digit numbers beginning with a '9' and they no longer had to dial '0' for an outbound 'XRL' number. Behind the scenes a new exchange had been installed, but acting as one of the 'XRL' (Leicester Square) satellites, with direct junctions to Baker Street, Acton and Earls Court. Since there was for practical purposes only the one network now, the code 'XRL' slowly dropped out of use, and the expression 'Auto network' emerged as the best name — rather quaintly in these all-electronic and interconnected days it is still the name used — simply to distinguish it from the direct lines.

Expansion of the Auto ('XRL') network

During the late 1950s London Transport took over responsibility from BR for stations east of Bow Road on the District Line and embarked on the construction of a new depot at Upminster. To meet the more opulent lt standards this required the provision of a considerable number of additional telephones. It was therefore decided to build another telephone

* This is but one of many mysteries. XA (or 92) would clash with the first two digits of the XCL exchange (925), although the latter may possibly have just gone out of use. Perhaps with the vast reduction of satellite exchanges XA (A for Automatic) was briefly chosen as a successor to the unnecessarily long 'XRL'?

† 6116/6190 for Manor House and 4821 for Greenwich

Summary of mini-PABX Exchanges on LT Network:			
Exchange	'XRL' No.	Entered Service	Withdrawn
Effra Road Ticket Works	4272/73 later 9931	14th Jan 1963	Still in use in 1978, gone by Aug 1981
Cromwell Curve Substation Control Room	8399	17th June 1963	Circa 1981
Baker Street Substation Control Room*	7406	23rd Dec 1963	August 1981
White City RTC	8397	23rd Sept 1963	29th April 1974
Leicester Square Substation Control Room	4033	Jan 1974	August 1981
Leicester Square Substation Control Room	4035	Jan 1974	August 1981
Manor House Substation Control Room	6401	25th May 1968†	November 1981
Lillie Bridge Signal Overhaul Shop	8151	17th Nov 1974	Between June 1983 and January 1985
Neasden Substation Control Room	7341	14th August 1966	Circa 1981

exchange at Barking (this appears to have been a 100-line unit with numbers in the 59xx range, parented on Aldgate). However, Upminster depot was commissioned in December 1958, before the new telephone equipment could be brought into use, requiring temporary arrangements to be made. A small automatic exchange was installed at the end of a normal 'XRL' line (5022), and this had 16 lines in the range 2-9 and 01-19. On dialling the 'XRL' number a second dial tone was received inviting the last one or two digits to be dialled. This second dialling tone comprised a repeating chiming noise generated by a Morphy Richards electric doorbell, but it was perfectly satisfactory. Calls could be made locally and to dial an 'XRL' number the code 00 was used.

The Barking exchange came into use during April 1961, with stations east of Barking (and the depot at Upminster) receiving new 'XRL' numbers and the mini exchange was removed. Effra Road ticket works was given a similar mini auto exchange from 14th January 1963 on auto 4272/3 (later 9931), with 11 lines (the existing lines from Camberwell [XCL] exchange were removed). These mini auto exchanges were also installed at White City Training Centre upon its opening from 23rd September 1963 (originally 8 lines), Cromwell Curve substation control room from 17th June 1963 and Baker Street substation control room from 23rd December 1963; thereafter several others emerged until 1974. These latter exchanges had their dependent substations on the extensions, releasing a number of little-used auto lines. These exchanges had a comparatively short life, following which normal Auto lines replaced each PABX extension.

It is recorded that during the 1960s the capacity of the Leicester Square – Earls Court junctions was becoming strained and lt was talked into purchasing some carrier equipment originating from Australia which was intended to allow six circuits to operate over a single cable pair. The Eastern Electricity Board had even more pressing capacity problems on their private network and bought the same equipment which worked perfectly; lt never got theirs to operate satisfactorily but fortunately new digital technology was soon to become available.

During this period a large number of additional lines were installed on the network to avoid sharing and to improve efficiency, and many of the old exchanges were expanded. The electrification to Amersham and Chesham in 1960-62 also provided Auto telephones north of Rickmansworth for the first time. It looks as though the last purely lt omnibus or code circuit (No 18, between Harrow and Rickmansworth) was removed with effect from 11th March 196244, although British Rail circuits on the Marylebone – Harrow – Amersham and stations to the north thereof, remained a little longer. All this must have come as a blessed relief to all that had to communicate with these northerly outposts. It is recalled that Marylebone (BR) thoroughly disliked putting calls through to the lt

* The control room closed in November 1967 but the telephone exchange and connections remained substantially unaltered.
† Exchange came into use when new control room opened (replaced Wood Green)

Number	Function	Location
19	Breakdown Message Recorder	55 Broadway
402(2)	Central Control	Baker Street
462(2)	Northern Control	Cobourg Street
642(2)	Victoria Control	Cobourg Street
732(2)	Metropolitan and Jubilee Control	Baker Street
752(2)	Bakerloo Control	Baker Street
832(2)	District and Piccadilly Control	Earls Court
908	Information Assistant	55 Broadway

stations and that it was sometimes easier to get hold of anyone who had an automatic line and ask them to relay messages.*

During 1964/5 extensions on the East Finchley exchange were renumbered from 62xx to 41xx, although one or two new lines in the new series crept in earlier. Perhaps connected with this was the anticipated increase in traffic to the Finsbury Park exchange which required enlarging to deal with the demand for new extensions for the north end of the Victoria Line, subsequently numbered in the 63xx and 64xx series. It is likely the cabling had run alongside the BR line between Finsbury Park and East Finchley, anticipating the arrival of the Northern Line; if so, withdrawal of freight services would further have exposed this virtually unused line to theft and vandalism and rerouting the cables would have been inevitable, it no longer making sense to base the extensions on Finsbury Park when Leicester Square was now more convenient.

London Transport came to believe that centralization of the railway control function was not entirely satisfactory and that it was better undertaken with a closer relationship with the line administrative organization, which was already dispersed. However a headquarters control function was felt desirable at 55 Broadway. From 27th May 1962 the Headquarters Controller and the Information Assistant were shifted from Leicester Square to 55 Broadway, taking the Breakdown Message Recorder (on '19') with them. From the same date the Metropolitan and Bakerloo control function was moved to a new control office at Baker Street. This made it awkward to retain the 'C' or 'CE' function and the new control office was given the number 73C (or 73CE for emergency calls), the leading digits directing calls to the Baker Street exchange. After protracted delay the other controllers eventually moved to their new homes, and were similarly allocated new control office numbers. The Victoria Line on '64C' came into use from 5th August 1968, followed by transfer of the Northern Line from Leicester Square to Cobourg Street on '46C' from 16th November 1969. The District and Piccadilly controllers moved back to Earls Court on 26th April 1970 and shared '83C', but the Central Line Controller moved to Oxford Circus only from 20th May 1979, following which the old control office at Leicester Square was disused. In the meantime lt was desperate to liberate 1000 or so extra lines in the 2xxx series which could be deployed as soon as the Central Line controller gave up use of the letter 'C' (equivalent to a '2') which was still in use. Accordingly he received the new number '40C' from 21st January 1973. This number was not long in use because from the April 1973 directory all telephone numbers were henceforth quoted in all-number format, so the 'Cs' all became '2s'. A factor in this was no doubt the adoption of all-figure numbers by the Post Office and the probable complications surrounding the continued supply of telephone instruments with lettered dials. When the Headquarters

* The late Peter Provest recalls: "Some aspects of head office work needed contact with ticket office staff to establish passenger history details off their Season Ticket Record Cards. For some reason unknown Marylebone exchange seemed to thoroughly dislike receiving calls from LT office staff, and would often make it 'as awkward as possible' over connecting a call to one of these outlying ticket offices. After `failures' through Marylebone the contrast was to telephone Chesham signal box on the RL and apologetically ask if they could possibly contact the ticket office for you. By contrast you were made to feel that a `telephone call from 55 Broadway' was an important event in their uneventful lives. "Of course, I will go right over there for you just as soon as l have despatched this train" would come the willing and helpful response. The ticket office staff, once contacted, were equally helpful. Having finally got hold of the Chesham clerk, one could "push one's luck" and ask "Whilst l have got you would you mind getting in touch with Wendover and asking about Mr xxxxx for me ?, I am having such trouble putting a call through Marylebone" They always would. Happy days!"

Controller moved to 55 Broadway he was allocated a normal Auto line,* mundane queries being routed to or via the assistant on 'INF', later 463; from 9th May 1979 the information assistant was allocated the perhaps more memorable number '908'.[45] The final part of the jigsaw fell into place in May 1979 when the Jubilee Line opened. The existing Metropolitan and Bakerloo control office (on '732') became the Metropolitan & Jubilee control office and a new one —also at Baker Street—was opened to serve the Bakerloo Line; this was allocated the number '752'.

From 30th October 1967 interconnection was provided with a new British Railways automatic exchange at Euston (LMR). This was allocated the number 4891. It was then necessary to dial the code '63' (which was the br code for Euston) followed by the LMR 4-digit number. It was also possible to dial in the opposite direction. Paddington (Western Region) automatic exchange had followed by 1973 using the auto number 4893 and the wr code 76 and the 4-digit extension. The system was changed from 10th June 1974 when the rest of the London area BR exchanges were automated. Thenceforth the following 4-digit codes were used, the last two numbers corresponding to the br trunk dialling system exchanges to which the calls were routed (these codes were followed by the 4-digit br extension numbers):

2015	BRB HQ
2021	Kings Cross ER
2021	Liverpool Street ER
2063	Euston LMR
2076	Paddington WR
4646	Southern Region (manual board, ask operator for extension).

These codes (except 4646) echoed changes on the British Rail network that was being modernized at the time.† Under this system local calls required a 4-digit number to be dialled but 'Extension Trunk Dialling' (ETD) was available whereby a 3-digit code beginning with a zero would switch calls to other exchanges around the country without operator intervention. The lt code '20' connected directly into a br trunk switching centre with the remaining two digits corresponding to the br ETD code, so in effect any br number in the country was accessible from any Auto telephone. From 15th December 1976 ETD was extended to the Southern Region and, amongst others, codes for Waterloo (2011), Wimbledon (2086) and Croydon (2095) were introduced. This completed the interlinking of the two networks. It was also possible for any br extension to dial into the lt auto network using the ETD code '016'.‡

In the 1970s, with the extension to Heathrow in the offing, it was decided that communications could most efficiently be met by provision of a new exchange at Hounslow West. This was the first exchange connected (to Leicester Square) using 'electronic' pulse code modulation technology and was opened in July 1975; at the time it was described as the first of its type to be operating on any British exchange.[46] It was not large, but covered local stations as well as the new ones at Heathrow and could handle 30 calls simultaneously. With level '2' now available, numbers on the Hounslow West exchange were allocated codes beginning with '22'. Various existing extension lines nearby were renumbered in this series freeing up some numbers on the congested Acton exchange, which were reallocated.

During the early 1970s the speech quality from telephones on the Barking exchange was considered unacceptable, a problem probably caused by the very long distances involved. To remedy this, changes were made to the transmission system to Barking exchange resulting in the need for all

* On auto 9597.

† It would appear that dialling the zero trapped the call at Leicester Square which recognised it as an ETD code.

‡ The ETD code '08' was later introduced for access to LT's 27xxx numbers as all ETD numbers had to be in the form 0xx yyyy.

telephones to be renumbered from 59xx to 29xx.* The change was introduced from 1st February 1976. For similar reasons telephones on the Loughton exchange were renumbered from 52xx to 21xx from 15th January 1978.

One of the final innovations on the electromechanical system was introduced from 10th January 1971 when it became possible to dial '999' on the Auto telephone in order to contact the British Transport Police (LT area information room). Although the number was familiar to those wishing to make calls in an emergency it was also intended for routine calls and replaced three normal numbers.† In due course, 999 was reserved for emergency calls (and from around 1981 it was possible to dial a fourth '9' if an emergency call was not answered quickly enough); 9438 and 9849 were allocated for routine calls.‡

At the end of the Strowger period the special numbers in use are summarised in the following table. Be it noted that the supplementary number in brackets indicated to the controller that the call was of an emergency nature and that it had changed to a '2' from a '3' (or 'E') in 1973 when all figure numbers came into use; in practice it didn't matter what the extra digit was.

The leasing of space from 1974 in the previously empty Telstar House in Paddington required the provision of new telephone facilities and the arrangements made were innovative, if short-lived. It had been LT's intention that there be only one telephone on each occupant's desk, accessible by both LT and PO networks, and this was indeed what was achieved at first. A Post Office switchboard was provided to handle incoming PO calls within the building.§ Initially incoming calls from the Auto network arrived on Auto 7381 and the operator on the po switchboard put calls through to the extension required. A small PABX exchange entered service on 21st April 1975, which allowed calls internally within the building to be switched automatically; telephone numbers were of 4-digits in a 2xxx series and the PO switchboard operator could also put calls through to all lines. The PABX was linked to the Auto network by dialling a '7' to make outbound calls;** inbound calls required callers from an Auto phone to dial '27' and after receiving a second dial tone they could ring the extension required. Published numbers thus took the form 27-2xxx. Inbound callers could, by means of dialling '27-0' gain access to the operator if they did not know the extension required.

Despite this promising start a lengthy debate then ensued upon the principle of an interconnected network and the Post Office became intransigent. They held the line that nothing was to be interconnected unless they maintained the totality of the network (ie the entire Underground), and this was quite unacceptable to LT. The outcome was that LT opened its own PABX from 12th September 1977, this time more comprehensively integrated with the rest of the Auto network. New telephone extensions were provided, all arranged in the 27xxx range and all digits had to be dialled whether from Telstar House or not. These were the only 5-digit numbers ever to be used during the days of Strowger equipment. The existing extensions on the 4-digit PABX remained connected to the PO network, but links to the Auto system were severed. Eventually LT occupied the entire building and then had several hundred Auto extensions, many sharing a desk with the original PO extensions.

In passing it might be noted that the Chief Signal Engineer's report centre had a facility to connect urgent calls originating from the Post Office network into the LT system or vice versa. Incoming calls needed to come in on KENsington 9034, and outgoing calls on 'XRL' 4573 or 8279. It is not known when this facility was introduced, but it was possible in 1963. This was an entirely legitimate connection which (after much wrangling with the GPO) was authorized on the basis that any connection was made through a robust barrier unit, in practice a heavily insulated transformer. It is also recorded that at Chiswick Works the operators could

* This probably involved parenting on another exchange and using PCM transmission technology.
† The initial '9' directed the call to the Broadway exchange.
‡ This change appears to have been made in 1982.
§ The PO switchboard was 01-402 4022.

** It is likely that outbound calls to the PO network, for authorized users, could dial a '9'.

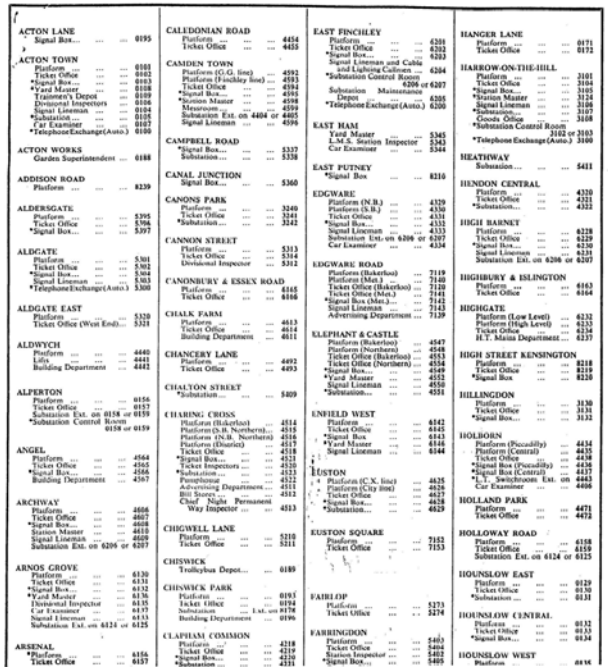
do the same thing on an entirely unofficial basis for senior staff; by implication it has to be suspected that it happened elsewhere too, probably without barrier units.

Various Sheet Railway Telephone Directories

Below *is illustration of part of a telephone directory sheet posted in platform telephone kiosks, this one dating from 1932, just after Piccadilly Line extensions were moved onto the Earls Court exchange. These were about 19 inches wide by 21½ inches deep.*

Right top *is part of the first Automatic telephone directory proof (October 1939) including entries for every station to be provided by the New Works Programme, including those where not a sod of earth had yet been turned. Where stations were never completed the numbers became spare and were later reused, for example Bushey Heath platform (4343) is later found in Timekeeper's office at Golders Green Depot. Except as noted above, these were excised for issue version.*

Right lower *is the first directory sheet i for the new Automatic system, dated 1939 and anticipating the final equipment changeover in 1940. This includes numbers for stations whose opening was then thought imminent (Northern Line to High Barnet, but not Finchley-Edgware, and Central Line except north of Chigwell Lane).*



Chapter 4 - The LT Road Service network

Tramway telephones prior to London Transport

London's tramways were developed on an area basis either by local commercial operators or by local authorities, or sometimes by the former on behalf of the latter. By the First World War the commercial operators had all found themselves under the practical control of the Underground Group. Of the local authorities that still operated trams by far the largest was London County Council (LCC) that ran a dense network throughout the Council's area. A multiplicity of very much smaller systems was operated by a number of outlying County Boroughs, Boroughs or Urban District Councils although inter-running between networks was extensive. The bigger private operators were the London United Tramways in West and South-West London, the Metropolitan Electric Tramways in North London, and (behind by some way) the South Metropolitan Electric Tramways in the south.

Trams were a bit like railways. Because they operated on a fixed infrastructure, breakdowns could halt services and delays could spread rapidly across a wide area. To keep the services running efficiently there were many roadside staff to be kept advised of the state of the service or who might need to report unusual traffic conditions. Furthermore the vagaries of electric tramway operation occasionally required various electrical sections to be isolated and the substations and powerhouse had to be kept abreast of what was going on. All this called for good communications. Fortunately tramways were statutory authorities and could build extensive underground infrastructure through which to lay power and communication cables.

For isolating the traction supply switch boxes (or feeder pillars) were erected at least every half-mile and in many cases it proved valuable to install telephones at these points so they could share the same cableways into the under-street ducts. Not all tramway companies necessarily provided fixed instruments in feeder pillars, sometimes just plugs into which portable (or tram mounted) instruments could be plugged. Telephones were important so that anyone needing to operate the switches (for example for testing) could liaise with other officials, and a by-product was that tram drivers and others could use the telephones in an emergency. In many cases these feeder pillars were of a more or less standard design supplied by equipment manufacturers to the particular fancy of the operator. While it was perfectly possible to mount a telephone within the switchbox itself, it was considered poor practice as the interiors tended to 'sweat' and get damp, and in time would damage the delicate instrument.[47] In consequence any telephone was often fitted into a separate box mounted on top, or at least into a separate compartment, and in either case the handset was accessible through a hinged flap.* A number of these 'feeder' telephones were used on a routine basis by roadside officials regulating the services; so the officials could hear the bells (where they were fitted) many of the telephone housings were louvred so that the internal bellset (described as very loud) was even more audible.

The LCC system was the largest and had an extensive telephone network, probably from its electrification around 1905. The early headquarters was at 303 Camberwell New Road and although the head office function itself removed to the Council's main offices in Westminster soon after the tramways were electrified the Camberwell offices themselves remained as the divisional headquarters of the tramway's southern division. The northern division had offices at Shoreditch. Early information about the telephone network on the LCC is sparse, though in 1923 it was intimated that there was an established system, based upon telephone instruments mounted at some feeder pillars or occasional intermediate points, and this involved considerable wiring back to (at least) one tele-

* The West Ham system was not like this and had telephone boxes on top of short poles.

phone exchange. By inference from subsequent events there were probably two exchanges, one each for the two divisions.

Of the smaller local authorities even less is known—with one happy exception. In 1919 West Ham Corporation adopted a system devised by the Western Electric company for railway use.* West Ham tramways already had a simple telephone system but the new one brought several advantages of which two in particular deserve to be noted. First was the use of an 'omnibus' circuit which served eight 'way stations', as they were called, but with apparatus which allowed any one of these to be called separately; this overcame the usual objection to the use of such circuits where all the telephones would ring together. The second feature was that the circuit was terminated at the head office on equipment manned by a supervisor (called a controller) rather than the telephone operator; in this respect the trams began following the practice adopted on the UERL railways. In consequence decisions about the service could be dealt with immediately and as way stations could not call each other the controller was invariably in the communication chain whenever something had to be done. The way stations comprised telephones with loud bells situated at strategic locations around the borough where tram regulators or timekeepers were likely to be stationed. The instruments were either mounted in iron cases and were fitted with a fixed microphone, separate 'bell' receiver, magneto generator, and internal battery, or comprised separate instruments providing the same functionality but placed in existing huts or buildings. The West Ham control office was on the upper floor of the corporation tramways head office in Greengate Street, ultimately the site of LT's West Ham bus garage.

For incoming calls to the controller the system was rudimentary. If the controller were already on the line, the caller just spoke and interrupted the conversation; otherwise the controller's attention was called by a normal magneto bell. In the other direction the controller could call up any one of the way stations. For each station there was a separate ringing key mounted in a case on the controller's desk. Operation of a key by a quarter turn produced a succession of electrical impulses unique to that key as it returned by clockwork to its normal position. The impulses operated a line relay that converted them to a higher voltage for transmission down the control line.

Each way station was provided with selector apparatus that detected the start of a train of impulses and sought to identify the code relating to that particular selector. The principle was not unlike contemporary automatic telephony in that it comprised a quick-acting magnet and pawl arrangement that stepped round a contact wheel one step for each pulse received. If the selector wheel stopped on the contact relating to that particular way station then the bell would ring; if not, then it wouldn't. There was also a slow-acting magnet which operated at the start of a train of pulses and only released several seconds after the entire train had stopped. When this magnet reset it restored the selector wheel to its normal position. The circuit was arranged so that if the selector wheel was rotated all the way around then the bell would also ring, and it was contrived that the controller could thus send out an 'all-stations' code which would cause all the bells to ring.[48]

The LCC was evidently very impressed by this system which appeared to offer considerable benefits to its own very much larger network. The system was accordingly adopted and came into service on 26th July 1923[49] on its northern division[50] and was very much based on the West Ham experience but in an improved form to operate on the larger network. Functionally, the northern network was divided into a number of sections (or circuits), on each of which was installed a number of instruments wired in parallel across a single pair of conductors. On picking up the handset, which was mounted in a locked box, the caller was put in contact with a controller. The northern division was thus subdivided into nine areas, and each of these had its own control circuits that led to the control office that had been established at Hackney depot; although this required considerable cabling the original telephone cables were re-used. Unlike

* West Ham was the first tramway to use this system, followed shortly afterwards by Southampton.

West Ham, callers did not seem to be provided with magneto ringers and had to shout 'control' and the controller, hearing this through a loudspeaker in the control office, would then plug in his headset on the appropriate circuit.

In the other direction the controller could call up any of the more important telephones of his choosing (usually a telephone at a manned location such as a substation, car shed or regulating point). As at West Ham each of these telephones was provided with a separate ringing key this time mounted in one of four cases on the controller's desk. Operation of a key by a quarter turn produced a succession of electrical impulses unique to that key as it returned by clockwork to its normal position. This time alternating current was used for line transmission of the pulses. In view of the complexity of the system it was now necessary to use three toothed wheels in order to discriminate between the large number of possible codes, each wheel responding to just one of the three trains of impulses sent. A completed circuit (if finding the predetermined path through the three wheels) so caused the desired telephone bell to be rung, and all the other instruments would remain quiet. By this means only two wires were needed for a complete circuit, but each of the major telephones could be summoned individually. There were in addition other telephones on the circuit for use in emergencies that did not have bells and could only be used for making urgent calls to control.

The nine circuits in use served the following sub-areas:

Clapton	Hackney	Limehouse
Mildmay Park	Shoreditch	Holloway
Camden Town	Holborn	Islington

There were on commissioning 36 telephones at traffic regulating points and 17 in car sheds (which in both cases could all be called by the controller), and 111 other instruments, which had no bells.

It was stated at the time[51] that were the system to prove successful then it would be replicated in the southern division, which was considered even more difficult to operate. Although this took a while to implement, the southern division was eventually equipped with a similar system from February 1928, this time from a control office based at the Oval.[52] A description of the LCC network in 1933[53] refers to a system boasting some 400 roadside telephones (on 167 miles of route) and stated they were 'in direct communication with a central exchange, called Control, and is in the charge of a traffic official with roadside experience'. The wording could be construed as suggesting there was only a single 'Control' by 1933, but it is known otherwise (in 1940 there was still a 'Control' exchange at Hackney[54]). A photograph of the 1933 'Control' suggests an exchange switchboard of about 80-line capacity, but seems to be of a pattern quite unlike the apparatus originally put in at Hackney. The geographical location of this control office is not stated; it is likely to be the southern control at Oval, and it is possible that the equipment provided was of a more advanced design than that at Hackney, perhaps even of CB pattern. Incidentally the Oval controller seems not at first to have had his own GPO line and had to make do with an extension from the Camberwell offices;* this changed when the divisional offices moved to Vauxhall (Wandsworth Road) in 1936 whence the controller acquired the number as his own.[55]

As a working hypothesis it is assumed that each of the other larger tramway concerns had a central switchboard connected to the roadside boxes, power station, substations, senior officials and other tramway exchanges, though they may not have innovated as much as the LCC and West Ham had done. The Metropolitan Electric Tramways would seem to have had a control function with its own telephones, and this system was moved from the control office at Manor House to the former LCC office at Hackney in January 1940 (though by then it just served trolleybuses). The small local authority networks may have shared switchboards with other local authority services. Leyton Corporation had a tramway system operated by the LCC and was part of that body's telephone system. Of the other tramway bodies not much has been discovered, though Croydon

* on RODney 3401

Corporation tramways are known to have had two or three regulators' huts with telephones direct to the depot.[56]

Bexley and Erith Councils are thought to have had small telephone systems each provided by their local councils. On 14th August 1933 it was decided by the new LPTB that telephones in those areas should be reconnected to the Board's Southern Tramway Network telephone system at a cost of £32,058.[57]

Tramways in London Transport days

After 1933 LT had the challenge of welding together a large number of tramway organizations into a single entity. Because of the sheer size of the LCC network its finely tuned practices and principles were generally adopted as the model for the new organization. Initially the existing tramway head offices continued to function as previously, but from March 1935 all 'head office' type functions began to be consolidated at 55 Broadway, beginning with the ex-LCC staff. Responsibility for day-to-day management was parked with divisional offices, whose duties were in effect enlargements of the administrative arrangements of the former LCC, still with their offices at Camberwell and Shoreditch. Temporary arrangements were soon put in hand for improving this day-to-day control, and several different groupings of the old organizations seem to have been tried; by February 1934 matters seem to have been managed from offices at Hackney, Manor House and Camberwell. By April 1934 both the northern and western divisions were being controlled from Manor House, and in April 1935 when a new permanent organization was in place the number of divisions had reverted to two. The northern division was controlled from Manor House and the southern division from Camberwell.* In July 1936 the southern divisional chief moved to offices in Wandsworth Road, Vauxhall, but some administrative functions continued at Camberwell, including, it seems, the telephone exchange. The administrative offices at Shoreditch seem to have been retained but quickly dwindled in importance.[58] All this is significant in that it affected likely communications requirements. It is worth recording that the Manor House offices had previously been the headquarters of both the MET and London United networks; the South Metropolitan Electric Tramways & Lighting Company seems to have functioned from Sutton Depot (Westmead Road), but these offices did not feature in the new LT organization.†

It is recorded that in March 1934 LT decided to construct a new telephone network with which to manage the whole of the tramways. There were to be direct lines to control points from key locations on the system and a number of new telephone exchanges. The work was apparently completed in about two years.[59] The exact scope of work is not known to the author but clearly there was a need for an efficient single system to replace the various separate networks that had been inherited, and which in some cases were probably offshoots of telephone systems serving no longer relevant non-tramway functions. Certainly the intimate association between the Metropolitan Electric Tramways and the North Metropolitan Electric Power Supply Company caused them to share (at least in part) a private telephone system; this was never entirely untangled until the demise of trolleybuses in the 1960s when the LT elements became redundant. (In 1940 there was still a large private exchange at Wood Green which had lines to Hackney control office, and this was a NorthMet facility; it had at least 134 lines). Appendix Two covers the NorthMet facilities in more detail.

From the mid-1930s trolleybuses began to replace trams on a large scale, but in most cases these services followed the tram routes they replaced and used much of the existing power supply infrastructure. There was a later design of feeder pillar which was much narrower than the old

* The northern division comprised the former LCC (north), West Ham, East Ham, Leyton, Walthamstow, Ilford, Barking and M.E.T. networks while the southern division comprised the former LCC (south), London United, South Metropolitan, Croydon, Bexley, Dartford and Erith systems.

† Manor House offices were on the GPO network on Tottenham 0077, and Sutton Depot on Sutton 454, both presumably PBXs. In 1914 the Manor House offices were Tottenham 77, with LUT additionally having offices at Chiswick tram depot on Chiswick 1500, and SouthMET in offices at 114 Church Street, Croydon on Croydon 1304.

tramway pillars and was installed from 1936 on trolleybus routes in areas supplied by fully automatic substations; these had push button switches to isolate overhead sections and had a telephone housing integral with the design.

With the arrival of trolleybuses the existing organization was retained (except now known as Trams *and Trolleybus* department). Certainly the existing (and just revitalized) private communications systems would have been adequate with little change. Furthermore it is clear that for most administrative purposes the GPO network was the main means of communication, though it may well have been augmented by inter-exchange private wires. Indeed a reference has been found to just such an arrangement in 1940 where Hackney control office could be reached on the 'private' network on extension 51 of the Shoreditch exchange (as well as three 'XHO' numbers, and a line from Wood Green).

It is clear that in the early 1940s there was a major expansion of the private line networks, based on the existing tramway communications arrangements, which were linked together as best as could be achieved without wholesale replacement. At some point between 1941 and 1942 the Tram and Trolleybus controllers were consolidated in a single office at Oval[60] (the bus controller was also there), but what impact this had on the method of operation has not been determined, except that CB operation is likely to have predominated if not already universal.

Some details of the Oval Tram exchange (XOT) and three other tramway related exchanges (Camberwell [XCL], Shoreditch [XSH] and Greenwich Power House [XGH]) have already been given when describing the new Head Office tandem exchange introduced in 1937. Suffice to say here that they were accessible from the Head Office and Railway automatic networks by dialling access codes that would put callers through to the exchange operators and between the tramway exchanges themselves there were a number of direct lines.

Of the other (all manual) exchanges connected to the tramway network there was a significant exchange at Chiswick (tram) depot, which had once been the LUT headquarters. Although Chiswick was not connected to the Head Office tandem it had long been considered worthy of connection to the railway system and was allocated an "XRL" telephone number when that system was commissioned in 1939/40; this superseded an earlier line to Earls Court railway manual exchange.* In the context this line seems to have been an incoming line on the Chiswick exchange switchboard, from which any extension could have been reached.

There were also manual switchboards of 100 lines at Charlton Works (the ex-LCC tramway works) and a 50-line switchboard at Fulwell depot—a large ex-tram depot latterly used for trolleybuses and which undertook some overhaul work. The extent of their integration with the rest of the LT network is obscure. In 1950 there is no obvious evidence of interconnection and they may simply have been GPO switchboards, probably with at least one private wire extension from a convenient LT exchange available for internal calls—indeed this sort of arrangement may have been quite common. However it is curious that in the 1953 directories no GPO number is offered for Fulwell.

Bus telephone systems until 1950

Having neither infrastructure nor statutory powers, the option of having a dedicated internal communications system available for the operation of buses was for many years unrealistic. That is not to say that the telephone was not considered vitally important and Philip Burtt[61] remarked of the London General Omnibus Company in 1926 that:

> 'there are about 3500 [buses] in daily working, and to get the right and economical distribution of these vehicles over the different lines along

* Chiswick tram depot was originally allocated the number 112 on the Earls Court manual exchange but by co-incidence or otherwise acquired the number 'XRL' 0112 when converted to automatic, being almost alone in receiving a corresponding number on conversion. The auto number was to have been 0189 when new numbers were allocated, but by 1948 this is found allocated to Goldhawk Road trolleybus substation, presumably meeting some curious demand for a separate auto phone. The Chiswick switchboard was also, apparently, allocated the number XCH 300 on the Chiswick Works exchange.

> which they work is a matter of complexity, requiring constant attention, with an ingenious and resourceful mind in charge.'

And:

> 'Telephonic reports are systematically being received at a central office of how the buses are being loaded, as well as constant information from each terminal-point as to the extent to which vehicles are arriving late or whether they are to time.'

So, even during the 1920s it is clear that the telephone, coupled with a central control office, played a vital part in the operation of the buses. Incidentally, at that time the bus control office was at Leicester Square where its activities were co-ordinated with that of the tubes, a form of operational transport integration soon abandoned by London Transport.

Having no system of its own the bus operation necessarily relied on the GPO telephone network for its communication requirements. However in the 1920s and 30s bus officials were authorized to use the platform telephones of the railway network if they needed to, providing that railway business took priority. To whom they might have wanted to speak is not clear, but the bus controller would undoubtedly have had an extension on the Leicester Square exchange.

Prior to the Second World War the LT bus network was controlled through three divisional offices situated at Camberwell (Warner Road)*, Dollis Hill (Edgware Road), and Dalston (Kingsland Road). During this period the evidence suggests that the offices and the 52 dependent garages had only GPO telephones for communication; the bus controllers had GPO telephones and almost certainly railway telephones. The controllers whilst at Leicester Square had at least one extension line from the Broadway Head Office exchange and it is not known whether they then had any local direct exchange lines. From December 1939, when they moved to offices at Oval, they had several exchange lines on the RELiance exchange,† but appear to have lost their ABBey 1234 extension.‡ The facilities initially provided for the bus controllers at Oval are unknown. As there was no private network all business would have been conducted on that of the GPO except, perhaps, for some direct lines to headquarters or the railway traffic controllers, but this is conjecture. It is possible the bus controllers would have been equipped with a dedicated GPO PBX but the possibility of sharing with the tramways cannot be ruled out (though at that time the south London tram system was still largely intact and there is little reason to suppose any spare facilities would have been available).

It was during the Second World War that the bus system began to make use of a private wire network. It is extremely confusing to find these private telephones described in LT publications as being on an 'automatic' network as the instructions for use clearly describe an arrangement where lifting the receiver alerted the telephone operator, who then completed the call on being advised which number was needed (in fact normal central battery, or CB, working). Significantly there is evidence of interconnection with the tramway telephone networks and certainly from 1942 bus officials were advised they could, if necessary, use tramway telephone boxes by asking the tramway exchange operator to put a call through to the bus exchange operator, who would then complete the call (they were, after all, in the same building as a large tramway exchange).

Unravelling the exact sequence of events is fraught with difficulties. Evidence seen so far suggests that it was in May 1943 when Central Buses first began to use private telephones. An announcement[62] appeared that '23 garages have now been connected to the LT private network' (by which was meant the tramway telephone network). Of these garages, five were put on the Shoreditch exchange, five on the Camberwell exchange, five on the Chiswick (tram depot) exchange, three on the Oval (tram control) exchange, and three were on the Manor House exchange. The remaining

* These were opposite the tramways offices at 303 Camberwell New Road but in an entirely separate building associated with the bus garage.

† RELiance 4255-58

‡ This seems to have been ext: 37, retained by the railway controllers.

two numbers were not garages at all but were lines to the bus controller, one put on the Oval (tram) exchange and the other serviced by Camberwell. All these exchanges were manual boards and the numbers allocated do not form much of a pattern, presumably reflecting spare numbers thrown up by tram conversion schemes.

It is perhaps noteworthy that some numbers were on the tram control exchange. It was about the time the tram controllers had new equipment and there may well have been spare capacity on the switchboard for a modest number of bus extensions, perhaps only on a temporary basis.

In August 1943 (curiously soon after the introduction of the private lines in May) it seems that Central Buses acquired a new switchboard at Oval. Whether this was a replacement for, or in addition to, any earlier switchboard it has not been possible to ascertain, but it seems to have been provided to deal at least initially with administrative calls rather than 'control' calls, so was probably manned by telephone operators rather than the controllers. Being located at Oval it was convenient for both the railway system's tunnels and the under-street tram ducts for the laying of private wires. It is likely that this exchange had private lines to at least the Head Office exchange and to Oval Trams (XOT) but whether it was otherwise connected to the Head Office tandem at this time is open to question – there would have been precious little need with the small number of lines in question though at some as yet undiscovered date (perhaps 1946) such a connection was installed and Oval Buses was allocated the code 'XOB' (for Oval Buses).

Each of the 21 garages that had been put onto the private network only in May, was now given a number on this new exchange[63] The telephone numbers were distributed in three ranges. Those numbered in the range 600-699 were apparently in the Camberwell (or 'A') division, 700-799 in the Dalston (or 'B') division and 800-899 in the Dollis Hill (or 'C') division. Two additional garages (in 'C' division) are also added to the scheme, making 23 garages in all. The numbers allocated are not in a continuous range and are widely distributed, which might imply that many more numbers were allocated than were initially put into use. It is just possible that the leading digit is a mere cipher as the final two digits do not repeat but instead drop into neat ranges (of the numbers used the ranges were 602-614, 733-746 and 867-884). Whether or not it was necessary, as soon as the new 'bus' numbers were issued the numbers allocated on the various tramway exchanges were regarded as redundant and the original instruction for bringing in those exchange lines was cancelled. While this may have made sense the lines themselves seem to have remained *in situ* as they are found in use again later, largely unchanged.

From no later than March 1944 the bus controller's switchboard was using the number 'XHO' 409. This was advertised to railway staff as a means of getting in touch with six of the 21 bus garages on the bus private wire network that were part of the wartime LT ambulance system. Staff dialled the number then asked for the extension required. It is perhaps some slight evidence that the code 'XOB' was not yet in use for the bus controller's exchange, and that the Head Office number was probably used from the start.

There does not seem to have been any great hurry to put all the remaining garages onto the bus private wire system, which must have restricted it to being of very limited real value; even by April 1946, of the 52 central (red) bus garages there were still only the 25 on the bus private network, and all were still connected to the GPO system.

The next phase of development saw bus control telephones beginning to be installed on the private network, some new and some converted from GPO lines. In March 1945 instructions were issued[64] advising that 27 'terminals and intermediate points' (referred to hereafter as control points) were now on the private telephone network and could be contacted via the bus controller's office. Significantly, every one of these was outside an Underground station and one can be pretty certain that the exchange lines were taken through Underground tunnels. One cannot be at all certain that these were the very first private roadside telephones on the network but they certainly appear to have been. Irritatingly there is a reference in

November 1945 to a changed number at Wembley Central station, which is not on the original list and is not an Underground-owned station. From this one infers that new roadside telephones were by then being installed at other locations, and the means of publishing their numbers had changed. Incidentally, the locations at Arnos Grove, Finsbury Park (Wells Terrace), Golders Green station, Uxbridge station and Victoria Forecourt each retained a GPO line as well; it may well be that all these locations had been control points previously when only GPO communication facilities were available (Victoria had been a major control point for many years).

In November 1945 there were 36 control points listed as connected to the private network, but of these a mere five (including the one at Wembley and another at Kings Cross coach station) were not at an Underground station; they do appear to have been near ex-tramway power supply ducts which is presumably how the lines were routed. There were, however, a further ten control points which had only GPO direct exchange line numbers. There seems not to have been any great rush to expand from this core. By April 1946[65] only another lone point, at Forest Gate,* had been added to the private network, although Aldgate had received a private telephone as well as its GPO line. All the roadside telephones on the private network were allocated numbers geographically, like the garages, in the three divisional series.

However by now there is evidence of activity taking place in a new direction. First, each of the divisional offices had begun to acquire two or three private lines on the Oval Bus exchange, by now advertised as 'XOB'. Secondly the number of extensions had, overall, increased to the point that there was duplication within the final two digits, suggesting that if the original exchange board had been a small, temporary one it was no longer so—the bus controller's exchange is known later to have been of 300 lines.

By January 1947 the number of garages on the private network had increased to 37 of the total of 52. There were now 58 control points on the private network with a further 12 on the GPO system only, and with 10 of the 58 still on both. Most of the additional numbers were well away from Underground stations. The telephone numbers continued to be allocated in the 'divisional' series.

By October 1948 the Central Buses communications system was reaching its zenith. Of the 52 garages only Muswell Hill was not yet on the network, though Croydon now sported two lines. The number of control points on the private network had by now shot up to 124 with only four others being served by the GPO, but still with eight of the 124 served by both networks. Not every control point had a dedicated exchange line and 25 such points were extension lines based on a nearby garage. October 1948 appears to have been the first time the bus controller's number (698) was published and it is open to speculation the extent to which the private network was hitherto used for control purposes.

Many of the external telephone instruments were mounted on metal lamp posts or cast-iron bus stop posts (often known as Birmingham Guild posts) as they were readily earthed; sometimes posts had to be changed over for this purpose. Instruments appear generally to have been made by the Telephone Manufacturing Company and were mounted in a metal box (probably following the pattern already in use on tram and trolleybus standards). In some cases instruments were mounted in special metal boxes fixed to other structures (such as railings). Of the exchange lines little is known except that where possible private cables were laid along LT (tram or railway power supply) ducts and where this was not possible then private wires were rented from the GPO and connected to LT infrastructure at some convenient point.

The LT Bus and Trolleybus Network after 1950

In the autumn of 1950 the Tram and Trolleybus department merged with the central (red) bus network to form Central Road Services (CRS); this comprised parallel operating and mechanical engineering departments with coterminous boundaries. This change in the organizational structure required the fusing together of the former Central Bus and Tram &

* Romford Road (Green Street)

Trolleybus telephone networks. All this was an organizational prelude to the final withdrawal of London trams during 1952 and their replacement by buses. But for the War the trams would have been replaced some years earlier by trolleybuses and it may be suspected that the communications arrangements had contemplated this, at least in part (be it noted that trolleybuses did not finally disappear until 1962).

The new CRS organization was based on a 4-division structure as follows:

Division	**Location**
North West	Dollis Hill (Edgware Road)
North East	Finsbury Park (Seven Sisters Road)
South West	Vauxhall (Wandsworth Road)
South East	Camberwell (Warner Road).

Telephone numbers on what were formerly the Oval exchanges ('XOB' and 'XOT') were completely recast into two new series: 100-399 served the South East and South West divisional areas and were described as being on the Oval South switchboard (coded 'XOS'), while 600-899 served the North East and North West divisional areas and were described as being on the Oval North switchboard (coded 'XON'). Probably the existing switchboards were adapted as 'XOB' and 'XOT' disappeared at the same time. Examination of the telephone list suggests that numbers were broadly allocated in alphabetical order of location name but within discrete blocks of 100 lines themselves geographically based. By inference the 100-199 block covers South West, 300-399 South East and 200-299 southern garages and dependent control points on extension lines. Equally 600-699 covers North East, 800-899 North West, and 700-799 northern garages and dependent control points on extension lines. This was probably done to improve the efficiency of the telephone operators, as most calls would have been local to a particular sector. These switchboards were physically separate units and in their heyday were busy. In 1956 over 40,000 calls per week were being handled around the clock by a team of fourteen operators, mainly ex tram or busmen.[66]

Possibly associated with this was the removal of the Camberwell (Trams) switchboard from the old offices at 303 Camberwell New Road to the Oval from 13th July 1950, an event necessitated by the demolition for redevelopment of the former tramways offices (the site subsequently became Walworth bus garage, opened as such in 1951 though the renaming took effect from 12 July 1950). The precise impact on the equipment or the wiring has not been determined except that Post Office consultation was necessary and some private wires were rented. Since the switchboard was essentially for administrative purposes it seems to have been kept separate from the 'XON'/'XOS' equipment and retained a separate existence as 'Camberwell' (or 'XCL') for at least another decade[67].

By the end of 1950 there were 84 'garages' as they included a number of trolleybus depots and former tram depots converted into bus garages; all but seven were on the Oval network. There were by now 309 control points representing the existing bus and tram & trolleybus roadside telephones; three (in Epsom and Staines) were still only on the GPO network. 53 of these control points were only accessible through their dependent garages as extension lines.

In many cases garages were by then connected not only to Oval but also to one of the four head office exchanges, apparently based on geographical convenience rather than by strict divisional boundary (these included the garages originally allocated such lines in May 1943, with only a very few numbers having changed). There is some evidence that existing tramway arrangements continued unchanged in some areas, and certainly a number of existing lines on the Manor House (ex Metropolitan Electric Tramways) and Chiswick (ex London United Tramways) offices continued to serve the same ex-tramway locations in addition to new lines to service bus garages. Similarly there were a few former tramway control points only connected to ex-tramway exchanges (five only to Manor House and three

only to Chiswick). Uniquely, Loughton garage had in addition to a bus network telephone a single 'XRL' automatic line.*

The four divisional offices each had a number of telephone lines. All had several lines on the Oval network but in addition most had several 'head office' lines. The NW office had lines to Chiswick and to the LT headquarters automatic exchange at 55 Broadway ('XHO'). The NE office had a number of lines to 'XMH' and an automatic line to 'XHO'. The SW office had just two automatic lines to 'XHO' and an 'XRL' automatic line on the railway network.† The SE office had just two automatic lines to 'XHO'. By 1958 various garages had acquired additional private lines, this time on the Oval exchange, which had clearly become the hub of the system.

There was even a move towards the introduction of automation. At the end of 1952, or during early 1953, Rye Lane garage was equipped on a trial basis with a mini automatic exchange instead of its manual switchboard (most garages seem to have had some sort of switchboard). The apparatus was designed by LT's signal engineering department and it was stated at the time that it was hoped similar equipment would be introduced as standard in LT's garages; this would avoid the need for calls to be routed both through local switchboards at the garages as well as the Oval switchboard. Evidently judged
reasonably successful, similar PABX installations followed at Croydon, Elmer's End and Walworth, again all connected to the Camberwell manual exchange. Although the number of lines at these mini-exchanges was not large, a common numbering system was used so that, for example, the chief depot inspector was allocated the same extension number ('4') in all cases, which simplified finding staff in the absence of an operator. In 1956 it was hinted that the system could be extended on a fully automatic basis in the future.[68] This did not happen, but see the section on the railway automatic system for more detail about what had been in mind.

This brief quest for automation might explain why, in 1958, it is found that Hounslow and Loughton garages had also been equipped with the mini-exchanges but this time they were connected to the automatic ('XRL') network, on extensions 0213 and 5230‡ respectively; callers on these lines would receive a second dial tone (consisting of repeating chimes) inviting them to enter the remaining digit or digits to reach the required recipient. The mini exchanges appear to have been of the same type used on the Railway network from 1958 (initially at Upminster) but based on the experience at Rye Lane five years earlier, though probably there without the chimes. By this time the tide was beginning to turn and the Central Road Services network had reached its zenith. Automation of the private network was not extended beyond the locations mentioned. Twickenham and Wood Green garages had also received 'XRL' lines (on 0235 and 6112 respectively) though these do not appear to have been connected to automatic exchanges at the garage end. Of course for most bus officials wishing to speak to one of these four garages they would still have needed to go through one of the manual switchboards so that the operator could dial the number; it is unlikely this was viewed as a satisfactory long-term arrangement and that further automation was almost certainly contemplated.

The final digits used at these mini automatic exchanges were as follows:[69]

District Traffic Superintendent	3	Assistant Foreman	7	Canteen	02
Chief Depot Inspector	4	Day Foreman	8	Clerk (Engineer's)	03
Traffic Office	5	Night Foreman	9		
District Engineer or Assistant	6	Stores	01		

* 'XRL' 5230
† 'XRL' 5436: it is difficult to see how this could have been very useful
‡ This was the existing number to which the exchange had been added

In addition, the codes numbered 04 – 09 were available to contact dependent roadside control points to which the garages were connected. Although not confirmed it is thought that '00' was always the code for seizing an external private line.

Later years of the road services network

By 1958 the number of roadside control points had risen to 363, or at least those were the points to which the telephone numbers were published. Staines and Epsom control points still account for three only served by the GPO. Of the remaining 360 some 28 points were now served by automatic telephones on the 'XRL' network. Many of these represented new control points but a few were in substitution of manual extension lines and in one or two cases manual direct lines. By no means were these 'XRL' telephones necessarily near Underground lines, but of those that were not most if not all were near former tramway ducts through which the cables could have been installed. There appears to have been little other change to the existing control point lines, of which a significant number still operated as extensions through garages or in a few cases with lines to head office buildings only. References to the LT telephone system in 1958 claimed that the road service network comprised around 1200 roadside telephones, which is impossible to reconcile with the published lists. It is hypothesised that the balance is explained by there still being very a large number of (traction) telephones on the trolleybus system intended purely for emergency use that did not feature in directories and, being on omnibus circuits, could not be dialled direct.

As mentioned previously there were two other road-service related manual exchanges in use at Charlton (Tram & Trolleybus works) and Fulwell (major tram depot), both being PMBXs. That at Charlton was certainly in use during the Second World War and was allocated no less than four Head Office lines;* it had probably been there since the establishment opened. By 1953 Charlton had also received a direct 'XRL' line† and this probably terminated on the switchboard as well. The position of Fulwell is less clear. For many years it could be reached via the Chiswick (tram) exchange on 'XRL' 0112, and then asking for Fulwell (this was probably always possible as Chiswick had long been connected to the railway system).

In addition, Chiswick Bus Works had a 150 line automatic exchange ('XCH') though many calls from garages would have originated from manual exchanges. The code 'XTW' has appeared as an automatic exchange by 1952 and seems to have been a second unit at Chiswick Works (perhaps for the bus training school there).

Perhaps the installation of automatic telephones at control points and elsewhere was now thought the way of the future. It must be recalled that at that time the entire bus and rail private network was handling over eight million calls a year using over 7000 telephones and forty exchanges, only half of which were automatic. It was described as comparable to a GPO system in a town the size of Luton or Portsmouth. The question that was arising was whether to update the entire network with further automation, or to consolidate the existing automatic network and dispense with the manual system by utilizing the GPO. For various reasons examined shortly, the latter option was adopted.

During 1958 there was a general provision of new GPO lines to a large number of garages and other offices, and the first three garages lost their private lines with many of the rest following during 1959. The 'XON' and 'XOS' exchanges ceased to function with effect from Sunday 11th September 1960. The bus controllers were instead given numbers on the so-called 'Camberwell' exchange, north becoming 'XCL' 183, and south 'XCL' 182 (together with 'XHO' 349). The controllers seem to have moved in February 1961 (probably to Broadway) as their GPO telephone numbers changed from RELiance 5251/6 to SULlivan 4952, and they lost their

* 'XHO' 540-3

† on 5416

'XCL' numbers at the same time. They moved again, to Mansion House, from 1st January 1964 but by now only had GPO lines.

The Shoreditch exchange (described as Shoreditch Trolleybuses, or 'XSH') closed from May 1961 and its extension lines were transferred to Manor House[70]. However the Manor House private switchboard also closed with effect from 17th January 1965 (as mentioned in the railways chapter the code 'XMH' was abolished on 7th April 1963 and the switchboard relied in the interim on GPO access and 'XRL' lines 6116 and 6190). Following switchboard closure any remaining bus communications with Manor House must have taken place solely via GPO direct extension lines but railway departments sharing offices there received nine new direct 'XRL' lines instead. The code 'XCL' must have gone out of use by mid 1963 but the fate of the 'Camberwell' exchange is not known (as it was actually based at Oval it may have gone when the controllers moved out in 1961).

Of the roadside control telephones, their demise appears to have started during 1959 and carried on until the abandonment of the trolleybuses in 1962, which would of itself have caused many telephones to have gone out of use including the last of the ex-tramway telephones. Significant numbers of replacement control telephones were installed on GPO direct exchange lines. While the GPO handsets were standard '164' pattern the rest of the unit was specially designed to meet LT's requirements. The dial was mounted inside a small locked metal compartment accessible to users holding a standard key held by roadside officials; the handset cradle was mounted inside the top of the compartment.

The number of telephones was gradually reduced as modern control techniques came into use in the 1970s and both buses and officials received radios linked directly to the controllers and garages. In June 1983 there were 380 roadside telephones on the Post Office system (as the GPO system was becoming known) and in 1990 there were still 248 in use, the operator now being BT of course.[71] The remainder went more quickly and it is to be doubted there are any roadside telephones left now, although officials at bus stations still have access to BT lines.

While the GPO system of the 1960s, with new instruments with many useful facilities, undoubtedly produced a more flexible network than the cobbled-together private network it very soon proved to be a very expensive solution. LT seemed to have become concerned about its continuing rights to use the former power supply ducts after they were no longer needed for power supplies and also felt the loss of cables would reduce circuits. The system was also very old and required switchboard operators.

The legal position was indeed curious. As already mentioned the tramways had statutory powers to provide equipment to facilitate the operation of their network, and this was regarded as including the operation of associated telephones. With the advent of trolleybuses further powers were needed. The London Passenger Transport Act 1934 therefore provided that existing tramway infrastructure could be utilized to facilitate the operation of trolleybuses and that LT could install new infrastructure to facilitate the operation of trolleybuses. This appears to have allowed both trams and trolleybuses to use a common telephone network. The Board considered that the equipment could also be used to assist in the operation of bus services providing there was no need to install additional or special apparatus for the bus element (which would not have been lawful). The problem presenting itself after the Second World War was that trams in south London were now to be replaced by buses (not trolleybuses, as originally planned) and the legislation did not provide for buses to have their own telephone service even if the trams they replaced had one. The British Transport Commission had (perhaps justifiable) reservations about LT running its own telephone service for buses but was persuaded to seek new legislation, which passed in 1951. This in essence allowed the Commission (in practice LT):

(1) to continue to use existing tram and trolleybus telephone equipment for all its road services;

(2) with the permission of the highway authority (not unreasonably to be withheld) to use existing tram and trolleybus telephone equipment for other of the Commission's purposes; and
(3) using street works powers adapt, alter and extend any retained tram and trolleybus telephone apparatus to facilitate operation of buses along routes or in the general areas previously served by trams or trolleybuses, but only in Westminster and the City of London, and certain other specific Metropolitan Boroughs (and four outer London areas) which happened to coincide with areas where trams were still in fact operating in 1951.

These powers were quite restrictive and on the face of it seemed to make it difficult to achieve the flexibility needed in the future to alter the network, especially in north London and many outer areas that were not covered by proviso (3). In the event LT subsequently came to regard their title to all the existing ducts as good and many remain in use for railway power supplies, some railway communications, and leasing to third parties for fibre optic cables. Some of the more remote ducts have been filled in as being a maintenance liability with little probability of occupation.

Country Buses and Coaches

Evidence has been sought whether or not any private telephone facilities were deployed in the LT country area, but despite enquiries it must be said that no evidence has been found. Indeed any need for such facilities in such a vast and dispersed area would have been minimal in the face of the considerable cost involved for a comprehensive system, or the futility of having just a few lines; nor were there any convenient duct networks to use. References do exist in descriptions of the LT network to its eastern extent encompassing Dartford (which was in the country area), but this was doubtless related the 'traction' telephones on what had become trolleybus routes 696 and 698 which happened to operate in the area. It can thus be said with some certainty that the country bus operations had no private network facilities, though extensive use was made of the GPO system and there were certainly a number of bus stop mounted control telephones, all on direct GPO extension lines.

The country bus operations did, however, come to include management of the Green Line coach network whose routes converged upon central London, and the position here is marginally less certain. Again the operations depended heavily on the GPO system and the network had its own controller. The earliest routes through central London began on 10th December 1930 and it seems a District Inspector was in charge; his location is unspecified but it is likely he was based on the Embankment where the routes converged.* When Poland Street coach station opened in April 1931 he was relocated there, and given a new number.† By September 1933 this number was being referred to as Poland Street Control. Although the coach station closed in October, the controller remained there until 12th February 1934 when, from the following day, it transferred to Cranbourn Chambers, rooms 29, 30 and 31. At this point it was known as Central District Control;‡ it may be inferred from this that the Green Line and central bus control functions were to a large degree merged. As stated elsewhere, at this time there is no suggestion that any private telephone network was in use.

Green Line coach operations were suspended during the Second World War, but when re-established in 1946 the Green Line controller was located at Western House (Oxford Circus) where it remained until the enterprise passed out of London Transport hands in 1970.§ During the period when the controllers were together at Cranbourn Chambers they certainly had access to the railway telephone network, and it is likely from 1946 that the Green Line controller would have had access to the private network enjoyed by central buses. Nevertheless the GPO network is likely to have been the main means of communication.

* He was given the number TEMple Bar 6397.
† The Poland Street number was GERrard 2101.
‡ Central District Control was on TEMple Bar 5044 and 5045.
§ The Western House controller was on GERrard 7323

Chapter 5. The GPO Switchboards

The main LT GPO switchboard was not entirely undisturbed from the time it was last mentioned prior to the Second World War. In 1938, when LT was planning for wartime conditions in some detail, it was decided to provide a second switchboard in a different part of the building that could be used if some misfortune became the first one. In the event the Broadway complex was bombed in October 1940 and the main switchboard received a narrow escape and in December was moved to less vulnerable quarters, though the emergency exchange was retained.

The LT main switchboard was renumbered (again) from 20th February 1956. At that time there were 76 incoming lines handling around 3000 calls a day (300 an hour at the busiest time). By then over half the calls received were for travel information and the standard of service being given was comparatively poor.* In order to improve the service a second switchboard was provided to deal exclusively with travel enquiries and of necessity it had to retain the number (ABBey 1234) which had become known to the public. In fact for 18-months the new number was used in parallel with the old one to give everyone a chance to communicate the change to the general public and, in particular to business users who were familiar with the old number (though frequent injunctions to staff only to give out the new number suggest this was for a time an uphill struggle). Finally in late 1957 the lines carrying the old number were transferred to the travel inquiry office, which could now take calls without the switchboard intervening[72]. The old switchboard now carried just the new number ABBey 5600 although there was interconnection with Travel Information so that calls to the wrong number could be redirected to the other; certainly in later years this link had become notoriously unreliable.

* At some point a 'public enquiry office' had been established with trained enquiry clerks. By 1950 there were 20 clerks, all women, who manned the telephones at which time two calls a minute (all put through by the switchboard) were regarded as quite busy (*LT Magazine*, June 1950). It is thought that from the time it achieved its separate existence it had always been located on the ground floor of the 55 Broadway building.

At this time the main PBX comprised a 10-position type CB9 multiple switchboard and amongst the private wire circuits were six to the British Transport Commission and one to Scotland Yard.

The Travel Information office was reorganized at the same time, with new equipment designed to improve efficiency and cut down noise. A number of operator positions were provided (at least five) with space at each position to store the more frequently accessed travel information documents and a small vertical switchboard. Instruments were of the PO 300 table pattern with handsets (no headsets yet) but modified with push buttons and a lamp. Calls were taken by operating a button when the lamp flashed. Between the telephone positions and the incoming lines was a piece of equipment designed jointly by the Chief Signal Engineer's department and GEC. This allowed incoming calls to be distributed efficiently to the positions at which the enquiry clerks sat, and in the event of their being more calls than clerks the surplus calls would be held in a queue and distributed to the clerks as they became free in the order in which they arrived. This was a novel setup at that time.

The equipment at the Travel Enquiry Office lasted for twenty years but by the mid 1970s had become unreliable and hopelessly outdated. A new and much larger open plan office opened on the fourth floor in the newly-built 100 Petty France building with what were described as 'finger-tip' controls and headsets. The new electro-mechanical equipment was supplied by *Telephone Rentals* using ACD (Automatic Call Distribution) apparatus with a capacity for 48-positions, though only about half that number of operating positions was actually provided. For the first time the staff were given headsets (instead of normal handsets) so they had both hands free to deal with paperwork. The new office opened during July 1976, and the number of calls received shot up from around 12,000 a week to 13,500, indicating the number of calls which were previously failing under the old arrangements.[73]

In around 1983 all this equipment was replaced with new apparatus supplied by Special Telephone Systems; this utilized digital technology requiring all desk equipment to be replaced with push-button units. In the early 1990s the office was slightly relocated and modernized equipment (also by STS) was installed; this incorporated 'IVAS' (interactive voice activated system) which offered callers a pre-recorded message for general service information as an alternative to speaking to an operator. This did not have a particularly long life as it was all replaced again in March 1999 with automatic call distribution equipment by Rockwell. The Travel Information Office is currently provided with 80 incoming lines.

To reduce pressure on expensive administrative staff the Travel Information number was supplemented by a recorded 'state of the system' message on a new number (0171 222 1200) which was at first provided with 20 BT lines and 5 on the Auto system. This appears to have entered service in 1986 and was based on an open-reel tape system that relied on a voice activated menu to select bus or rail information—tone calling telephones did not then predominate. After about ten years it was replaced with more modern equipment that used menus selected by telephone keypads and the old equipment was despatched to the Science Museum to fill a gap in its collection.

Another heavy user of communications is the British Transport Police. In September 1976 they moved into a new control room at 55 Broadway which was equipped with purpose built communications equipment providing access to LT Auto and Post Office lines, direct lines to key points, and radio channels which had recently been made available to them for personal radios and police mobiles. The equipment was designed and built by LT and replaced batteries of separate instruments.[74]

As this is an article primarily about the LT private network it is not intended to cover in detail the GPO (and Post Office) switchboard arrangements, as these were to a large extent unremarkable examples quite likely to be found anywhere. However it would be wrong to ignore them completely and in any case many of them were accessible to the LT private network and existed as incoming lines on the switchboard which could be put through to the extensions in the same way as a GPO call, or the reverse.

The position of the Manor House offices exchange has already been referred to but the large installation at Broadway was similar. In the latter case the GPO telephones were not equipped with dials and all outgoing calls had to go via the switchboard; private calls were prohibited except in urgent cases where the caller agreed to pay, whence a luckless official from the Establishment Office would eventually descend on the perpetrator to exact the company's money. External through dialling was provided in the late 1970s and instruments were changed to 700 series push button.

In 1964 manual exchanges were still provided at the following locations, each accessible by an auto extension and in each case the operator could put an incoming call (Auto or GPO) to any extension.

Acton Works	0110 and 0111*
Baker Street	7244-7248†
55 Broadway	4573 and 8279
Griffith House	7289
Manor House	6116 and 6190
Parsons Green works	8251-8255‡
Greenwich Gen Stn	4821§

A number of these locations have been referred to previously, but the large offices at Griffith House (Edgware Road) were occupied from 1940 and the Parson Green establishment was the hub of the Works and Buildings organization and had been around since the 1920s, both with a requirement for GPO telephone access as well as internal.

The 1970 directory repeats the above information except that the Chiltern Court exchange has been added on 7445, and Chiswick Works on 0558 and 0559 together with new offices in Regent Street, on

* These lines were probably provided in 1939-40.
† These lines were provided in 1939-40.
‡ These lines were provided in 1939-40.
§ There is some reason to think this may have been the original magneto board.

4640/41/44; Manor House has disappeared (its closure has already been referred to). Telstar House appears in November 1973 on 7381 but soon disappears when the LT exchange is commissioned. This is also the last directory to show Greenwich Generating station (key people at this much-reduced facility had already got separate Auto lines). Qantas House emerges in January 1975 on 0318/0326/0689. Lots Road is given a revised Auto number (8137) for the PO switchboard in the 1971 directory.

Thus in 1978 the list of exchanges comprises the following:

LOCATION	AUTO	POST OFFICE
Acton Works	0110, 0111 and 0720	01-992 3262
Baker Street	7244-7248	01-935 6688
Chiltern Court Estate Manager	7445	01-935 5544
55 Broadway	4573 and 8279	01-222-5600
Chiswick Works	0558 and 0559	01-994 3641
Griffith House	7289	01-262 3444
Lots Road Generating Station	8137	01-352 3727
Parsons Green works	8251-8255	01-736 1292
Pelham Street	8601	01-581 1311
Qantas House	0318/0326/0689	01-995 4861

The Lots Road exchange Auto number fails to appear from 1983, though the PO line remains in service. During this period it should be noted that there were a large number of locations having separate Post Office lines but except as above these were all either discrete lines or PBXs in no way connected with any internal network, albeit that some of the PBXs were quite large. The lists include places such as Manor House* and it is perhaps to be inferred that such locations might have had more modern equipment fitted (perhaps the sort of 1960s equipment that sat on a secretaries desk) which was not compatible with incoming auto lines, or else there was simply no longer a demand.

By the time the new Auto network had been commissioned Qantas House had been vacated but the Railway Training Centre seems to have acquired some sort of interconnection and some of the other Auto lines had changed. The following therefore represents the final position prior to the demise of these remote switchboards when the LT telephone system was comprehensively upgraded, as dealt with in the next section.

LOCATION	AUTO	POST OFFICE
Acton Works	30002/3†	01-992 3262
Ashfield House	‡	01-381 7171
Baker Street	37004-7	01-935 6688
Chiltern Court	§	01-935 5544
Chiswick Works	30558/9	01-994 3641
Griffith House	37289	01-262 3444
Parsons Green works	38251/4	01-736 1292
Pelham Street	38601	01-581 1311

It may be noted that Broadway does not appear on this list, and it may have lost the interconnection facility when a new switchboard was commissioned. From 28th July 1980 a new Post Office electronic telephone exchange had come into use at 55 Broadway and its satellite offices. This exchange used 4-digit numbers and the opportunity was taken to update desk instruments with push-button telephones of the PO 700-type. Various classes of service were provided and not all extensions had direct

* Manor House on 01-800 5441 and Chiltern Court on 01-935 5544

† These numbers are given in the Head Office directory. The Railway directory quotes 30110/1

‡ This new building was supplied with large numbers of Auto telephones and no 'internal' local switchboard facility appears to have been available other than from Broadway. Clearly a PO switchboard was provided.

§ No Auto line to an exchange can now be found, but several offices moved to Chiltern Court and these each received direct Auto Lines as well as extension lines from the Chiltern Court PO exchange.

access to the PO network (those that did required a '9' to be dialled first). LT had persuaded the Post Office to provide for favoured staff a bank of direct dialling-in (DDI) numbers in the range 01-227 3xxx, which coincided with Broadway extension numbers in the 3xxx range (numbers in the 2xxx range had to be got through the operator). This soon showed itself to be inadequate.

Chapter 6 – The new London Underground Auto network

The existing 'Auto' network was approaching the end of its life in the 1970s and thoughts turned to its replacement. By the late 1970s the capacity had risen to about 5000 lines, but it was obvious that any new system would have to cater for considerable network expansion during its life. To meet the requirements of users, digital switching was believed to be required, and by this time a number of manufacturers were available to supply the latest technology. London Transport approved a telephone renewal project in 1978 and in January 1979 approved expenditure of £14.3m to buy and install the necessary apparatus.

A new factor was a requirement to accommodate the needs of the data processors within London Transport, and the technology of the day was deemed to call for data transmission to be available around the network by using the telephone service to do the switching (at that time data transmission consisted of conveying around by hand paper, magnetic tapes and punched cards). With this in mind LT took over in 1981 IBM's former London showroom at 58-62 Newman Street and installed new IBM computer equipment there.* With data communication very much in mind LT constructed under its existing statutory powers an under street duct between the new offices and Goodge Street station and installed what is recollected to be a 128-pair copper cable between the two. At the Newman Street end the cable was for the time being connected directly into the computer network. Telephone equipment was also installed and with automatic data switching in mind LT were persuaded to obtain Thorn Ericsson MD110 equipment. The speech circuits were allocated numbers in the 6xxx series with integration with the updated Auto network in mind, though the exchange was at first only operated as a PABX off the Post Office network.† This equipment was extraordinary flexible and actually required the services of programmers to set up properly (which was convenient as the building was full of them); because of this various 'classes of service' were developed which could be implemented quickly by Office Services staff, and this set the precedent for future telephone provision. In the event changing policies meant that the computer equipment never was connected to the telephone exchange. In due course the need for communications facilities to extensions on the Auto system required normal Auto lines to be installed, and the duct to Goodge Street was useful here.

Several companies were invited to tender for the main telephone replacement scheme and the contract was let to Thorn Ericsson Telecommunications Ltd for PABX equipment based around MD110 processing capacity (with which LT now had experience). The new system, like the old one, was to be a distributed network based around 16 local exchanges linked together by means of two tandem exchanges at Baker Street and Embankment. The new exchanges were purpose built. Nine of them‡ were built to a standard design, with two being of variant design to suit site conditions. Six were built in adapted accommodation§ and the remaining one, at Hounslow West, was built in the existing telephone exchange which, being of modern design, had the space available without needing to disturb existing equipment.

Each of the local exchanges had junction circuits to both Baker Street and Embankment tandems to provide network resilience in the event that one of them failed. This considerably added to the cabling required but was felt a very worthwhile investment as the Underground had become so dependent on its communications.

The basic unit of exchange equipment is a device called a Line Interface Module (LIM), which is an autonomous exchange unit with a capacity for up to 198 lines. The exact line capacity is determined by the number of

* They had moved in between July 1975 and July 1977
† The PO number was 01-637 9144

‡ Becontree, East Finchley, Golders Green, Hainault, Loughton, Manor House, Neasden, Rickmansworth, Ruislip.
§ Baker Street, Embankment, Head Office, Lillie Bridge, Stockwell, Telstar House

6-line cards that are inserted, of which the maximum is 33. Where two or more LIMS are provided at an exchange then a Group Switch Module (GSM) is also required in order to manage the traffic between them. A GSM can handle up to 30 LIMS, which means the maximum exchange capacity is just fewer than 6000 lines, which is more than sufficient.

The tandem exchanges are also built up of a number of LIMS sufficient to handle all the traffic on the satellite exchange junctions. Routeing of calls both for GSM-LIM and LIM-Tandem exchange traffic utilises pulse code modulated signals (PCM) operating at 2 Mbit. The local loop continues to operate generally on an analogue basis except that a small number of cards can operate lines digitally for users who have appropriate equipment on their desks.

The location of the exchanges required some thought, and matters were influenced either by the location of cabling to existing exchanges, or by the economics of reducing very long extension lines. Much of the existing cabling was re-used, at least in the first instance. Six of the new exchanges were of 100-150 line capacity and only needed a single LIM, five were of 200-300 line capacity requiring two LIMS, two required three LIMS, one required six LIMS, one required 10 LIMS and the last one (Acton) required 11 LIMS. The location of the Baker Street tandem offered itself as the result of changes within the data processing department which had specialized accommodation at 210-212 Baker Street. The provision of a new ICL 1900 computer on the first floor signalled the removal of an antiquated (and large) Emidec machine from the specialized area on the ground floor, and the secure, air-conditioned and cable-friendly area was ideal for a telephone exchange. At Embankment the new tandem was built within the large but comparatively new substation, built in the 1960s.

Although initial planning was done on the basis of the new cabling being of copper, with various means of regenerating signals on long routes, fibre optic technology was now available and offered considerable cost advantages as well as reducing the cabling and regeneration actually required. PCM transmission had already been used for telephony at first to Hounslow (and also to Harrow) but this used copper technology that required signal regeneration at intervals of around 2000 yards. In practice these regenerators proved unreliable and a fault would result in the loss of all circuits using the cable, around 30 in all. In consequence the Hounslow route was duplicated in 1979 by a fibre optic cable in order to gain installation and service experience, the outcome of which was that it was found to be very reliable. The LT fibre installation was a very early example of such use on Britain's rail network* and comprised a 7.2km system with seven intermediate joints and operating at 8448 kBit/s. The cable was constructed by Telephone Cables Ltd and contained just four fibres, each of which was made by a GEC subsidiary. In undertaking this exercise experience was gained in installation and jointing which required quite new skills to be developed. All this was to have a major impact on the design of the new telephone system under development.

The new telephone network is constructed on the basis of a pair of 134 Mbit fibre optic cables linking the tandem exchanges, pairs of 34 Mbit cables (one of each pair to each tandem) connecting seven of the satellites, and 2 Mbit copper connecting six of the further out satellites to a nearer one. Golders Green, East Finchley and Stockwell are connected directly to the tandems by 2 Mbit copper.

The new system was commissioned at 02:30 on Saturday 9th February 1985. For the time being very large numbers of existing rotary dial instruments remained in action, although key staff did receive new push button instruments immediately. A programme of replacement began for the old instruments, though it was about a year before all of those regularly used had been attended to (though dial instruments could still be encountered in little used places for some time longer). The new system used 5-digit numbers. The general rule was that the new number would be the same as the old one, but prefixed by the number '3'. This was subject to local variation where not all lines to an old exchange were transferred

* BR had installed a fibre optic cable at Wilmslow in 1977 but this was purely a field trial.

on bloc to a new one, the 'odd' lines having to be renumbered completely, but still beginning with a '3'. As Telstar House already used 5-digit numbers in the 27xxx series these were retained. After some years operation the 3xxxx series of numbers were supplemented by an additional range in the 2xxxx series.

The outbound British Rail interconnection numbers were retained, but prefixed by a '1' (eg 12063 for Euston, LMR). From the late 1980s the BR network was reorganized with all London area numbers replaced with 5-digits with a common access code from LUL of 1200 xxxxx. In the reverse direction several codes were used over the years. The '016' code could not be used with LT's new 5-digit numbers as dialling was initially restricted to the zero plus six other digits, so a new code '08' was allocated. This was very limiting because from a technical viewpoint the leading LT digit was in reality a third BR ETD digit and only a limited number were available (ie 08 34444 was technically 083 4444); this became a problem when LT numbers in the 6xxxx range were allocated. In recent times the restriction of the limited number of digits which could be dialled was eased and the code '0678' was allocated, followed by the LUL 5-digit number. The BR interconnection was for many years not of the most reliable quality but in the early 1990s a digital interconnection was provided which dramatically improved matters. So much so, in fact, that LUL began publishing the number '12009' ('009' being the BR network speaking clock) as the normal means for staff to obtain an accurate timecheck. When the Crossrail project was based at Telstar House in the 1990s a direct PCM link was provided between Euston (BR) and Telstar House to boost capacity and provide digital signalling.

One of the objectives of choosing standard exchange technology was that it could be connected to the Post Office network, getting rid of the need for office staff to have two telephones on their desk and generally improving efficiency. This was less straightforward a proposition than it might have been. The Post Office telecommunications people (by now regenerated as British Telecom) were in the throes of privatization and new legislation and regulation presented difficulties. New equipment connected in any way to a public telephone network now had to be compliant with the regulations of the British Approvals Board for Telecommunications, and much of the archaic equipment on stations **was** connected to the LT automatic network and was definitely not compliant. Although 'grandfather' rights might have applied things would have been very difficult in practice. The decision was made during 1987 to remove the Auto lines from the station panels (and anything else non compliant) and provide separate telephones at these locations. The Auto system thus became entirely independent of the direct lines and interconnection with the BT network became complete. In the meantime limited interconnection became possible from 4th April 1986, starting off from the Baker Street exchange and offering facilities to the various offices at Baker Street and Griffith House.[75] The Baker Street switchboard was allocated the number 01-724 5600 for calls not being directly dialled, but when the Broadway area was converted it retained its existing number on 01-222 5600. 'Interconnect' was rolled out across the system and was all but complete in 1988.

On the subject of switchboards the opportunity was taken to consolidate nearly all of the existing telephone switchboards at either Baker Street or Broadway. Initially the view was that this provided in-built backup facilities as each switchboard could switch calls to any extension. In practice this bordered on the perverse, since the operators would 'refuse' to take dialled calls to extensions nominally allocated to the other exchange but would often receive them anyway as calls were automatically diverted on overload. After some tentative testing it was found the Broadway switchboard could easily handle all calls but the equipment at Baker Street was kept available (and regularly tested) as a backup facility. The official number for virtually all of the London Underground is thus 020 7222 5600. Although the switchboard is closed outside office hours the comparatively few incoming calls requiring operator assistance are diverted to the Travel Information Office which is manned 24 hours a day. As an aside it

might just be mentioned that irrespective of the 'class of service' of an extension, operators could put through calls to any extension, which gave rise to some concern within the railway operating department about the possibility of distracting personal calls and other mischievous contact with the outside world. In these more enlightened times there are various direct lines to all stations now (largely to facilitate communication with contractors or emergency services) and the problem (if there were one) has been managed away. Of course, as most staff have mobile phones (maybe their own as well as the company's) the fuss made about personal calls via station phones diminished anyway.

In addition to connection to the LT network five classes of external service were possible from telephones on the new Auto system:

- via operator only
- local calls only
- local and national STD only
- local and national STD and limited international only
- unrestricted.

Technically any user could have any class of service on a line, but internal controls would restrict the class to the lowest necessary. External calls were made dialling a '7' before the number. Number unobtainable was sent if a call beyond the class of service were attempted.

Dialling in from BT was also restricted to users prepared to pay for the facility. In this instance it was necessary to allocate a new telephone number in the range 4xxxx. Externally the incoming junctions were placed on BT's 01-227 exchange and the last four digits corresponded to the xxxx of the user's number. There was no correlation between extension lines having incoming and outgoing call facilities, and incoming calls could in fact be made to any extension via the switchboard operator at either Baker Street or Broadway, as could outgoing calls.

The cadence (or ringing tone) on the old Auto system was based on alternate periods of ringing and silence of equal duration, so that Auto telephones could be distinguished from the 'Brr-Brr' of the GPO system. This approach was also followed on the new Auto system for incoming calls from another Auto phone; calls from the BT network rang as a BT call, though on the same instrument. Following the Kings Cross fire in 1987 the fire brigade became more closely involved with the inspection of Underground stations and considered that the ringing of an Auto telephone could be mistaken for an alarm bell, following which LT standardized the cadence on the BT pattern.

Although everyone received a 5-digit extension number it was contrived that 'short codes' of three or four digits (or two, in the case of '19') were allocated to key officials (and the BMR) where high volume was probable; these numbers all began with '1'. In fact the equipment simply translated the number into the appropriate 5-digit number prior to routeing. Among the key users of these numbers were the line controllers and engineering works controllers, but there were a few others. It was possible to give a dedicated short code to an external number which overrode the class of service restrictions so that, for example, station supervisors could contact certain contractors who only had BT numbers. When 'Travelcheck' was launched it was also available to staff and given the short code 159, and soon afterwards another short code 156 gave Auto telephone users access to the Travel Information clerks, though in this case the code merely directed calls to the existing, but less memorable, Auto number.

The 3-digit short codes originally issued were as follows (numbers in brackets for emergency use only):

User	Location	Code
Bakerloo controller	Baker Street	102 (902)
Central controller	Baker Street	103 (903)
District controller	Earls Court	104 (904)
Jubilee controller	Baker Street	101 (901)
Metropolitan controller	Baker Street	100 (900)
Northern controller	Cobourg Street	106 (906)
Piccadilly controller	Earls Court	105 (905)

Victoria controller	Cobourg Street	107 (907)
HQ Information desk	55 Broadway	108
BT Police	55 Broadway	109 (999)
Signal Report Centre	Acton	141
Shift Supply Engineer	Long Acre	145
Lifts & Escalator report centre	Griffith House	146/7
Signal Report Centre (telephones)	Acton	151

Subsequently various other numbers were added, all beginning with a '1' but new codes nearly always being of 4-digits.

By the time the new equipment had come into service it had become obvious that the forecasting was awry. It was not that it had been poorly thought out, but merely that so much had happened. One factor was the renationalization of London Transport in 1984 and the setting up of subsidiary companies that chose to make less use of the Auto telephone. There was then a host of other initiatives which had pushed up demand elsewhere (plus the arrival of fax machines which were eating into spare capacity). In 1987 it was agreed to reorganize the exchange capacity at a number of locations to meet the demand as then perceived, increasing overall capacity by about 600 lines on a base of 11,900 lines, of which about 2500 were spare. 4-new LIMS were required to service East Finchley, Golders Green, Ruislip and Telstar House.

The Newman Street equipment carried on regardless until the 'interconnect' programme was rolled out, and from around 1986 the MD110 PABX equipment was finally integrated with the rest of the new network. The existing telephones were renumbered into the 47xxx series with, so far as possible, the last digits corresponding to the 6xxx of the existing numbers; this made possible the removal of the additional Auto lines. This effort was partly wasted as LT Data Networks were in the process of disposal* and after a brief use as extra office space the building was disposed of in the mid 1990s. The MD110 did provide a useful source of spare parts though.

The attitude of the Post Office authorities towards business customers had been regarded for some time as indifferent, and from the customer's perspective this was reflected in a general lack of interest in offering discounted prices for high volume traffic and a lack of vigour in providing the facilities really required; in its early days it was perhaps inevitable that BT's ethos was similar, and was but a mere name change. The general obstructiveness towards interconnection has already been referred to.

Also referred to was the new PO switchboard, introduced in 1980, with DDI provided on a bank of 1000 lines in the 3000-3999 range which soon proved inadequate. When LT announced that it wanted an entire 10,000 line exchange to be made available for DDI BT regarded the request as quite ridiculous and even if they were disposed to meet it then it would be at least six years away: only a maximum of 3000 lines could be made available at the time, and having no choice LT temporarily acquiesced. It so happened that a little later (when further DDI capacity was still being sought) the new company, Mercury Communications, won a battle against BT on the question of obtaining blocks of telephone numbers for their own use, BT having previously regarded the matter as their own monopoly. Knowing that Mercury were offering substantial discounts for high volume traffic, and that they now had codes available, they were asked if they would provide an entire 10,000 line block. Although taken aback, they soon agreed to do so, though this was apparently at the expense of later customers who had to wait for new capacity to be made available. The outcome was the decision of LT to switch to Mercury as its service provider. Unfortunately this then meant changing the incoming telephone exchange number from the prevailing 071-227 to 071-918, which took effect on the night of 24th/25th August 1991, after a period of parallel running to give time for stationery to be altered. A number of users were able to retain their existing 4xxxx numbers but for technical reasons others received a new number (still in the 4xxxx series) which was useable in

* They were sold off in July 1986 to a joint venture company; LRT later sold their interest.

parallel until the changeover. A small block of numbers could only be changed on the night. None of this affected outgoing calls or the 071-222 switchboard and travel information numbers. The new exchange was entirely devoted to LT's requirements.

As part of the deal done with the Government for funding the Jubilee Line extension LT was invited to occupy one of the various new buildings being constructed at Canary Wharf to get some life going into the area. In the end it was decided to move LUL's entire engineering directorate there (and a few other departments) and this required efficient telephone communication. Initially the Jubilee Line Extension project team were shifted in about 1993 and were provided with a BT switchboard on 0171 759 4xxx. Interconnection with the Auto network was provided by dialling the access code '68' on an Auto telephone followed by the 4-digit extension number (producing what was in effect a 6-digit number. When the building became available for the rest of the engineers to occupy a second BT facility was installed on 0171 308 xxxx, but this time the equipment was completely integrated with the Auto network with 5-digit numbers being allocated in the range 6xxxx (the numbers coinciding with the DDI ranges). The Jubilee Line project kept going with the existing arrangements but interconnection was provided between the systems ('68' worked for calls to the JLE project and the code '71' was used in the other direction, requiring 7-digits to be dialled).

During 1995 and early 1996 the software on the Auto system was subjected to a comprehensive £1 million upgrade which, amongst other things, increased the versatility of the equipment and give the system a further 10-year lease of life. Enhancements included closer integration between local exchanges so that (for example) the call-back facility was available across the network instead of only locally, and similarly with call-divert. Another feature was enhanced data handling so that the requirement could be handled in-house rather than by an external telecommunications operator.[76]

The construction of the Jubilee Line extension required the provision of considerable additional telecommunications resources. To service this requirement 13 Siemans Realitis PABXs were installed (including one at each station) that were integrated into the network. During 2004 further software upgrades were undertaken across the entire network to bring it up to the latest standards and further improve capability. By this time the parameters of the network were:

- 41 locations with MS110 exchanges;
- 13 locations with Siemens Realitis exchanges;
- About 24,000 telephone extensions, numbered in range 20000-50000 (40000 range has DDI facilities);
- 435 digital connections to PSTN;
- 160 analogue connections to cellular telephony operators;
- 120 digital connections to switchboard services.[77]

In addition the network has outgrown the DDI facilities offered by the 020-7918 PSTN exchange and from about 2000 has been supplemented by 020-7027. Extension numbers on this exchange are accessible on the Auto network in the range 5xxxx which are fully integrated with the rest of the system.

The new auto system was originally conceived as a business tool for the entire London Transport organization, but, as already alluded to, corporate restructuring resulted in a slightly confused outcome. The bus business became even more heavily devolved and then largely privatized, resulting in almost complete reliance on the BT network. London (Regional) Transport itself went through two major restructurings resulting in less than complete use of the auto network, whereas London Underground Ltd relied on it entirely. More recently still, the migration of former London Transport functions (except London Underground) to Transport for London, based at Windsor House rather than 55 Broadway, has left London Underground the sole user of the Auto network.

Having said that, Transport for London has a typical head office network at Windsor House and has access to the Auto network. Equally the

three Infrastructure companies which have taken over responsibility for London Underground maintenance and upgrading each have their own head office systems with similar 2-way connectivity. From this it will be apparent that the so-called "Auto" system has lost much of its unique character over the years and, though it has still a few special features, is tending to develop more and more simply as a very large interconnected PABX.

Chapter 7 - Other communications

Wartime communications

Following the outbreak of the Second World War the LT organization had to adapt rapidly to meet the new demands upon it, which included significant relocation of facilities, duplication of critical facilities, and provision of hardened accommodation to deal with wartime activities not otherwise necessary. All this had to be done in addition to keeping existing services running and inevitably required major changes to communications equipment.

In particular the wartime engineering HQ at South Kensington needed efficient communications with north and south area HQs at Chalk Farm and Clapham Common. Direct lines were installed between the HQ and each area, and between the areas. These were duplicated by routes running via Parsons Green and Lillie Bridge switchboards, which also had access to GPO lines. Chalk Farm had direct lines to district HQs at Wembley Park, Chalk Farm and Whitechapel (each of which had GPO connections, and likewise Clapham Common was linked to district HQs at Aldwych, Stockwell and Chiswick Park. It is assumed the direct lines were leased from the GPO where direct rail routes were not available. All this infrastructure was removed after the War.

Direct Lines

In LT practice direct lines are those between two points the connection of which does not require the assistance of an exchange operator or automatic switch; they exist in large numbers and the story was left in an earlier chapter in 1939. At that time direct lines were in essence the old LB exchange lines which had been run via the traffic controller's switchboard to enable immediate communication to take place between the controller and important control points. These were retained after the introduction of the Auto system, so control points received a separate Auto line for general calls. Notwithstanding the earlier system of calling the controller by means of a special push-button switch, direct lines became standardized on the magneto system for many years (though calls from the controllers were signalled by a ringing key operating from an AC supply). CB working might have been more convenient but LT regarded the magneto as much more fault tolerant, and more reliable at outlying locations where line lengths would produce unacceptable voltage drop. At the station end many direct lines were terminated on small switchboards or 'annunciator' panels. In the control offices the direct lines terminated on one of four switchboards* with circuit selection now by means of key switches, and incoming calls denoted by lamp. Since this system was simple and reliable, very little was to change for the next twenty years.

With the coming of the Victoria Line it was considered that new equipment would need to be introduced on a large scale and that something a little more modern could be provided. The outcome was a completely redesigned station telephone panel using a '700-series' wall mounted telephone, and with the jack plugs replaced by small modern key switches which were now available. A major step forward was to replace the magneto generator by a transistorised inverter (fed from the local battery) that generated AC ringing current and was operated by a self-returning key. Incoming calls were still denoted by drop flaps that had to be reset by hand. These panels were installed at all Victoria Line stations (in some cases at existing stations they superseded older panels only after some delay) and at other stations as they were modernized. The direct lines on the Victoria Line itself were of the CB type (and may have been the first of this type). Similar panels at other stations or jointly operated stations still need to operate using LB technology. With the key operated panels the keys were pushed downwards to connect to the telephone and upwards (in pairs) to bridge two extensions together. Victoria Line station-to-station telephones were not passed through these panels but were

* There were separate boards for Metropolitan & Bakerloo, Northern, District & Piccadilly and Central Lines.

operated directly from headwall units, a key switch selecting station ahead or station in rear.

Other users of Victoria Line direct lines generally received a table telephone of the Post Office '700' pattern, but without dials, and almost invariably grey. Now using CB technology it was merely necessary to lift the handset to call the person at the other end. As new equipment came into service on other lines similar desk telephones were provided. These were usually of the '710' pattern which allowed for up to four push buttons which could be used to call different people, though in practice separate instruments were very often provided each with only one push button. To provide ringing current these instruments were necessarily equipped with transistorised inverters mounted internally; these took up all available internal space and made them very heavy. They were not impressively reliable and required battery boxes nearby, usually creating a nightmare of cabling.

The line controllers and signal regulators (there were no traditional signalboxes) were at first provided with large key operated telephone panels which were mounted within their control desks and '700-series' instruments which sat on top or on the desk. At least one instrument had a dial and one of the keys could connect with one or more Auto lines. On these desks incoming calls were denoted by small lamps. Decentralization of the control function resulted in desks such as this being installed at Earls Court (District & Piccadilly Lines) and Cobourg Street (Northern & Victoria Lines). In the 1980s newer (computer-based) technology became available whereby incoming calls were shown on a display screen, together with their source, and calls could be answered or generated by means of push button switches. Separate telephone instruments were no longer provided, just handsets which were wired or plugged into the control desks. In the latest desks menu-driven touch screens are used both to make and receive calls, and this pattern is now used on all lines. The new equipment did require some further circuit alterations which resulted in general conversion of the controller's direct lines to CB operation; although at the remote end the lines continued to be terminated on old equipment it was no longer necessary to operate the magneto to make a call to the controller. It is a cause of reflection that one end of a call might take place on such modern technology while at the other end it was still possible to speak from an early 700 type telephone operating on an LB circuit fed from four huge 'flag' cells. It is only comparatively recently that the last of the old 300-type instruments was finally displaced.

When the new Auto network was introduced during the 1980s serious consideration was given to the abandonment of the archaic direct line system and its replacement with direct electronic paths through the new telephone network. There was considerable user resistance to this, coloured largely by the appalling unreliability of the old Auto network and the desire to retain a simple and independently powered system. The direct lines remained, at some cost, though it must be said the new Auto system is extremely reliable.

From 1987[78] traditional telephone panels in platform kiosks were progressively removed and new equipment installed. The station-to-station lines were replaced by new equipment at headwalls that could connect with stations ahead and in rear (as on the Victoria Line). Other direct lines were terminated on a new instrument with electronic sounder. A separate instrument was provided for the Auto telephone. This initiative allowed replacement of some very elderly equipment as well (as referred to earlier) as separating the Auto network from miscellaneous equipment so that it met modern regulatory standards. The station-to-station telephones were of the Racal 2C707/3 pattern comprising a modern handset, two selector buttons (and calling indicator lamps) for selecting station ahead or in rear, a ring button and a power test button. Where a station was regularly closed during traffic a bypass switch was also provided.

Before leaving the subject of direct lines a word might be said on the use of direct lines during the Second World War. Before the conflict started it was recognised that railways would have a very important part to play and that there would be a pressing need for a co-ordinating authority

to obtain the best possible response to national economic and military demands. The railways (including London Transport) would be placed under government control and managed through a Railway Executive Committee (REC). The Committee was appointed on an advisory basis only in September 1938, and on a mandatory basis on 1st September 1939, when the government control order came into force. A government grant was made available for air raid precautions (ARP) purposes and part of this was earmarked for establishment of emergency or duplicate command and control facilities in locations considered less vulnerable to air raid than the peace time facilities, or the making of peace time facilities themselves less vulnerable.

At first the REC met at the headquarters of the Railway Companies Association in Great College Street Westminster, known as Fielden House. It appears that as the wartime headquarters and control centres became available for use on an 'if required' basis telephone lines were laid direct to Fielden House (which was owned by the LMS); lines are also known to have existed with the functional railway headquarters, including that of London Transport, but in view of the nature of this building they may very well be of a much earlier date. The routeing of cables is not known but is likely that at least a few of them used the Underground in part, and there were also inter-railway direct lines for which the Underground would have been the most direct route.

It was considered important that the REC be based in London, but an investigation into the suitability of Fielden House ruled it out. The novel solution was adopted of converting a disused deep level underground station and Down Street (between Green Park and Hyde Park Corner) was adopted. The platform tunnels and passageways were converted into offices, meeting rooms and dormitories and the surface access was made bomb and gas proof. The structural work was undertaken by London Transport, but equipment and fittings (including telephones) were provided by the LMS. Although not finished, it was made operational on 1st September 1939 by which time the telephone switchboard was available. Plans indicate that most, if not all, the emergency lines to Fielden House were transferred, and that a good deal more were also installed. These included a link to the LT Auto system at Leicester Square and direct lines to a LT wartime headquarters units at Dover Street (Green Park), and Holborn, as well as 55 Broadway. The Down Street switchboard was also in direct contact with (amongst many others) the Admiralty, War Office, Ministries of War Transport and Shipping, Railway Clearing House and (via 55 Broadway), the London Civil Defence HQ and Scotland Yard. Without doubt, many of these cables would have been laid along the Underground tunnels. Down Street fell out of use quickly once hostilities had ended, though nobody troubled to remove the switchboard whose battered remains continue to languish there in its tiny underground office. Brompton Road was also used for wartime purposes, this time as an anti-aircraft operations room. This needed reliable direct lines to be in place to the various searchlight and gun batteries in the London region and again the Underground tunnels were used, although there is no reason to think there was any network interconnection.

Train Telephones

Underground trains were not originally fitted with any means of communication between the driver and the other train staff. The number of staff on a train (perhaps six) made it possible to convey messages after a fashion, but when in the 1920s the number of train staff fell to two (driver and guard, one at each end of a train) some means of communication between them was desirable. The bulk work of converting trains from two guards to one began in May 1927 and included the fitting of train telephones at each driver's and guard's position[79], the equipment at the guard's positions only operative when a guard was present. At first each was equipped with a microphone unit (operated by a lever) and a receiver in the form of a loudspeaker (the trade name for all this was 'Loudaphone')[80]. From the 1930s the new trains were equipped with integral units operated by push button, and the design of which survived to be fitted to the 1962

stock. They were never the most efficient pieces of equipment and staff came to believe that thumping them with their heavy position switch keys improved performance, which resulted in the 1938 stock guard's telephones being modified with a protective plate, which was fitted to later stocks too. Surface stock trains were not fitted with telephones until the 'O' stock arrived in 1936, but subsequent trains were all fitted and the earlier District cars converted to 'Q' stock were also retro-fitted. The 1967 tube stock (which had no guards) had electronic telephones using '700' style handsets which also doubled as public address microphones, and this set the pattern for later trains, surface and tube. The 1972 stock was similar to the 1967 stock and the same cab telephone was used. They also had traditional guard's positions (the last trains to do so); at these positions equipment looking like the traditional train telephone unit were provided, though they were actually electronic.

Another kind of train telephone came into use on new and refurbished trains in the 1990s comprising an intercom at the passenger emergency alarm points. This enables a driver to speak to a passenger who has operated the alarm to ascertain what the problem is.

Tunnel Telephones and Drico

The original purpose of the tunnel telephone line was as much to enable train drivers to gain information as it was to tell someone about an emergency. By the 1930s, however, the emergency function had prevailed and it was not possible to seek or communicate information without also removing traction current. This was entirely unsatisfactory and LT had come in for some criticism after an accident on the Northern Line in 1938 where difficulty in communication was a factor;[81] but it wasn't until after the Second World War that technology allowed the problem to be addressed.

The solution was a system called 'Drico' (short for Driver-Controller). This was superimposed upon the tunnel telephone lines and allowed a train driver to call and then speak to the traffic controller without discharging traction current.

The on-train equipment was mounted in a special cabinet but the driver would speak into the ordinary train telephone after pressing a 'speak to controller' button in the Drico cabinet. Also in the cabinet were two long fly leads that had to be clipped onto the telephone line. The guidelines for use were that a driver should call the controller via Drico if he were detained for five minutes, or if because of breakdown it was obvious the train could not be moved for at least five minutes. The instructions at first stated that in the event that Drico was not available (but the tunnel telephone line was still operative) special boards were to be displayed bearing the letters 'DC' crossed through. It seems that with all the delays which then followed, such boards were never actually provided and in early 1957 the instruction was rescinded.

The technical difficulties at the time were formidable. In particular it proved extremely difficult to get rid of excessive line noise and powerful filters had to be used, which were fitted at Leicester Square. Valve technology was used extensively and it has to be said that the reliability of Drico was not as good as may have been desired. In particular, the circumstances which would cause one driver to use Drico would be likely to cause many others to use it at the same time, and anecdotally it was said to be near useless when several people were trying to use it at once.

Drico worked by means of special equipment on the train which applied amplified voice-frequency current to the tunnel telephone line via a DC blocking circuit to maintain tunnel telephone line voltage (otherwise traction current would be discharged). At the substations voice frequency amplifiers would detect speech that would be transmitted over normal telephone pairs to the control office at Leicester Square where it would be further amplified before being fed to loudspeakers over the control desks. Each telephone pair could service up to seven substations and was restricted in length to ten miles. To enable the controller to reply to the driver a special microphone was provided and the amplified signal was

transmitted over different sets of telephone pairs back to the substations. After further amplification the signal was applied to the tunnel telephone wires and the response would finally emerge through a dedicated loudspeaker in the driver's cab. In the more modern control offices the Drico calls were terminated on a '700' type desk telephone reserved for the purpose, equipment having been added to detect an incoming call and causing the bell to be rung.

Drico was phased in across the network gradually, though it was not a quick process — the decision to install it was made as early as 1947[82] but it took five years for it to be born. The first line to be equipped was the Northern from 9th March 1952; this struggled into life after a year's delay and then 'on an extended experimental basis' only (and without the Bakerloo and Northern City Line as had been planned). After the teething difficulties had been dealt with as effectively as possible the Bakerloo Line followed on 31st January 1954 (three years after intended), the Central Line from 1st September 1954, Piccadilly Line from 5th February 1956 and the Northern City Line from 18th March 1956. The District Line (except north of High Street Kensington) followed from 13th January 1957, but only in respect of 'Q' and 'R' stocks. From 5th May 1958 the Metropolitan Line was equipped with Drico (including the 'District' section from High Street Kensington to Edgware Road), but only on the 'O' stock; it was extended to 'F', 'P' and 'T' stocks from 2nd March 1959, with the area extended to cover the East London Line. From this point the whole network was equipped and apparatus was also fitted to subsequent rolling stock until the system was abandoned.[83]

The advent of train radio systems during the late 1970s and 1980s meant that radio rather than Drico became the usual way of communicating with the line controller and Drico fell out of use for all practical purposes. As train radio was not particularly reliable in its early days Drico was in theory maintained in a serviceable condition for several years after radio became available (at least until 1990), though it is questionable if it would have worked properly or at all if used in earnest. It is now but history though there would have been few who were sorry to see it go.

Drico did not affect the normal operation of the tunnel telephone line. What did affect it was the modernization of the low-tension power distribution system in (in particular) the 1960s when substations were systematically de-manned. In the first phase, which began in the 1950s, there was gradual demanning as new mercury-arc or solid-state rectifier equipment came into use. The operation of the tunnel telephone line still removed traction current at the local substations but the speech circuits had to be diverted to the remote substation or substation control room which exercised supervisory control. By the end of the 1960s most substations were controlled by one of a very small number of control rooms. In the 1970s it was considered more useful to terminate the tunnel telephone circuits in the line controllers' offices. As any removal of current would inevitably be of concern to the controllers it was better that they got information first hand from the driver concerned rather than via a remote substation operator. As part of this philosophy the controllers were given special tunnel telephone panels on which all relevant traction current sections were marked, together with lamp indications and speak keys which would alert him (with audible warning) to a tunnel telephone call and allow him to talk to the driver who would be using the tunnel telephone handset. In addition the key panel also allowed the controller to operate the tunnel telephone circuit himself so in a perceived emergency he could remove (but not replace) traction current. These arrangements had to be co-ordinated with the substation and line control office modernization programmes and were introduced in several phases between 1967 and 1976, and are still in force today.

Tunnel telephone lines were considered susceptible to dangerously high induced voltages from adjacent, parallel-running overhead line equipment. The electrification of the City Widened lines in the late 1970s involved about 2-miles of such equipment (energised at 25kV) in tunnels adjacent to the Metropolitan Line between Moorgate and Kings Cross. It was

decided to dispense with the tunnel telephone wires and instead to provide separate telephone instruments at about 50 yard intervals, the position of each indicated by an illuminated marker lamp. They operated in the same manner as the station headwall instruments (in other words lifting the handset discharged traction current). This system proved more satisfactory than the tunnel telephone lines and on later extensions of the Underground (beginning with the Heathrow Terminal 4 loop) has become the standard approach. It has other advantages too. In particular it means that a telephone is always available within a few yards; the logistics of keeping handsets available for drivers became formidable and even possessing a handset was no guarantee it was at the right end of the train when needed. In more recent years instruments have been stowed away in driving cabs, which removed the responsibility from drivers for carting one about all day in its little wooden box.

Signal telephones and other trackside telephones

The humble signal telephone is not the most exciting piece of communication apparatus on the Underground. A form of direct line, but largely out of site and generally very little used, it is their large number and their importance in keeping trains moving during irregularities that gives them some claim to fame.

In the early days of the Underground it was not necessary for telephones to be placed at signals. In the event of failure or serious delay where a signal could not be passed then either the tunnel telephone line was used, or, where not provided, the guard had to walk forward to the next station or signal box to gain information or instruction. Having earlier noted that the tunnel telephone line was hijacked for emergency discharge of traction current a problem thereby arose; the delay occasioned by staff having to walk to a station was considered unacceptable. In addition the electric power frame was capable of controlling signals a considerable distance from the signal box (or anything else), and again the delays caused by staff seeking information were going to be unacceptable.

The earliest example so far discovered of the provision of a telephone on what became the Underground is on the Ealing & Shepherds Bush Railway, which was actually owned and equipped by the Great Western even though the only passenger service was provided by the Central London Railway. This line was equipped with three aspect semaphore signals and telephones were provided at six of the controlled signals which happened to be some distance from a signal box or were otherwise situated awkwardly. This line opened to passengers in August 1920.

The earliest reference to signal telephones on the Underground 'proper' was the provision of four such telephones at Baker Street Junction on the Metropolitan; when they were installed has not been determined but they were certainly there by 1920 (but do not seem to have been there in 1913 when the new signalling was introduced). The next location on the Metropolitan to receive a signal telephone was in May 1924 when one was provided at Moorgate (Met) up outer home signal which was connected to the Circle Line signal box with an extension bell in the ticket collector's box. In 1926 Praed Street junction signal box was closed and control transferred to Edgware Road cabin. As the junction was now remote from any form of assistance three signal telephones were provided at the junction signals.

On the UERL lines the earliest reference to signal telephones was on the Edgware extension where by 1925 nine such telephones were installed at home signals, all connected to the associated signal box; the first part of this extension (as far as Hendon) opened in November 1923 and the Hendon northbound home signal appears to have been equipped with a telephone (linked to the signal box) from that date. Five telephones were provided at signals at the complex junctions at Camden Town so that irregularities could be reported promptly and help summoned (it was not safe for staff to walk forward without protection being provided). More signal telephones were provided on the Morden extension when it opened in 1926.

On the District signal telephones had been provided by 1930 at Hanger Lane junction (which had been remotely controlled by Ealing Common since May 1925) and at Aldgate East (eastbound) where the layout was dangerous for staff to walk. No evidence has yet been discovered for the commissioning of the Aldgate East telephones, and they may well pre-date 1920. The East London Railway had a signal telephone at the Canal Junction down outer home signal by March 1923 (and two others by 1930) but dates of introduction are not known.

After 1930 signal telephones were increasingly provided on new and updated signalling installations as the utility of such a means of communication was obvious. However they were far from universal until comparatively recent times. The mass closure of signal boxes during (in particular) the period 1955-1975 meant that local signalmen could no longer see or hear trains (or their whistling for assistance), nor communicate with the drivers in any way. Under these conditions signal telephones became very important.

Details of early signal telephone equipment has not been established. One might suspect local battery operation (with magneto ringers) would have been in use at the early sites, though battery maintenance would have been irksome. Later installations used central battery circuits terminating on key panels in signal boxes, usually at one end of the signal frame. The signal telephones themselves were a maintenance problem. As they were little used the contacts corroded or became gummed up with dust. After the Second World War LT standardized on instruments without any moving contacts at all, each handset contained a mercury switch that connected the circuit as soon as it was held away from the horizontal. Signal telephones usually but not always contained bells so that a signalman could call a driver back if necessary. Where bells were not provided a driver making a call might be asked to hold on if the signalman needed to come back, as it was not possible to call the driver. Instruments are mounted in square iron boxes usually with a black and white diagonally striped door.

Ground telephones were also provided to allow communication with signalmen but not necessarily in association with any signal. The earliest definite discovery of such provision was at Acton Works in January 1924 where a telephone was installed at a stop board near the works outlet. Trains had to stop at the board and get instructions from the Acton Town signalman prior to proceeding further. A similar arrangement was provided in Wood Lane depot in April 1925. Such signals were also installed in many goods yards so that drivers or shunters could advise the signalmen when shunting was complete. Obviously telephones installed for these purposes could be used by any staff in an emergency. Some of these still remain even where their original purpose has long gone.

With the move to centralized control, following closure of a signal box a telephone panel was usually provided at the nearest station. Use of a signal telephone sounded a bell and the station supervisor would then go and deal with the matter. In practice this was immensely inconvenient. Quite apart from the delay occasioned by getting increasingly scarce station staff of appropriate grade to the telephone, the person answering would then have no idea about the disposition of the trains in the area or the routes either wanted or already set up, creating further delay while enquiries were made (often requiring use of another telephone elsewhere on the platform). The last resignalling scheme where this practice was followed seems to have been that on the eastern end of the Piccadilly line in the early 1980s. In more recent installations signal telephones are terminated in the remote signal boxes or control rooms where direct communication with the signalmen can again be made.

For some years, special conditions applied on the former Met & Great Central line north of Harrow-on-the-Hill, perhaps made rather more special following a serious accident at Northwood in 1945. In particular the line was not equipped with trainstops and numerous main line trains and goods trains operated. In consequence, in 1949, it was decided to dispense with the so-called 'stop-and-proceed' rule. To ensure traffic could be kept moving in the event of failure signal telephones were provided on

a large scale. These signal telephones were terminated on a number of special panels, each of which was equipped with track circuit indications relating to the area covered and each had a '300-style' telephone handset mounted at one end. The whole area between Harrow and Croxley was covered by panels at Harrow-on-the-Hill, Watford Junction* and Watford, though when the boxes were manned panels at Northwood and Pinner were available (these were covered by Harrow or Watford Junction when the intermediate boxes were closed). The installation survived until line modernization in 1962.

From 1964 the painting of cabinets containing lineside telephones began to be standardized in a distinct pattern, according to main line practice. Those intended for use by train drivers to contact signalmen had alternate black and white stripes diagonally across the door of the housing (new telephones had been painted like this for some years) while other lineside telephones connected to signalboxes had a black diagonal cross on a white ground. Lineside telephones connected to other locations were simply marked telephone on a white ground.

From 1938 (following an accident) lineside telephones were also provided in tunnel sections longer than ¾ mile and at a number of current rail gaps, so that a train detained at a rail gap indicator by a dead section ahead, or a long walk from help, could make contact. The initial installation on the Northern and Piccadilly Lines covered 11 current rail gaps and 17 signals within long sections. They were intended to warn station staff that a train had either failed or required passengers to be detrained, or that current had been cut off for over ten minutes and a train was being detained (this was later reduced to five minutes). Several other sites followed later, though in theory Drico rendered further installations unnecessary after the 1950s. The last of these special telephones seems to have gone out of use from December 1988, presumably superseded by train radio.[84]

A final form of trackside telephone worthy of mention is the 'Stanophone'. This was used on the Hainault loop from 1965 when experimental automatic trains began to operate and it was considered that the train operator should on no account leave his train. Amongst the various measures put into place (including 'carrier wave radio, referred to later) telephone sockets were installed at each signal into which the portable 'Stanophone' handset could be plugged. The other end of the circuit connected to the signalman at Woodford. Strictly this was a device more like the tunnel telephone in that the driver had to keep a handset with him, but it was in operation more like a signal telephone (although it could not be used for permission to pass signals at danger unless controlled from Woodford). The 'Stanophone' had a red 'call' button and a black 'speak' button. The drivers of these trains had also to have with them a tunnel telephone handset, as the Grange Hill tunnels were so equipped.

'Talk Back' Loudspeakers

One of the problems associated with getting trains into service from depots is that they can start from any of the sidings. In days gone by drivers (who would have an approximate idea when they would be called to the outlet signal) had to wait until specifically ordered by a shunter to draw forward, which was immensely inconvenient. To help overcome such difficulties some of the larger depots were equipped with loudspeakers so that drivers could be called up without the shunter or supervisor having to move around, much to the irritation of residents nearby. Since the driver might for some reason not be in a position to move his train it was felt expedient to provide some means of responding to a call short of having telephones all over the place, and 'talk back' facilities were tried. By this means a driver was supposed to find the nearest loudspeaker and 'talk' into it, though it is more likely he would shout from where he was. The first installation appeared at South Harrow in 1956, with communication between the sidings and the signal box (at first South Harrow signal box but from 1957, Rayners Lane box). This was followed by a large installa-

* The triangular junction between Moor Park and Rickmansworth was collectively called 'Watford Junction', not to be confused with the main line station two miles away.

tion at the new Upminster Depot in 1958. So far as it can be established these were the only locations ever provided with this apparatus; the next large depot to open was Northumberland Park in 1968 and although it had loudspeakers for a while, one could not 'talk back', as carrier wave radio was available. Thankfully train radio has put paid to the general use of loudspeakers, whether talk back or not.

Breakdown Broadcast Message Service (BBMS)

The BBMS was not strictly a telephone system as it operated only in one direction, but it did use telephone pairs in order to distribute the signal and to an extent it replaced the need for information to be broadcast by means of a cascade of telephone calls, which was not efficient. Getting accurate and timely information to staff quickly has always been very difficult. Experiments began in 1931 with a broadcast system from a microphone within what was described as the Central Control Office (probably Leicester Square) to certain stations. These tests having evidently proved successful the system was installed at several key stations in 1939, in some cases it was then retransmitted to other stations that were not equipped.[85] It has not unfortunately proved possible to determine which these stations were.

The centralization of the control offices at Leicester Square from 1939 provided an enhanced opportunity for the one official who knew everything that was happening to share that information with others on the system, though the war interrupted any progress until things had settled down; after some deliberation it was not until 1947 that it was decided that 'an extended and improved' broadcast system would be introduced.[86] In its 'improved' form the equipment consisted of a number of circuits (nine initially) connected to the control office, each one of which served the major stations around the network, usually on a line basis, or by section of line in the case of the larger lines. At the stations a broadcast loudspeaker was mounted in the ticket offices as these were the one point on the station which would almost always be manned and which also had a

telephone so that the stationmaster could be advised. The loudspeakers were connected to the distribution circuits via local 60-watt amplifiers. The arrangement was very much 'real time'. The Information Assistant at the control office would read his pre-prepared message, usually in his most sombre and ecclesiastical voice, and all the stations necessary would hear it at once. Often the same message was then put onto the Breakdown Message Recorder ('19') so that it could be enjoyed a second time around if not fully understood the first time.

Various code words were used to precede the message in order to alert listeners to the type of message that was going to follow. These were supposed to be written down by the booking clerk and immediately conveyed to the station supervisor who had to record each one in the station log book (as well as acting on the message, of course). This was wonderful in theory but was fraught with practical difficulties as well as the vagaries of human nature. The system is still very much in use and in the absence of any better method of communication does work after a fashion. Since the advent of station control rooms many have also been fitted with BBMS apparatus. The loudspeakers also pronounce the hour by

means of a gong-like noise which, apart from being useful for checking the time, is an indication that the system is operative.

In its 'improved' form the system was introduced in 1948 and at first only 29 stations were equipped, presumably these included some of the pre-War locations. At most remaining stations it was expected that staff at an equipped station would telephone the message to one or more predetermined non-equipped stations, and they, in turn, would pass it on to a final tier of quiet stations. By 1950 the majority of stations had been equipped and only 20 had to retransmit messages to other stations (many of which had to retransmit to others and so on — the maximum number of retransmissions was four).

Lift telephones

The high speed lifts at Hampstead (numbers 3 and 4, installed during the 1950s) were each equipped with a lift telephone mounted behind a paper seal and intended to allow a lift operator (or, by invitation, a passenger) to communicate with the ticket office. The ticket office could also make a public address announcement to the lift, via a loudspeaker in the car. A magneto telephone was also installed at both landings so that staff could co-ordinate their activities if the lift was in trouble (but there seems to have been no link to the telephone inside the lift car).

All modern lifts (ie those installed during the 1970s and later) are equipped with a communication system allowing conversation between any combination of the fixed stations (each lift landing and the machine room) and the relevant lift cars. These are essentially electronic intercom units. Each 'station' is equipped with buttons to select the 'station' to receive the call and a 'send' button to be depressed while actually speaking. Calls are confined to use by staff and cannot be initiated from within lift cars (passengers have to use the alarm button to attract attention, but can speak to staff initiating a call after silencing the alarm bell).

Platform information points

Also having the essential elements of a telephone system are the platform information points around the LUL network. These became possible once the decision had been made to introduce station operations rooms that were normally manned. An experimental operations room opened at Holborn in December 1962 and several passenger information points (PIPs) were installed around the station, each mounted in a contemporary sound-deadening hood. A passenger requiring information called the supervisor by pushing a button and then spoke into an intercom microphone; the supervisor's response was heard through a loudspeaker. The system was later extended to Russell Square, though this was still connected to the Holborn operations room. Deemed successful the idea was introduced on the Victoria Line, though at the quieter stations the operations room equipment was installed in ticket or supervisor's offices. The Victoria Line system received considerable publicity when the line opened but the PIPs fell into some disrepute through unreliability and lack of staff to respond

Although PIPs were slow to be rolled out any further, at least partly because few stations had a staffed operations room at which to terminate the equipment, there were isolated instances. Most obvious were some stations at the south end of the Northern Line were crime levels were higher than average, and public perceptions of crime (much larger than actual crime) had risen to such a level that specific action was called for. As early as 1975 CCTV cameras were installed at Clapham North and Clapham Common; these were monitored from the Operations Room at Stockwell (already provided with CCTV and an operations room as part of the Victoria Line project), and Brixton, another troublesome station, was also monitored by CCTV. A specific crime prevention initiative was introduced in the early 1980s and covered all stations Clapham North to Tooting Broadway (Stockwell was already fully catered for). As part of this, new or additional CCTV was installed throughout and PIPs were installed at each of the stations. As most stations did not have an operations room,

so-called focal points were constructed where they were highly visible, and these were normally manned by the supervisor and provided facilities to monitor the CCTV. PIPs were for the first time provided with alarm buttons which sent a warning to the Focal Point which if not answered within 10 seconds transferred the warning to the BT Police station at Stockwell. The operation of the alarm also directed the local CCTV camera onto the PIP and started a tape record. The PIPs also included provision for making simple enquiries for information via a 2-way loudspeaker system.

Over the last decade or so PIPs have enjoyed a revival around the network at a wide range of stations, and seem likely to increase in number as funding permits. The main spur for this is that many stations now have operations rooms that are staffed most of the time, and PIPs are seen as a useful means of improving customer security and can also incorporate fire alarm call points that have to be provided anyway at below ground stations. Concentrating all this in a single unit is seen as beneficial, especially as they can be monitored by CCTV. The fact they can also be used to give information is also felt helpful on a busy system where not all platforms can be staffed throughout the day.

In its present form the passenger equipment is mounted in a large wall-mounted white pill-like unit which also contains a fire alarm and emergency button as well (expansion of the system and high reliability is sometimes adversely affected by lack of serviceable telephone pairs).

Public Telephones

Telephones available to the public deserve a mention for several reasons, not the least of which is that for many years they were available to staff as the means of communication of last resort in the event that the internal system failed; in addition, they had access to the outside world which very occasionally staff needed to use.

Speaking generally, telephones available to the public at large were first authorized by the GPO in 1884. Originally such telephones were fixed in 'call offices', or, to use a less oblique name, a private booth, some of them even equipped with an attendant. To ordinary people living in the twenty-first century they are simply 'payphones'; this far more directly states their purpose, which was to make money firstly for the telephone companies and in turn for the siteowners. For this purpose there had to be a means of charging for use of the apparatus. An attendant could make the necessary financial exaction, of course, but where none was provided (which rapidly became the norm) then some sort of cashbox had to be provided, for a while this was sometimes a coin-in-the-slot door lock but the more elegant arrangement was to link the cash collection arrangement with the telephone itself. By the early days of the twentieth century this could be done in a way where the exchange operator could remotely monitor payment; later arrangements improved on this such that local calls could be made automatically for a fixed fee (culminating in the famous 'button A – button B' coinboxes), and from the 1960s more modern equipment allowed all calls to be made automatically with the coinboxes capable of dealing with varying call rates, call distances and call lengths with no operator intervention (and later still they accepted pre-paid telephone cards and credit cards, though not necessarily all combinations on the same instruments).

The date of the first use of a public telephone on the London Underground is unknown. Railway stations were an obvious early location for the siting of a public telephone but there were some logistical problems. For a start the noisy background was a potential problem for the comparatively inefficient equipment of the day. A practical solution was to place a public telephone in a wooden compartment with a door on it to help keep noise out (these were officially referred to as 'silence' cabinets). At any rate it does not necessarily follow that at the early London Underground stations there would have been room for such things, though the site rental revenue would have been attractive. Detailed information has not yet emerged, but from photographic evidence it does not appear that even the busier and more commodious stations on the Metropolitan and District Railways had

call offices, even at the beginning of the twentieth century.* The new tubes do not appear to have had public telephones at the outset either, though by 1907 there are references to telephone boxes at stations[87] and photographs clearly show that they were being fitted on a considerable scale; by about 1912 it is difficult to find photographs of stations without the familiar external telephone sign. Most telephones appear to have been provided by the NTC, though the CSLR appear to have entertained at least one set of Post Office equipment at Euston.

Public telephones were nearly always provided in station ticket halls where they were accessible to the public at large. Although there were telephones fitted into individual cabinets the bulk were fitted in ranks of wooden silence cabinets, which had a folding door arrangement, and which are so familiar in old photographs of stations — these were usually arranged in ranks of two or more. Some of these ranks of cabinets lasted over ninety years though they all lost their doors in the late 1960s, by which time modern equipment could better win the battle against external noise.

An interesting insight into the problems created by accumulations of cash in telephone boxes is found in Metropolitan Railway records which recall that in the early 1930s the GPO was so worried about the volume of theft that they were minded to fit vulnerable cashboxes with alarms. In 1932 the GPO already had some of these devices on the London, Midland & Scottish Railway and sought to persuade the Metropolitan to have some on their own stations but wanted staff to detain anyone in a kiosk when an alarm went off. The Met's general manager mused on the time it would take to rebuild the damage done if an innocent passenger were wrongly apprehended if an alarm went of irregularly (he regarded them as inherently unreliable) but agreed to a modest programme of installation and gentle encouragement of staff to co-operate by pointing out the GPO usually offered a reward for successful prosecution. The sites chosen were regarded as secret, but the GPO was very keen to install its equipment at Goldhawk Road and it likely they did so. The results of this enterprise are sadly unknown, but it is improbable that London Transport would have perpetuated support for direct action by staff. Theft from cashboxes remained a problem for many years and modern equipment either accepts no cash or is heavily armoured.

When post-payment equipment was installed on a large scale (in the late 1960s) and where telephones were resited, or new equipment installed then a variety of acoustic hoods were provided, rather than a cabinet. With the advent of more modern electronic equipment from the 1980s hoods were regarded as unnecessary and standard fittings were designed for use on LUL which included a small floodlit information panel. Telephones were rarely installed at platform level until recommendations following the Kings Cross fire suggested that one should be installed on each platform. As new electronic vending machines were being installed at the same time a telephone bracket was devised by which means a telephone could be mounted on the side of the vending machine rather than requiring a wall fixing; cabling for the telephone was incorporated into that for the vending machine. To avoid cash handling difficulties all platform phones accepted pre-paid telephone cards only. Until about 1994 all station telephones were provided by the PO (or BT) but since then there has been a policy of allowing other operators to install equipment at ticket hall level. Telephones have generally been kept up to date and from the end of 1999 a number of BT 'Multiphones' were installed which incorporated touch screens by which, for a price, the internet could be accessed.

As part of London Transport's contract for provision of platform telephones arrangements were made for special codes to be dialled which would route calls to, for example, a station operations room. This facility has not been heavily used as other projects have provided dedicated intercom equipment that includes fire alarm call points and a button for non-fire emergencies. Trials have however been undertaken at a few stations where the facility has been enabled and local signs (stating either 'Help Point' or 'Information Point) erected to advertise the feature. The

* The earliest photograph seen of an external sign is that of Chiswick Park in 1906

signs requested customers key in the code '**5' to communicate with staff, and the experiments were conducted at Turnham Green, Stamford Brook, Ravenscourt Park, Chancery Lane, St Paul's, Bank/Monument, Euston and Goodge Street for a planned 6-month period beginning in April 1995. This used BT's 'featurenet' facility, which routed the calls back to the station control room that had been pre-programmed. A comparable idea was tested for six months from 30th July 1998 from BT ticket hall telephones at Arnos Grove, Manor House and Wood Green, this time making a free connection to the LT Travel Information Office.[88] In this configuration a special button was provided next to the telephone concerned. Although both concepts showed some promise it was not of sufficient magnitude to attract the budgetary attention necessary at the time.

An unusual public telephone exists at Earls Court, just outside the entrance in Earls Court Road. This is a modern replica of an old Police Telephone box provided in April 1996 as part of a joint local crime initiative between London Underground and the Metropolitan Police. It contains modern communications and surveillance equipment as well as the customary (free) public telephone to a local police switchboard. Apart from the geographical link with the Underground may it be noted that it was actually constructed by London Underground at their Lillie Bridge workshops to an original police design.[89]

Mobiles

Ordinary mobile telephones for use on the Auto network were not issued, as the necessary base station equipment is not available. However at certain large stations staff were provided with special hand-held radios which can be patched through to a particular Auto line and which have keypads which allow outgoing calls to be made as well. This saves time having to find a fixed phone in order to talk to someone or gain information, and also means the supervisor is always easy to find wherever he is on the station.

Special codes are also available on the Vodafone and former Cellnet networks (only) which allow callers (usually staff or contractors) to dial straight into the Auto system and to enjoy low connection charges, but to prevent unauthorized access each mobile number requiring this facility has to be explicitly enabled by LUL telephone services.

Under the subheading *'Connect'* it will be seen that new technology now makes it possible for most operational staff to access the telephone system using the handheld units.

Control Teleprinters

The increasing importance of the railway control offices information hubs gave rise to a need to transmit a summary of events to other offices within the companies that had a need to know what was going on. There were a number of these and during the 1920s the task of constantly having to make telephone calls to them was beginning to become onerous an inefficient, especially with the network expanding. The idea emerged of broadcasting the information on 'tape machines' of the sort used by newspapers and in clubs, which is perhaps where the idea came from. During the summer of 1928 some 18 tape machines were deployed around the system in a number of offices from which staff could read the 'news' shortly after it happened;* the information was entered at the control office at Leicester Square.[90] Four years later the number of machines had risen to 20.†

By the 1950s the equipment had been updated, with nineteen Creed No. 7A Page teleprinters now connected to the network, and with the extension terminals reshuffled to reflect office moves. Two transmitters were provided in the control office at Leicester Square.[91] By the early 1970s the equipment had been updated and the transmitting was undertak-

* Six were deployed around the general offices, one in both of the control offices, four in the rolling stock depots, one each in the signal, permanent way, chief mechanical engineer and Lift & Escalator department offices, one in the power house control room and one in the rolling stock superintendent's office.

† A useful but brief article is given in TOT Magazine April 1932.

en by the Information Assistant in the Headquarters Control office. The system is still in use today, though further updated with modern printers.

Clocks

On any rapid transit railway the clock will rule. All the early Underground lines had clocks. All were clockwork and needed winding and keeping to time and by and large this was all less than entirely satisfactory. The ideal arrangement was to have only one accurate and conveniently sited clock to fuss over, with less complicated timepieces everywhere else that automatically copied this main clock – an arrangement called master and slave. The arrival of railways that had telephone lines facilitated the introduction of this arrangement, which eventually came to dominate the Underground.

The Central London Railway used Standard Time Company's clocks (at least in signal cabins) and these received an hourly synchronizing pulse from Greenwich Observatory, almost certainly using telephone pairs connected to the STC's own network. The Metropolitan used the Magneta system which involved local wiring around stations (perhaps shared with telephones) but with no connections between stations.

The Yerkes railways were great master-slave enthusiasts and used a system by the Self-Winding Clock Company (of America). This utilized a master clock at Lots Road power house connected by telephone pairs to all tube stations and the busier parts of the District, with stations grouped together in batches of up to twenty on each single pair. The telephone pairs carried hourly synchronizing pulses from the master clock to the slaves, and the latter were electrically-wound clockwork devices which could be corrected hourly when the synchronizing pulse operated a solenoid that physically dragged any errant minute hand to the correct position. In later years the master clock was moved to Earls Court (it was certainly there by the Second World War). The same system was also extended to stations on the Edgware and Morden extensions when they opened in the 1920s. The Metropolitan Railway had used master-slave arrangements at central area stations but from early LT days the Magneta station 'master' clocks were replaced by Synchonomes which were themselves linked to a master clock at Earls Court, which almost certainly required the appropriation of at least one telephone pair.

As this dissertation is about voice communications and not clocks it is not proposed to say more here, except that telephone lines were used for synchronization and after the construction of the automatic telephone exchanges they emerged as good locations into which to place master clocks. In the late 1920s the instructions for the tube lines required officials in charge of stations without synchronized clocks to ring up the Leicester Square exchange for the correct time twice a day so their clocks could be checked (in the automatic era the Information Assistant was the contact point).*

There were other types of clock used to regulate the train service, including headway clocks mounted on station headwalls, and headway recorders in the control offices which record the passing of trains at specific locations; these are also users of telephone pairs.

At many more recent stations only slave clock dials were provided which relied on receiving a pulse every half minute from a suitably located master clock in order to move the hands. As a former user of the electro-mechanical telephone network I can testify that it was possible if one was on a call to hear a 'clunk' every half minute as a clock pulse was sent down an adjacent telephone pair.

Foreign Cables

It was mentioned towards the beginning of this book that in the early days of the Underground the value of the rights of way to the major telephone companies was not lost to railway managers, and a lucrative source of income resulted. Nationalization of the companies under the

* The transmission of the correct time was always regarded as important and on some omnibus circuits the exchange operator was required to send a daily time signal using a special bell code. Staff today can ring up the speaking clock if there is an urge to know the precise time.

Post Office eventually scotched that, as the GPO preferred to embark on the construction of extensive under-street ducts using their statutory powers.

The First World War demonstrated that aerial bombardment would be likely to damage cabling just beneath the street and as the destructive power of bombs went up alarmingly it eventually dawned on the GPO that important circuits could usefully be protected. It is reported that from the 1930s a number of circuits began to be placed in some of the deeper tube tunnels for protection.

With the Second World War looming the process was accelerated but in 1940 a systematic scheme was begun for a hardened network that involved laying 250 miles of cable, no less than 116 of which was in tube tunnel.

In due course the GPO embarked on the construction of its own tunnel network and the value of the tube system to them significantly reduced (one tube tunnel was damaged during the War and the severed GPO cable proved difficult to repair). The advent of radio telephony effectively sealed its fate.

More recently the de-liberalisation of telecommunications meant the loss of the GPO monopoly and the need for competitors to have their own cable systems (they do not use BT ducts). LUL have thus made available its tunnels again for the use of telecommunications operators and (in conjunction with its own road ducts) this provides a very useful source of income. Cables are generally fibre optic but even so the small size of its tunnels and the congested cable hangers mean the opportunity is limited.

Organisation

In common with other railway networks the internal telecommunications requirements of the Underground were for many years specified, installed and maintained by the staff in the signal department. On other railways such a department would have been called the Signal & Telecommunications Department (S&T dept) but on the Underground it was always just the 'Signal Department' or (using LT's peculiar affectation for personalizing the departments of their chief officers) the Department of the Chief Signal Engineer. The cost of the provision of internal communications was never broken down by user; it was historically borne by the Signal Department as part of their overall budget allocation.

External communications were always the province of the direct labour force of the National Telephone Company or the Post Office, who installed the lines and switchboards connected to their own systems. Until 1912, when it was absorbed by the Post Office, the NTC was the older and larger telephone operator in London and such was the impact it made that outside telephones were often referred to as the 'National' until as late as the 1950s. In terms of specifying what equipment was wanted by the organization, and who would get what, the job usually fell to the prevailing department responsible for accommodation, for many years the Establishment Office, or the Facilities or Office Services departments. These people also acquired responsibility for dealing with, and reconciling, the bills and financial settlements for PO/BT accounts and agreeing maintenance and fault repair arrangements.

In the 1980s the 'external' communications staff became increasingly involved in the development of the Auto network as interconnected apparatus was in the offing; this culminated in a specific Telephone Services division which was established within London Transport's Central Personnel Department and this gradually assumed 'client' responsibility for internal telephone systems as well as external, although signals staff still undertook or commissioned routine technical work. From 1992 Telephone Services staff took a much higher profile in planning the long term development of the entire telephone network and became involved in the business cases for even direct line systems (scrutiny of the existing network in the 1990s discovered, for example, unnecessary but maintained private wires such as one between the Southern Region and locations on the East London Line intended for use in connection with through goods trains which hadn't run for over Twenty-five years).

Chapter 8 - Radio Communications

Breakdown system

London Transport is no stranger to radio communication technology, although the nature of the Underground system for many years imposed severe limitations on its application.

A wireless transmitting licence was granted to the LPTB as early as 1947 for what was described as 'railway engineering purposes'. At that time the intention was to carry a pair of 'walkie-talkies' on a breakdown lorry, together with a vehicle-installed mobile transmitter/receiver. Before this system was brought into use a number of trials were conducted to identify the optimum configuration of equipment, and these were certainly being conducted during 1948, during which year the decision was made to install a permanent system[92].

The radio system was formally commissioned on 30th August 1950 when 'Walkie-Talkie' equipment became available for use (mainly) by signal and mechanical engineering staff attending railway accidents or breakdowns so that they might keep in touch with their headquarters either at the scene or *en route*.* A transmitting station was erected on the tower of the headquarters building at 55 Broadway that was linked by landline to the signal engineering headquarters at Earls Court (who was allocated the call sign 'Engineer Transport). From here, direct communication was possible with signal engineering staff or report centre staff could connect the transmitter to an extension on the railway telephone network. The transmitter was of 100-Watt power radiating at 87.225 MHz and was designed for a range of 15 miles, although ranges of up to 25 miles were possible depending on local conditions. This was sufficient to cover most of the area within which the Board's services operated. A second transmitter was installed for stand by purposes. The signals were received by one of the specialist breakdown vehicles despatched to the scenes of incidents and (if staff were already on site) retransmitted on 77.225 MHz at 15 watts to one or more walkie-talkies in the vicinity.†[93] The vehicles could either be used for local communications, or to relay messages to and from the walkie-talkies;‡ the range of the vehicles was about 12 miles.

In the reverse direction the walkie-talkies transmitted at 87.225 MHz and the breakdown vehicle retransmitted the signals at 77.225 MHz to the nearest one of four trackside receivers located at New Cross, South Woodford, Northwood or Hounslow§, from where messages were sent by land line back to the signal report centre. Since the walkie-talkies could hear all messages being sent on 77.225 MHz all users were aware of all messages being sent, both inbound and outbound.[94] At the outset the LT police, permanent way and building departments also had access to the system but there is a question mark over how long these other departments were involved in this particular scheme.

Even in 1949 it was envisaged that radio might be useful for routine departmental work, especially for senior staff who needed to be mobile or who were on call in case of urgent need.[95] By 1953 the signal department was also an enthusiastic user of walkie-talkies during signalling changeovers when apparatus or cabling was being tested, and four such units were available.** In addition some signal inspectors' vehicles were equipped. By this time experience in the use of VHF equipment had shown that it had

* The walkie-talkies weighed 14lb and had a range of a mile. Pictures show the kit comprised an attaché case sized box with separate PO 162-style handset.

† In 1948 the intention was to equip the Signal Engineer's breakdown lorry at Lillie Bridge, the Chief Signal Inspector's vehicle at Earls Court, the Permanent Way Inspector's vehicle at Lillie Bridge, the Building Inspector's vehicle at Parsons Green, the CME Railway's breakdown lorries at White City and Neasden. One signal and two mechanical engineers' vehicles were known to be equipped in 1953, but evidence is inconclusive about any other vehicles.

‡ The vehicle sets were described as 11 valve (six in the transmitter section) amplitude modulation superhets using crystal controlled circuits with automatic gain control and noise reduction.

§ In November 1949 it appears these receiving stations were intended to be at Harrow, East Finchley, Leytonstone and an unspecified site in South London (Clapham was being looked at), but clearly these locations were revised.

** All these appear to have operated at 78.74MHz

some application underground, it being stated that communication was possible up to a mile in tube tunnel. Equipment was also available to the Country Bus and Coach department described later.

By the late 1970s all the old equipment had been replaced by low band VHF equipment using frequency modulation rather than amplitude modulation. A main transmitter and receiver were placed at Hampstead, on the brow of the heath, sharing a GLC mast with equipment for the buses as well. Standby equipment was located at Telstar House, which was (then) LT's tallest building*, considerably dwarfing Broadway. Pocket radios were now available to emergency staff, the signals from which could be re-transmitted via the breakdown vehicles. The Emergency Breakdown organization was enhanced in 1993 when it became part of London Underground's Emergency Response Unit and received updated mobile communications equipment including a control vehicle equipped with radios, mobile telephones, a fax machine and even a television system. The mobile teams are controlled from the response unit's headquarters at Vauxhall.

Carrier Wave

One of the most challenging tasks, and also one of the most useful, has been the equipping of Underground trains with a continuously available communications system.

The first foray into this area was on the Victoria Line project where it was felt that something far better than Drico ought to be possible. However the technology was not then available to use radio signals (which were quickly absorbed in tunnels) and a system of 'carrier wave' communication was developed. This used frequency modulated (FM) speech signals at radio frequencies that were carried through the conductor rails and picked up by the train's power pick-up shoes rather than by an aerial; suitable barrier equipment was used to prevent traction current leaking into any of the equipment. It was not perfect. It was far better than Drico but in service it could sometimes be noisy and could suddenly become unreliable (especially if trains 'bunched' together, where their combined parallel signal paths would unduly reduce signal strength) and it was unusable if the leading car came off power at the long current rail gaps on the Victoria Line, or (most inconveniently) in an emergency when a short circuiting device had been placed across the power rails. It would, however, work with traction current merely switched off. The cab equipment consisted of a special yellow '700-style' telephone handset with integral switch and the terminal equipment was placed on the regulator's desk at Cobourg Street, and in the depot control tower at Northumberland Park. The Victoria Line was divided into four main sections (north and south for each direction of traffic) and the depot, and bonding equipment was provided which allowed the carrier wave signal to bridge any traction section switches that had been opened. In addition to the handset the Carrier Wave signals were broadcast to the cab via a loudspeaker system (which was switched out when the handset was in use). In any event all this pointed the way to the future and demonstrated the value of a continuous communication system.

The Carrier Wave system had previously been tested on the Hainault loop from around 1966, where it was considered a success. Trackside transmission took place at 130MHz and train transmission at 150MHz. Various considerations had led to the final design, which was replicated on the Victoria Line. The system itself was based on its successful use in Toronto which had used a 'Simplex' system (a system where calls could only be initiated by one party, as with Drico). For use on the Victoria Line 'Duplex' operation was considered essential whereby either party could call the other. Tests took place between Roding Valley and Chigwell during late 1964 and confirmed that the frequencies chosen were suitable and that a positive to negative rail configuration was better than either of these to ground. The trackside equipment was linked at intervals with two telephone pairs (outward and return) which conveyed the signals to the Central Line controller's office at Leicester Square. The Hainault loop was

* The building suffered a serious fire in 2002 and was subsequently demolished.

also used to test the production batch of Victoria Line trains when delivered and prior to use on that line, so Carrier Wave capability was a useful adjunct to this testing.

Victoria Line Carrier Wave was finally decommissioned in October 1992 following successful introduction and bedding in of train radio on that line, described shortly[96].

Train Radio

Another feature introduced as new on the Victoria Line was Train-to-Train radio. With only one member of staff on each train it was recognized that special arrangements would need to be made in case a train were disabled, as it was thought impracticable for a driver to fight his way to the rear along a crowded train to call upon the services of the train behind. A calling-on light was fitted to each cab that operated a distinctive light at the rear but could be operated from the leading cab. This called the following train forward. To provide effective communication between the trains two-way VHF radios were provided in each cab, and these too were connected to the driver's telephone handset and were selected by operation of an 'Assisting Train' button. The 'Inter-train' radio, cab-cab telephone and train public address system was designed as an integral system supplied by Nelson Tansley Ltd, and one handset (different from the Carrier Wave handset) served all three functions. The Train-to-Train radio eventually proved of limited practical value and a maintenance liability and was eventually removed (it had gone by the early 1980s).

The Carrier Wave system clearly demonstrated how useful continuous communication with all the trains on a line could be. It was, however, not without some technical shortcomings and was also quite expensive, as it had to be made to LT's own specification without much prospect of other commercial use. Radio, on the other hand, could use commercial available equipment if a means could be found for getting it to work. In addition, the looming possibility of extending 'one-person' operation to all lines created a need for more efficient communications, and in any case Drico was already becoming life expired.

During 1972 extended trials were embarked upon to explore the feasibility of widespread use of train radio on the Underground system. The operation of a train radio system in the open air is comparatively straightforward providing the challenges caused by trains moving between several base stations, the need to share frequencies across the network and the reception problems caused by cuttings are all addressed. In tunnels the least bad solution is for the base stations to radiate by means of continuous feeders along the tunnel. This puts up costs but the result is fairly reliable. The trials took place on the Hammersmith & City Line between Hammersmith and Farringdon, and on the Bakerloo Line between Elephant & Castle and Stanmore*. Together these sections provided the complete range of circumstances to be found anywhere on the Underground. At the time, train radio had been used in New York, Stockholm, Munich and Berlin, but nowhere in the world had radio been used in the deep tube, which was a particularly difficult environment where radio waves were quickly absorbed (and there was little space for equipment). The trials ran until April 1976 on the Hammersmith & City Line, and March 1977 on the Bakerloo.

Four trains on each line were fitted with radio equipment and aerials were mounted on the outside of the driving cabs. The Bakerloo Line trains were fitted with boom microphones and foot switches as the drivers needed both hands for the controls; on the Hammersmith & City Line, where there was only a single control handle, the driver was given a telephone-type handset on a flexible cord. In the open air, transmitting masts were erected at Neasden and Edgware Road. In the tunnel sections what were described as 'aerial cables' were used to transmit and receive signals continuously. The radio signals were terminated on the Line Controllers desk at Baker Street (one handset for each line); at that time

* In each case this involved aerial systems for open air sections and leaky feeders in the sub-surface and tube sections.

the same controller looked after both the lines engaged in the tests so all the equipment for the experiment was conveniently together. At Neasden a second mast transmitted locally within the depot between trains and the shunter so that experience could be gained of such operation, together with the associated channel-changing apparatus. The results showed considerable promise as a result of which the decision was made to fit all the trains on the Bakerloo and conduct a full-scale trial.

The trial equipment installed on the tunnel sections of the Bakerloo Line used Storno equipment, together with various amplifiers and filters, producing a result that was later described as 'expensive'. It was however very much an improvement on the provision of no radio facilities at all. The aerial cables comprised 'balanced' flat twin cable suspended from the cable runs in each tunnel fed by 25-Watt base stations located in the centre of each 2–3 km section. Transmissions were made to all sections simultaneously, but reception involved a 'diversity-voting' system whereby the output was presented from the receiver offering the best signal-to-noise ratio. This setup was found to be not entirely satisfactory. The positioning of the feeder cable was unduly sensitive, giving rise to dead areas if a cable were moved, and reception difficulties could also arise where adjacent sections came together (as the transmitters did not operate at precisely the same frequency). Transmission to trains took place at 165 MHz, and in the reverse direction at 170 MHz. The on-train equipment was fed from the train's 50-volt battery with the microphone again actuated by means of a foot switch. To enable communication to take place with the shunter inside the depot (at Neasden) a channel-change loop was installed on the track to switch the train to the shunter's frequency, the trains picked up the signal from the loops via a separate ferrite aerial under the train. The shunter was provided with a 10-watt base station, the main frequency was transmitted from Neasden at 25 watts. The equipment on the Hammersmith & City Line was broadly similar.[97]

When the full-scale trial was begun in 1977 the existing equipment on the Bakerloo was retained, but the opportunity arose to use something different on the Baker Street to Queens Park section, which had not previously been equipped. Here it was desired to use something which overcame the shortcomings of the earlier installation. It was decided to use a system developed by the National Coal Board whereby a transmitter was connected to one end of a 'leaky' feeder with a receiver at the other end (a configuration tested on the Northern Line in 1976). This arrangement reduced the cost of the amplifiers needed and allowed for the use of interchangeable amplifiers, which was useful in the event of failure. The Bakerloo Line installation continued to operate in the 170 MHz band using frequency modulation. The entire Bakerloo Line system was commissioned from 8th August 1977, and also included the open-air platforms at Queens Park and the north shed. It was not until 1988 that Bakerloo trains operating north of Queens Park (on British Rail track) was given radio communication via an aerial system, augmented by cable from 1991.

It was intended to extend the train radio system to the Jubilee Line when it opened; this would operate between Baker Street and Charing Cross as well as taking over the Stanmore branch of the Bakerloo. With this in mind it was decided to equip with radio only those driving motor cars of 1938 stock which would normally be at the outer ends of trains remaining on the Bakerloo once the new line opened, in other words 33 trains. At the time, the opening of the new line was thought to be quite close but in the event the Jubilee Line did not open until May 1979. In consequence when train radio was commissioned on the Bakerloo in 1977 by no means all trains were fitted. As 1972 Mark II stock (which was to operate the Jubilee) was transferred over to the Bakerloo in readiness for its new role it was fitted with Storno radio as part of the programme, the 1938 stock it displaced being the unfitted trains.

As an aside to the story of the provision of train radio it might be noted that from September 1980 the British Transport Police were issued with 80 pocket radios which could be used on the Bakerloo and Jubilee train radio channels. The BT Police already had radios that were used extensively above ground, but hitherto they had been out of contact as soon as they

went underground. Under this experiment they could at least contact the Line controller in an emergency, and the controller would then contact the police information room using a direct line; train radio did, of course, work in platform areas as well as on trains, but got progressively unreliable as an officer moved into the depths of interchange passages.

Returning to the technicalities, in essence a 'leaky' feeder is a feeder cable where metal sheath or screen is designed to allow a small signal sufficient to operate the train's receiver to 'leak' out along the length of the cable, several quite different designs exist. The constraints were that for a 25-Watt receiver to generate the necessary signal strength of 10 microvolts a feeder could not be more than 740 metres long (700 metres in practice), assuming that one base station fed one end of four cables (one in each tunnel running in each direction from the base station). This arrangement dictated a need for base stations every 1400 metres. The on-train transmitters were 7-Watt.

A tone calling signal was transmitted prior to a call being made in either direction with loudspeakers muted until the tone was decoded. Initially it was proposed that selective tones be used so that trains could be called up individually, but this was never implemented and the only distinction used in practice was to differentiate between a call to any train and a call to any hand portable mobile radio (these were issued to a small number of senior officials). A so-called confidence tone was also transmitted at intervals to give drivers confidence the system was actually working if radio traffic was light.

For the wider rollout the leaky feeder system showed clear advantages over the earlier equipment and was the system adopted. The main practical difficulty was to select frequencies at the base stations which did not transmit to one line signals which could be picked up on another, as this could cause potentially dangerous confusion. This was very difficult as only four frequencies were available for the entire LT rail network, including depots, and only three of these were actually used for train radio. By judicious use of power, coupled with frequency changers along the line, it was generally impossible for confusion to arise between lines sharing similar train numbers. However during certain atmospheric conditions the wrong line could pick up messages and instructions were issued, at frequent intervals, for strict radio discipline to be maintained, which included the need for staff to identify on which line their train was operating. LT came to regret not doing more to adopt radio systems earlier when many more frequencies were available to be adopted.[98] The need for frequent channel changing during a journey and on entering or leaving depots was a complicating factor requiring automatic switching. The frequencies used by the trains at any point were determined by track-based beacons that automatically changed radio channels. The beacons transmitted a 3-tone sequence on a 45 kHz carrier and as the trains passed over them the radio channel would be selected in accordance with the tones transmitted.

By 1984 train radio had just been extended to cover (in addition to the Bakerloo and Jubilee) the Hammersmith & City, Northern and District Lines (by 1983), the East London and Piccadilly Lines followed in 1984/5, and the Metropolitan and Central Lines by 1986.* The cost even by 1984 had been £5.6m and for that outlay had been installed 360km of feeder, 56 fixed stations five control systems and 780 driving cabs. The initial Bakerloo system was upgraded between 1990 and 1990 with new cables between Elephant & Castle and Baker Street.

By this time the possibility of cross talk between different lines and between the LT system and radio users outside London had become serious. Problems were minimized by the use of the tone calling codes used to remove the 'mute' condition of the train and controller's radios. Of the five-tone code (each code position could use one of twelve audio frequencies) the first was used to transmit the intended line, and the second whether the intended recipient was a train or a mobile. This largely eliminated wrong transmissions being received in entirety, but once

* The standard equipment was based on a Storno RA7570 control system with Storno CQF614 base stations.

transmission was in progress crosstalk was sometimes received, but was usually obvious. Drivers could transmit at any time but each microphone was equipped with a red indicator that illuminated if the channel was already in use. On all the later lines it proved possible to extend the distance between base stations to about 6km by installing repeaters every 400m.[99] By the end of the '90s there were roundly 1200 train installations, over 500km of leaky feeder, over 100 base stations and over 1200 repeater amplifiers.[100]

When one-person operation came into use it was agreed that additional safety precautions were required. Of these the train radio network was adopted to detect whether or not a driver had become incapacitated. This facility detected whether the driver's control handle (the so-called dead-man's handle) had been released while the control circuits were operative. After a delay of 90 seconds a warning was sounded and if the warning were ignored an emergency signal would be sent to the Line Controller indicating the train that was in trouble (the train number was obtained from preset thumbwheel switches in the driving cab). Further modifications to the radio system allowed the controller to listen in to the cab microphone in such an emergency, and if necessary to make transmissions which would be switched to the train's public address system.

With the introduction of new trains on the Northern Line in the late 1990s it was intended to convert the radio communications system to operate in the UHF range to provide a comprehensive trunked radio system. This would not be available during the early stages of delivery and what was described as an 'enhanced' VHF system was initially adopted.[101] Alstom introduced a new radio system coincident with its new trains from around 1994.

The last line to receive train radio was the Victoria Line (which had previously been equipped with Carrier Wave equipment, already described). On this line a transmitter at Euston—about half way along the line—fed out in either direction. Two channels were deployed, though normally one was configured for use north of Euston and the other to the south; either could be used as a standby for the other in the event of failure.* Equipment was supplied by Motorola. Both Central and Northern Line radios could also be patched through to the telephone system.

The Central Line was re-equipped with Bosch equipment from 1993 as part of the Central Line project, largely to accommodate the new trains and adoption of the OPO alarm system that was required for one person operation, when introduced. The Waterloo & City Line (which also used Central Line type trains) was also equipped with Bosch equipment. The Victoria and Central Line systems differed from the older ones in that individual trains could be called rather than requiring a broadcast message to be made with the possibility of the wrong train responding. This refinement is referred to as 'selective calling'. In addition train operators do not call the control room direct but send an electronic 'Request to Call' message which notifies the control room of the need for a message to be passed by a particular train; the actual dialogue is then initiated from the control room end. The advantage of this is that a controller already engaged on one call is not actually interrupted, although he is immediately alerted that someone needs to communicate. The new systems also have the facility to patch through sets in the field (whether train or hand-portable) which can be useful in emergencies.[102]

Train radio systems have been augmented over the years, not least by providing sections of leaky feeder cable in a few open air sections where experience had shown reliability to be weak.

Cut and cover sections were notoriously problematic because of distortion which could arise where the feeders could not be maintained within the very fine tolerances required when two feeders (one for each track) were run in a single tunnel. This was finally resolved in 1993 by reconfiguring the feeders so that in any one section they were fed by the same transmitter. Overall system reliability was further enhanced in the late 1990s when 'Intrac' was introduced across the network, using Motorola

* This arrangement mirrored the functional control of the line where one signalman supervised the north end of the line, and the other the south end.

equipment; this was a remote monitoring system that monitored each of the base stations and provided a central reporting functionality.

Station Radio

At about the same time as train radio was being installed on the Bakerloo Line an experimental station radio system was being installed at Oxford Circus station using similar principles. The Oxford Circus equipment was commissioned in 1978, followed by a second installation at Baker Street in 1979. Leaky feeder aerials were installed throughout the station and these fed transmissions to and from base station equipment in the station operations room. A number of hand portable sets were available for the use of station staff when going about their duties. Transmission took place on a frequency not needed for trains running through the area so communications were quite separate. Although these experiments proved invaluable, and the value to station operation was immediately obvious, expansion was not actually very quick as technical issues made comprehensive installation quite expensive.

The next leap forward was the provision of radio equipment at six stations at the south end of the Northern Line in 1987—these stations were not particularly complex and radio was deemed an important part of a vigorous (and successful) crime reduction initiative at that end of the line.* The system employed was the same as that at the two experimental sites, which continued in use. The specification for the Northern Line sites included provision for the BT Police to be able to use their own radio system, and this was enlarged to incorporate BT Police radio at 42 subsurface stations (and was added to the equipment at Oxford Circus and Baker Street.

All the station equipment described so far was designed to operate within the VHF frequency band. However, as installation was progressing it was decided to provide the station staff with station radio at all 42 stations to which BT Police radio capability was being provided. As 8 stations were already equipped with staff radio, this left 34 more to be equipped, but this time it was felt advantageous to provide equipment operating in the UHF band. At about the same time the 42 stations were also equipped to facilitate radio usage by the fire brigade. Bank-Monument was also fitted with a temporary system for station staff usage.

Kings Cross Fire

The serious fire at Kings Cross in 1987 resulted in the government making regulations for the operation of below-ground stations to improve resilience against fire.

The new regulations required all below ground stations to be equipped with radio coverage, in all parts of the station, not just passenger areas, as hitherto. This required a new radio system to be installed at 72 stations and the existing system to be substantially upgraded at the 42 already equipped; at the latter all the fire brigade base stations were replaced. All stations henceforth had facilities for station staff, fire brigade and BT Police. In addition station staff radio (only) was installed at ten stations to which the new regulations did not apply. For operational reasons the system was further modified in 1991 by adding station radio capability in certain running tunnels at ten stations (with 18 more added later). Station radio was later added to a number of surface stations for operational reasons (not equipped with police or fire brigade capability, though this is not usually a problem in the open air). By the late 1990s 158 stations had radio systems installed, 42 of which were at surface level. All VHF equipment had replaced with UHF equipment in 1993-4.

In its final form (before a major upgrade from 2004) the station radio was based on leaky feeder cables (shared with emergency services radio systems where they were fitted). By this means any station hand-portable could communicate with any other hand-portable or the base station, usually in the supervisor's office or station control room. The system was a so-called 'talk through' system where any message that is transmitted is simultaneously rebroadcast to all units so that all parties can monitor what

* The stations were Clapham North to Tooting Broadway, inclusive.

is going on; another advantage is that it increases the effective range of the broadcasts. Some hand-portable units are provided with keypads which allow the member of staff to gain access to or from the Auto network, which is a major benefit when (for example) the supervisor is not in the office where the telephone is situated. In the usual course of events, all station staff were issued with portable radios (where station was equipped), though at the experimental sites it was mainly supervisory staff.

Emergency Services Radio

The BT Police, who are responsible for policing the Underground and main line rail, have had the use of personal and vehicular radios in the open air for many years, but these did not work successfully below ground.

The radio equipment installed post King's Cross fire was extended (and if necessary reconfigured) to achieve the following. Radio reception at every station was achieved using the leaky feeder cable and dedicated radio equipment and conveyed by landline to the radio operator at BT Police area headquarters, and at the same time retransmitted to all portable radios so that all officers could hear all calls. Each time a call was initiated to a police control room a 5-tone signal was transmitted that identified the radio (and therefore usually the officer) making the call, and in addition a further 5-tone signal was injected into the sequence by the station equipment, so identifying the station. At the receiving end the existence of a call was presented to the operator on a display screen together the station and caller identity. A further refinement was an emergency button an officer could press which generated a further tone; this sounded an alarm in the control room and allowed an officer to summon help (the officer and station being shown on the display) without actually having to say anything. On the whole, police officers found this quite reassuring when tackling an incident alone.

The system described, based on Motorola hand portable sets, maintained communication between the force control room in Tavistock Square and surface-operating officers on channel one, with channel two providing communication between the LUL divisional control at Broadway and below-ground officers using infrastructure partly shared with the station and train operational networks (but on different frequencies). These BTP hand portable units with their emergency button were unique to the LUL division.

As an aside, no equipment was provided that connected with the Metropolitan Police network (they had their own system, of course, but it wouldn't work in the unusual event a Metropolitan officer had to descend underground). This was later to be a source of criticism following later incidents, but was at the time expensive, technically challenging and only likely to be needed in extremely unusual circumstances.

We will see later that this system has subsequently been replaced by 'Airwave', which is available also to the main London police forces.

The fire brigade system was also talk through (all officers could hear) but was not connected to a control point, so was hand-portable to hand-portable only. The mechanics for achieving this were constrained by the specification (set by the fire brigade) but the base station had a fault detection facility on it which warned station staff to report it).

Road Services

The first use of radio for LT's road services has been impossible to determine with absolute certainty, but LT claimed that radio was first tried at Epsom races in 1948 following the spring race meeting.[103] This apparently involved two radio cars, one at Epsom Downs near the racecourse and the other in Epsom itself; officials exchanged information about the movement of crowds and regulated the buses accordingly*. The equipment was loaned by the Signal Department and was presumably part of the experimental kit being tested. Certainly by 1950 a pair of portable units was available for use at major events where buses held remotely needed to be despatched to an inspector's instructions in order to handle departing

* But note LT Magazine November 1949 states the cars were located at the racecourse and at Morden station, which perhaps seems more logical.

crowds.* Wider trials were made in the Dorking area in July 1950 in an attempt to reduce queues in an area surrounded by beauty spots where relief buses were frequently necessary. Previously the buses had been despatched by telephone where inspectors had noticed excessive queuing or where conductors reported they were leaving people behind. During the experiment the LT Signal Engineer provided a radio van in the control of a Country Bus division official who would drive around and identify locations at which more people were waiting than the scheduled buses would clear, and radio the Chief Inspector's office at Dorking from where relief buses would be despatched. The system was used not only for local buses but also the three Green Line routes entering the area. The equipment comprised a Pye 10-watt radio telephone (using a 5-valve transmitter and 11-valve receiver) and operated at 27.132MHz. It has not been possible to determine how long the equipment remained in use.†

There was little further immediate development, notwithstanding the inconvenience of roadside telephones which either tied an inspector down or which rang when the inspector was awkwardly disposed to receive a call, such as on the other side of the road.

In 1969 and the early 1970s small scale experiments were conducted in Ealing and West Ham which showed the use of personal, or pocket, radios to be very successful. In consequence 212 such pocket sets were obtained for use in fifteen area schemes around the capital; this was subsequently augmented by further sets to bring the total up to 400 by 1978; the roll-out was very slow because of the difficulties of finding suitable sites for the base stations.[104] The system relied on just UHF frequencies in the 425 (mobile transmit) and 440 MHz (base transmit) bands and a tone-controlled call system was used so that only radios in the intended area would respond to calls, reducing the impact of overlapping frequencies.‡ Nevertheless there were problems when radio traffic was heavy and various measures had to be taken to alleviate the difficulties caused.

At about the same time experiments were undertaken of on-bus radio. Initially routes 74 and 74B were converted and the system showed great promise. During 1972 the system was extended to buses on routes 30 and 76 and during 1973 it was further extended to buses on routes 6, 9, 22, 22A, 33 and 73. All these routes (except 22/22A and 76) were already managed using the 'Bus Electronic Scanning Indicator' (BESI§) equipment which positively identified the location of buses passing the street located scanners to a route controller, who could conveniently take and generate radio calls.[105]

More advanced experiments with radio management of buses also began in 1973 when an experimental route control system was tested on 44 buses on Route 11. This comprised a radio-location system using digital information to transmit the location of each bus to a control room. Relevant here is that facilities were also provided for two-way speech communication between bus drivers and the controller. This was quite advanced technology in its day as speech was controlled by and transmitted over the data channels, a consequence of which was that the controller could call up any individual bus to which he wanted to talk but other buses would not respond. This development does not appear to have been further developed.[106]

By 1975 there had been some small-scale expansion and in May the radio control centre (for both buses and supervisory staff) moved from the Mansion House offices to Pelham Street in South Kensington.[107] Later that summer the GLC approved a scheme to equip buses in areas especially prone to hooliganism and to monitor the results; this envisaged equipping

* These used frequencies of 87.275 and 77.275 MHz. (*LT Magazine*).
† Technical Press Notice 728 (18.7.50)
‡ The system is called 'tone controlled squelch'.

§ BESI was the result of experimental work during the 1950s and relied on optical recognition of coded plates carried on the buses that had been equipped. It initially came into use on route 74 in January 1959. The roadside equipment was linked to the control room by dedicated telephone wires. The equipment was designed and tested by London Transport's electrical engineer (curiously not the signal engineer) and the telephone lines used may well have been private wires released by the telephone modernization scheme. It was extended early in 1961 to routes 6, 13, 28, 31 and 73.

1250 buses at a cost of £875,000. A second stage was authorized in May 1976 for another 1100 buses at a cost of £778,000.

In 1977 LT came to the conclusion that all buses should now be equipped with radios, partly as a safety measure related to the anti-assault and vandalism campaign, and partly in the hope that agreement would soon be reached about using radio for control purposes, although this was contentious, and even using the radio to report mechanical problems was not officially permitted (these practices were highly perverse but were not rectified for some years more). Again this followed tests on a number of routes, all responding to a single control point using a single radio channel. As the system was enlarged, the number of control points was increased to four, one in each of the bus operating divisions. There were various transmitters and receivers around the network, linked to the control offices by land lines. The Home Office allocated frequencies of 106/107 MHz for bus transmit, and 139/140 for base transmit, which presented a particularly large frequency spread and some interesting challenges to the aerial designers (the aerial also had to be fitted in a housing protruding no more than 0.75 inches above the bus roof). A development contract produced a 'twin halo' device (in use by 1973) that proved entirely satisfactory and was subsequently sold commercially; within the aerial dome were two aerial rings, one for transmit and the other for receive. By the end of 1977 some 1500 buses had been fitted and approval had been received for a further 1300.

In early 1979 buses on the 36 group (operated from Peckham garage) were equipped with a second radio channel—a channel quite separate from the existing emergency channel. This second channel was used purely for route control purposes, staff at Peckham fulfilling this function; these officials could also communicate with mobile radios used by officials along the route. All this was regarded as the first stage of a much larger programme, at that time referred to as *Busco* (short for Bus Control and Communication System). Although the additional radio channel proved quite useful it took a little while for the advantages of real-time route control to be fully understood. Nevertheless the decision was made to complete equipping the bus fleet by the end of 1982 with radios that were *Busco*-compatible, though shortage of home-office approved radio channels constrained *Busco* roll-out. *Busco* was also intended to provide real-time monitoring of bus position and its introduction was looked forward to with some enthusiasm (in the short term more inspectors were recruited and equipped with mobile radios).

By the end of 1982 in fact only 90 per cent of buses were equipped with radios, although most of the rest merely awaited commissioning. However, the inspector's mobile network had been upgraded to improve performance. *Busco* in its developed form was introduced in 1983, again on the 36 group of services, on an experimental basis. The ability to track buses continuously and issue instructions to each bus separately via a computer-controlled link was heralded as something of a breakthrough. However a variety of causes conspired to prevent its development systemwide; perhaps a little advanced for its day this entirely LT-specified concept was allowed to rest in the wings for a few years longer.

With bus tendering, and, later, complete privatization of bus services LT no longer owned any buses and bus crews, and each route was likely, periodically, to change operator. Arguably, bus control and staff security was now the province of each of the operators. However LT Buses, who were now the LT network 'customer' for buses judged that for network management purposes they would maintain a central radio control and co-ordination function as LT was far better positioned to make co-ordinated decisions than any of the operators. This central function is known as '*Centrecomm*' and is the effective successor to the pre-privatization bus control office. A corollary of this was that LT Buses would provide the vehicle radios for the buses and the contracts required the bus operators to fit them and use them. In addition LT Buses retained squads of mobile control and revenue inspectors who had pocket radios also channelled through *Centrecomm*. A later (initially voluntary) facility was the provision of an emergency service initiated by a bus driver reporting a 'Code Red' call

to which *Centrecomm* would respond immediately. Arrangements exist between LT Buses and the emergency services to initiate an emergency response to any Code Red call received (via direct lines). The facility is regarded as very useful, as an indication of which it is recorded that simply during 1995 over 58,000 Code Red calls were received by *Centrecomm*, over 150 a day, though not all by any means needed attendance of emergency services.[108]

By the end of 2000 London Transport Buses was making use of over 50 channels on its MPT1327 network, all in the frequency range 201.5 – 207.5 MHz, and had over 7000 users, the vast majority buses and most of the remainder handheld units.

Although the *Busco* project was allowed to die the idea of a real time vehicle location system linked to the bus radio network was very attractive and was resurrected in a newer form in 1987, when technology had perhaps moved on slightly. The outcome was a gradual roll-out of what had now become known as 'AVL' (Automatic Vehicle Location) that could digitally transmit route and running number, location and destination of each vehicle as it progressed along its route. The system was fraught with technical difficulties but worked well enough to allow passenger displays at bus stops to be driven off the computer system with a moderate degree of reliability. The shortage of frequencies continue to dog the system to this day and a upgrade project is currently in hand. The real time passenger display system (called *Countdown*) saw displays introduced from 1992 with current plans looking to install a total of 4500 units.

The AVL element operates in conjunction with roadside beacons, phased in gradually across the network; eventually these will cover all bus routes in the London region. AVL works through battery-powered beacons placed on lampposts along the route. As the bus goes past, the beacons transmit an identity code to the bus. The bus then sends this information, as well as a reading from a 'wheel turn counter,' to a central computer via the bus radio system. This system provides the operator with real-time information on the position of buses and their progress along the road. AVL equipment installation was intended to be completed in 1999 but *Countdown* is running somewhat behind that.

In 2000 the Countdown system was being described as the largest passenger information system in the world.[109] Information for the signs was originally transmitted from the network computer in Chingford by BT using their EPS42 analogue 'multi-drop' service that terminated in convenient exchanges near to the original display locations; distribution panels could serve up to 12 signs each and were linked by local cable. More recently the network has switched to an ISDN solution and by the end of 2000 some 1000 signs had already been commissioned, 60 on the ISDN system but rising very rapidly.

The Connect Project

With the explosion of rapidly evolving technology from the 1970s by the late 1990s London Underground was operating some 130 disparate communications systems that varied not only between lines but also within even the same stations. The outcome was an aging and inflexible network that fell far below the requirements actually needed on a modern railway, and failed to provide links between (say) a train driver and a station operative even on the same platform.

Sorting this out as a single project was thought prohibitively expensive, but with the emergence of the Private Finance initiative during the mid 1990s an opportunity presented itself for seeking a private finance solution. The outcome was the 'Connect' project, worth about £1.2 billion, with a 20-year contract let to a consortium of companies which would take over and run and maintain the existing infrastructure which in time it would replace by brand new infrastructure based on a largely new fibre-optic network; the consortium (CityLink Communications) comprised Racal Telecommunications, Motorola, and Fluor Daniel, in addition to funding organizations. The deal was signed on 19th November 1999.

Connect is a largely network-wide radio system based on TETRA (Terrestrial Trunked Radio) digital technology by which means the capability

exists for anyone on the network to contact (depending on access permissions) any other individual or groups of individuals or even broadcast more generally. In addition the fibre-optic network will facilitate the transmission of data, and of voice communications (such as public address) to and between stations. Each station will have a communications terminal from which a wide variety of services can be run. The plan had been to complete installation by the end of 2004, but a huge number of difficult technical issues arose that somewhat slowed down the plan. Some issues, for example, arose around very recent installations of previous generation equipment on the Northern and East London Lines which were theoretically capable of providing communications services to the latest requirements (as with all PFI's London Underground buys in an ongoing 'service' to specified standards rather than defining specific equipment). The District, Piccadilly and Metropolitan Lines were the first to be equipped.

Technically the system is not wholly unlike cellular telephony, with 290 radio sites (or cells) distributed around the network. Stations are usually arranged as local hubs and handle radio traffic in the tunnels half way to the next station. Between hubs connection is by fixed cables (mainly fibre optic). Much of the equipment is supplied by Motorola (hardly surprising as they are a partner in the PFI consortium. The equipment deployed included new radio equipment in every driving cab, the replacement of fixed station radio equipment and the issue of new handsets available to all station and train staff as felt necessary together with mobile management staff. Various other groups of people such as engineering and incident control staff, and other mobile staff such as revenue protection and security staff could also be given *Connect* radios to replace their own previously self contained systems.

Connect brings many benefits. For example a train driver no longer has to leave his cab in order to use trackside telephones to gain information, and appropriate levels of communication can be established between any number of people between whom communication is necessary, both for routine work and in emergencies. The new system will also support telephone and data services and text and video transmission, and there is considerable spare capacity available. There are, however, no immediate plans for the LUL-owned telephone service to be fully integrated into the new scheme, though interconnection will be possible and the widespread availability of radio is likely to have an impact of some sort. *Connect* also has to accommodate the frequencies of other organizations which have business on the Underground.

The introduction of the system was fraught with difficulty as legacy systems had to be maintained fully functional until the new system was proved and fully commissioned. This was a particular problem in the cramped environment of a tube driving cab. The system was installed line by line (sub surface lines first) and was substantially complete by the end of 2008. The last station to be switched over was London Bridge, on 26th January 2009. Altogether *Connect* has replaced 20 separate radio systems. Data is transferred at up to 2.4 gigabits per second and has 30 per cent additional capacity available to make it reasonably future proof.

Airwave

The threat of terrorism in London, coupled with the need for the Metropolitan Police to take a lead role in the event of a threatened or successful outrage, increased the pressure for Metropolitan and City of London police officers to be able to use radios underground. The modernization of the radio system via the Connect project was to facilitate this.

The funding came from a National Police Improvement Agency which was sponsoring a common radio system for all forces in the UK called Airwave, available above ground since 2005. The NPIA worked with CityLink and the Connect project team to identify how the Underground could be included in the project, to ensure the national specification could accommodate it and that equipment suppliers could deliver suitable equipment.

Installation of the equipment to 125 sub-surface stations began in 2007 and was completed in October 2008, after which a testing phase began. The equipment was officially commissioned on January 14th 2009 at a cost of £107 million; this is not inexpensive kit but it does include funding of its operations until 2018 and replaced some life expired equipment. The system is totally secure (high availability, encrypted signal and accessible by licensed users only) and has much greater configurability than the equipment replaced. In addition the fire brigade and London Ambulance service have access to the Airwave system. Technically the system uses the same Tetra protocol as Connect and where possible shared base stations were used.[110]

APPENDIX ONE

Recollections of an earlier age

A — Telephones

Article published in London Transport Magazine October 1947

DIALLING XRL ....

When you do this, do you remember that London Transport's vast private telephone system equals the whole Post Office network in a town the size of Brighton ?

Before the war, there were separate telephone systems for the different services of the Board. In 1940 all were linked together. To-day the system embraces no fewer than 29 exchanges, serving between them over 4,500 phones. It is now possible for practically any two places in the Board's area of 2,000 square miles to be connected together, for our own telephone wires radiate from St. Albans and Chesham in the north to Guildford and Reigate in-the south.

But the possibilities of the system go far beyond that. There are direct connections linking the London Transport network with the main line railways. For instance, for the Southern Railway you dial XSO.

The efficient working of the Board with its many services owes not a little to this intricate telephone pattern. To maintain it calls for the full-time work of no less than seventy-four members of the Signal staff.

The exchanges comprise four at principal offices, Broadway (XHO), Chiswick Works (XCH), Acton Works (XAW) and Baker Street (XBS), ten on the railway system, of which XRL-8 (Earl's Court) and XRL-4 (Leicester Square) are perhaps the best-known, nine for the road transport side-including Camberwell (XCL), Manor House (XMH), Shoreditch (XSH) and Oval (XOB)-and half a dozen small manually operated exchanges. The nerve centre of the whole system is the virtually unknown " Tandem X " exchange. This is at 55 Broadway and serves as a miniature " trunk exchange " between the others. When a person at Acton Works (XAW) dials another at Baker Street (XBS) his connection is made via this Tandem exchange.

Certain busy exchanges have also direct connections and callers need not go via Tandem unless their direct line is engaged.

Dialling on the London Transport phone system is kept as simple as possible. For the Leicester Square information desk, railwaymen dial " INF." Other numbers are even simpler. For example, persons wishing to speak to the Railway Traffic Controller dial " C ". " CE " also brings the Controller on to the line, but ii this case the " E " stands for " emergency " and cuts across any other caller who may already be connected. Its use therefore, is necessarily restricted unless one wants an irate Controller on the line !

In some respects London Transport's telephone service is superior to the G.P.O's. It is possible for instance, for a person sitting at an office desk at Earl's Court to dial the Chesham signal cabin direct on his automatic instrument. On the G.P.O. system, Chesham has to be obtained through the " Toll " exchange.

Another remarkable fact about the system is that a tram or trolleybus man can, in an emergency, speak to the Traffic Controller on a telephone fitted to a roadside feeder pillar, that is, the pole which both supports the overheat wires and carries the current cable. By lifting his roadside phone, he is in immediate contact with the whole London wide network.

Widespread as the London Transport phone network already is, increased services are calling for still further expansion. Soon the thirtieth exchange, one of the railway group, situated at Loughton, will be opened.

B – Our Hello Girls

Article published in London Transport Magazine March 1948

"Hello! Is that Abbey 1234? Can you tell me…?"

THAT is how the day begins and ends for the thirteen head office telephone operators in the private branch exchange quietly tucked away on the first floor at 55, Broadway. They are the "human element" behind that legendary telephone number ABBey 1234, which to most Londoners is as much a household word as the name London Transport itself.

These "Hello Girls" form a small but very important part of London's transport organisation and are very proud of their reputation as one of the most courteous switchboard teams in London.

Callers frequently have to be asked to "Hold on please" because the extension is engaged. If the wait is prolonged they get a reminder that they have not been forgotten -"Sorry to keep you. Hope they won't be much longer now." And then "Putting you through now. So sorry you had to wait."

Simple phrases, but they make the caller feel happy. Many callers write in to express their appreciation.

The number they serve is undoubtedly the most publicised number in London. Nearly every bus, tram and trolleybus has its poster inviting the public to write or call at 55, Broadway for travel information or phone ABBey 1234. It appears on timetables, maps and pamphlets. There is probably only one number that is better known - WHItehall 1212, the telephone' number of Scotland Yard.

The public response is great. An average of 2,100 incoming calls are handled during a day. Duties are staggered between 7.30 a.m. and 10 p.m. so as to have nine girls on duty during the busiest parts of the day - 9.30 a.m. till 12 noon and 2 p.m. till 5 p.m. After 10 p.m. a male night duty operator takes over.

One of the essential qualifications for this job is a good memory-operators have to memorise many hundreds of names of officials and their, assistants. There are 400 extensions serving a staff of 1,400. Catch question for the girls comes when they are asked for Mr. Smith, for there are fifteen in the building-each luckily having different initials.

Operators are also chosen for their absence of fuss and fluster. Getting flustered is something that must not happen when shepherding up to six callers at one time. They need, too, a good idea of the work done by every office, for many callers have only a vague idea of whom they want.

Miss Griffiths, supervisor of the exchange since 1936, explains that inquiries form 40 per cent of the incoming calls. "Our busiest periods," she says, "are always just before Bank Holidays." A delay in the services or foggy weather also set the lines humming with irate passengers who wish to state their grievance. But the operators are always polite and put the callers through to Public Relations.

Miss "Bobby" Labrom, who has been on the head office exchange since 1927, says ; "I well remember an incident in those early days when we answered 'Underground' to callers and not 'London Transport' as now. A very sarcastic caller replied: 'And that's where you ought to be.' "

She continues : "It is an interesting job, however, with never a dull moment. I have been asked to find everything from false teeth to a bouncing baby boy".

Miss A. Allday was trained by the Post Office and came to London Transport in 1942. She claims that the strangest feature of the job is that she has come to know hundreds of people by their voices only. " I find that quite unwittingly I build up a picture of the individual from the voice," she says, " but on occasions have experienced a sharp surprise on meeting the person concerned. It is not always the big portly man who fits with the deep-toned voice." The operator with the longest service Elizabeth Swanson. She started in 1918, when there were only four at the board. Helen Boulton and Ivy Jeffs both graduated from Earl's Court railway exchange. And, of course, there are eight others.

There is no limelight for any of the Broadway girls or for their colleagues at Griffith House, Baker Street, Chiswick, Acton, and elsewhere,

for they are doing an ordinary job of work - an ordinary job but a most important one. We thought you would like to hear about them!

C. Usage of the telephone systems, including HO and RL, in practice.

(Recalled by Peter Provest who was with LT 1948-1996)

Some more background 'trivia' detail from me, based on my head office administrative experience in Railway Operating at 55 Broadway from 1948 to 1963. By the late 1940s, post-war, period, a typical 55 Broadway administrative office of around 12-14 persons, including two supervisors at Senior Clerical Assistant or, more rarely, Executive Assistant grade, would have been very poorly served with telephones indeed compared with more recent times. There would be two telephone 'positions', one at each end of the office, with telephones on 'telephone tables' (small units about two foot square). These would be positioned closely to (but telephones not therefore on) the supervisors' desks, so that the supervisor could pick up a telephone directly. Two telephones on each table, both of the 'candlestick' (separate earpiece) type, but the HO instrument had a rotary dial which always seemed to have been 'awkwardly' fixed to the base of the telephone. (Were these 'add-on' modifications to what were basically 'non-dial' instruments?) Lifting the earpiece on the other telephone gave immediate connection to the 55 Broadway switchboard operators, and any outgoing call had to be asked for by its external number (woe betide anyone who was not ready with the exact required number!). Asking for any 'unusual' number (e.g. that of a passenger with whom one had a season ticket query) invariably brought the enquiry: "This is a business call isn't it?" before the call was connected. In such cases it was also likely that the operator would 'listen in' (one heard the line being opened) during the call. If some luckless person had bluffed the operator into connecting a 'personal' call, there would be a cry from the operator of "This is a personal call!"—followed by immediate and peremptory disconnection.

Although the telephone tables were positioned primarily for the convenience of the supervisors, it would be the more junior clerks who would be more likely to need to make the greater volume of calls in the course of their work. Thus each telephone table received 'high utilisation' by a procession of clerks who each awaited it becoming vacant before going to the end of the office to place call(s). There was (deliberately) no chair at the telephone table, so it was necessary to make calls whilst uncomfortably standing up and making notes on the relevant papers. Of course one was also right alongside the supervisor and well within his earshot, and it was another common practice, following completion of a call for the supervisor to comment or criticise on the way the call had been handled at this end. If, in office conversation, it was ever necessary to refer to the two telephones and distinguish between them, the unit connected to the switchboard was always still referred to by all older staff as "the National". (i.e. referring to the long defunct National Telephone Co.), the term "the Post Office" not coming fully into use until around the mid-1950s after all such staff had finally retired.

A majority of calls from Railway Operating needed to be made to stations, depots and other railway locations such as Lillie Bridge (stores, etc) so RL destinations were those most commonly required. In the early years, before we had a separate RL telephone of our own, I have clear recollections of how difficult it was to place a call to an RL number (thus 'XRL' prefix) from the HO telephone. After about 0900hrs each morning a high proportion of attempted calls would receive the 'engaged' signal immediately on dialling the `X', so by this date the head office connections to the Tandem were clearly inadequate to meet demand. In the office where I worked this was eventually improved by around the mid-1950s, when a near "clerks' revolt" over the wasted time and difficulty in making calls to stations resulted in a spare RL line being found off Leicester Square exchange, thereafter we had three telephones on one of the telephone tables, but at least it was now easier to place calls. As a very small aside, it would appear that when HO numbers had very first been allocated in the

immediate pre-war period, some effort had been made for the extension numbers to coincide as closely as possible to the wing/room numbering in which they were located. There was always a strict geographical protocol for room numbering in 55 Broadway (e.g. rooms n10 to n19 always to be found in the South Wing of a floor). Of course even by the late 1940s telephone transfers and reorganisations had virtually destroyed this 'system' of coincident or near-coincident telephone extension numbers (though the tiniest remaining vestiges of the policy can still just be discerned in some numbers that are still in use today).

D. Reminiscences of the LT network
Recalled by Desmond Croome

I certainly have some memories of using LT internal and external telephones. The internals had 'XOB' 'XOT' and 'XRL' "exchange" letters to gain access to the separate systems. The road service networks were via manual exchanges (Oval ?) and were principally designed to connect roadside telephones to control. There was later a major scheme to replace all the roadside telephones by individual GPO numbers, but presumably locked boxes and keys issued to individual officials were the only method of preventing misuse.

There was a complicated method of getting through to Chiswick Works via either the 'XOB' or 'XRL' networks. The simpler method was to go via the Broadway and Chiswick private branch exchanges. The 'XRL' system could be used to gain access to the main BR exchanges, and thereby all parts of BR if one had a directory.

I can remember the introduction of '19' to access a recorded message on Underground delays, presumably recorded by the controllers. One of these sounded as Himmler would have sounded if he had spoken English.

On the GPO extensions to offices at 55 Broadway, we normally had to go through the operator for any external number, presumably to prevent private calls. This was most frustrating when one had to arrange a meeting with several different officials in external undertakings, and to find a common convenient date and time. Following the law of natural cussedness a new system of direct dialling from extensions came in in virtually the very week when the work of arranging meetings was devolved to bus Districts. I can also remember a system under which one could have urgent private calls if one agreed to pay later. A little man from the Establishment Office came round offices once a month to collect the money for these calls, but his list of calls gave rise to much head-scratching and argument.

I heard stories of a tremendous row between the LT signal department and British Telecom (or its predecessor) about an LT attempt to link the internal and external systems at Telstar House, which meant that the two systems had to be separated. I cannot recall reading anything official on this.

Another feature (of the telephones in offices at 55 Broadway) was the possibility of putting down an Auto handset on a G.P.O. 'cradle' thereby cutting off a colleague's call, which gave rise to cries of anguish etc (or the opposite way round). When the more modern system was introduced, it was possible to 'take off' a call ringing on another extension. In an open-plan office the constant ringing for an absentee was a nuisance, and when the 'other side of the office' was occupied by staff one did not know at all, we sometimes 'took off' the call and cut it off. The caller usually returned shortly, so the action did not do us much good, and the best course was to tell the caller that the person was absent. There was also a feature in the new system to follow one round a sequence of offices, when visiting,

Finally, a switchboard operator would apologise profusely for the number required being engaged or unobtainable, (which was not her fault) but never for cutting you off (which might, of course have been the fault of the far exchange, or technical.) what happened then reminds me of what happens now on the BBC radio for outside broadcasts. Perhaps they buy their lines at cut prices.

E. Reminiscences of the LT network
Recalled by Brian Austing

At Manor House about 18 people worked on the Bus Operating administrative staff in a long room on the first floor a bit like an old school hall. Of these about 14 were on the Staff Section dealing with the allocation of conductors, drivers, supervisors, etc. I was allocated there when I started with L.T. in February 1961, but found the work rather boring (buses were hardly ever mentioned). I was desperate to be transferred to the Traffic Section whose four staff sat in splendid isolation at the other end of the long room. To my frustration I had to wait until an official vacancy arose there, which happened after about six months. At last I had daily access as part of my job to Time Schedules, Duty Schedule, Bus blind records and full geographical details of routes, stopping places and stand workings in the East Division—roughly the quadrant of London North East of the Thames.

Telephones were spread around on various desks, roughly according to need; the "autos"* had blanked off dial areas, whereas the G.P.O. phones had working dials, but normally all outgoing calls were set up by the operators. Very occasionally—presumably when the operators were extra busy—you were given the luxury of a dialling tone to make your own call.

Promotion took me to the Fares & Charges Office at 55 Broadway in 1964. There the telephone situation was the reverse of that at Manor House. Autos could be used independently as they had their own dials, but Post Office (GPO) instruments were the manual type with no dial—just a circular plate showing the extension number, all calls in and out being routed via the switchboard. The operators were normally women during the day, with men taking over at about 6pm for the night shift, an arrangement which also used to apply in public telephone exchanges and may still do so today.

Our small section (Railway Operating, New Works) was moved to Oxford Circus House offices in April 1981 and did not return to Broadway for several years. By then auto telephone instruments in offices were normally coloured grey and PO/British Telecom units were black plastic/bakelite.

F. Reminiscences of Telstar House
Recalled by Laurie Akehurst

In my Data Processing days I was among the first group of staff to move into Telstar and recall that when the exchange was commissioned we only had one instrument for both the GPO and Auto systems. They also had touch buttons rather than dials which was quite new at the time. The system also offered abbreviated dialling facilities by using three digit numbers - the Broadway exchange was one such and it always amused me that 444 was the abbreviated code for 999! After a short period we were provided with separate instruments for GPO and Auto as it was stated the linking up of the two systems offered the GPO (or was it BT by then) a loophole by which they could have taken over the private system.

* Confusingly, the bus/tram private manual exchange telephones were often called "automatic" telephones, even in official circles.

APPENDIX TWO

North Metropolitan Electric Power Supply Company (Northmet)
(Information Supplied by Andrew Emmerson)

A quirk of fate deriving from the close relationship of power generation and public transport operation in the early years of the twentieth century mean that the Northmet power generation business (which supplied an area embracing north London extending well into Hertfordshire) was an integral part of the Underground Group from 1912 until 1933. Following the formation of London Transport in that year, Northmet was floated as a separate company (and nationalized in 1947 to become part of the Eastern Electricity Board)* but the close historical relationship between the two organisations continued for a long time afterwards. This was reflected also in their telephone arrangements and a summary of these is given here for sake of completeness (based on the book **Northmet** by N. C. Friswell and other information supplied by him).

The core telephone system connected electricity substations and ran over the so-called pilot wires connecting these. At permanently manned substations the telephone circuits were connected to 'an early type of manual telephone switchboard' where the attendant could connect telephone lines to allow staff in substations to talk to one another or to Northmet Control. The attendant also had Post Office telephones to receive calls of no supply from consumers. Parts of this private telephone system were shared with the Metropolitan Electric Tramways (which also was absorbed later into London Transport).

The telephones were of the local battery type with magneto calling (as was standard in the electricity industry) and because the capacity of each telephone cable was restricted (typically six pairs), the number of individual circuits was also limited, with 50 or more substation telephones connected in parallel and sharing the same party line. No doubt a suitable system of code calling was devised. In an attempt to improve the loudness of speech, each substation telephone was fitted with a cut-out switch, which people often forgot to reset when leaving the site unattended. Growing complaints of "can't hear" were tackled by sending telephone technicians out in shared vans to find low insulation on cables or too many switches left 'on'.

A change came in the mid-1950s when the last manned substations at Hertford and Hatfield lost their attendants, meaning that all telephone routes were diverted to the one remaining manned point at Wood Green, which was situated in the London Transport trolleybus depot there (dating from its common ownership by Metropolitan Electric Tramways and Northmet).

In addition each district (administrative) office was provided with an automatic exchange, also two lines to Wood Green (one for the district manager and one for the district engineer). Northmet House† had the largest exchange, some 100 lines at that time, and could dial out to Wood Green and ask for connection to other offices and substations. Subsequently the Friern Barnet office was given the facility to dial into Northmet House.

Later, Northmet was forced to vacate the control point in Wood Green trolleybus depot, move its manual magneto 'trunk' exchange to the basement of Northmet House and give it a name that would not cause confusion with the existing Northmet PAX there. In the event it was named Walker, after the family that had once owned the Northmet House mansion.

The operational and administrative telephone systems were functionally separate but links between them were provided so that an engineer in an office could talk to a fitter in a substation, this being done through the

* Though the power stations themselves devolved to the British Electricity Authority.

† Located in Southgate, it is now a care home called 'The Beaumont'.

Wood Green (or later, Walker) operator. There was also a (manual) Post Office PMBX at Northmet House for public calls and it was possible to put internal calls from the Walker switchboard through to the public network. This was forbidden but done occasionally in emergencies.

More PAXs were installed in district offices during the 1960s and as telephone traffic grew, the number of tie-lines between the growing number of PAXs had to be increased as well. This problem was solved by installing ex-army four-channel carrier equipment to increase the tie-lines' capacity, starting with the circuits between Northmet House and Welwyn Garden City, then Welwyn and Stevenage. Subsequently new transistorised 12-channel carrier equipment was supplied by Ericsson Telephones Ltd.

The problem of automating the large number of substation telephones was resolved by providing a new kind of PAX (designed by Ericsson) at each grid point, with no more than 10 telephones connected to each (party) line. A ring-back facility allowed users to call other telephones on the same line and a conference call facility was also provided. These new arrangements effectively made magneto telephones obsolete. A five-digit numbering system was employed, the first three digits selecting the circuit and the last two the individual telephone required.

A dispute arose with the Post Office at one time over the status of the Northmet telephones and whether they infringed Post Office monopoly rights, particularly as they were interconnected to the CEGB and LT networks.

Administrative PAXs in the Northmet network as at July 1966:

Barnet	Hertford
Campfield Road	Hornsey
Edmonton	New Southgate
Enfield	Northmet [located at Northmet House, Arnos Grove]
Friern Barnet	St Albans
Harlow	Stevenage
Harrow	Wembley
Hendon	Wood Green

Northmet was the hub of the system, through which passed almost all cross-network calls. Interconnect to the CEGB network (tie-line to Cockfosters CEGB exchange) was also made through the Northmet PAX (dial 42). Connection to the substation network was via the Walker operator by dialling Northmet 0.

Glossary

CEGB	Central Electricity Generating Board (originally British [later Central] Electricity Authority)
GPO	General Post Office
PAX	Private Automatic Exchange (purely internal, with no public connection)
PMBX	Private Manual Branch Exchange (connected to the GPO)

APPENDIX THREE

Telegraphic Codes Associated With the Underground

The use of telegraphic addresses reduced the number of words needed to address a telegram with precision, and therefore the number of words to be paid for when sent over public networks. Rather like modern web/email addresses, no respectable firm could afford not to have one and some clever choices of name have been chosen. Names were also chosen that were less likely to be misheard when sent over the telephone.

The end of the inland telegram service from 1st October 1982 put paid to the need for any short address codes.

Address	Company	Note
Chendept, London,	London General Omnibus Company (Motor Dept), Albany House, Albany Street, NW. Mayfair 4020	In use 1910
Chisworks, Chisk, London	London General Omnibus Co Ltd, 566 High Road, Chiswick, W4. Chiswick 3641	In use for Chiswick 1930
Circumition London	Metropolitan District Railway	In use 1901
Diselec London	Metropolitan District Railway St James Park offices SW	In use 1910
Elnorthmet, Finspark, London; Elnorthmet, Palm, London	NorthMet Power Supply Company; North Metropolitan Electric Power Supply Co, The, Northmet House, Cannon Hill, Southgate, N14. Palmers Green 4001	Chief Engineer 1930; In use 1933
Eros London	Met & GC Joint Committee	Marylebone, in use around 1910. Was also GCR's Secretary's office
Lentiscus, London	Metropolitan Electric Tramways Ltd (Engineer), 4 South Place, EC. London Wall 17	In use 1910
Lentiscus, Phone, London	LUT, MET & SouthMet Trams	In use 1930
	Metropolitan Electric Tramways Ltd, Manor House Offices, Finsbury Park, N4. Tottenham 0077	In use 1933
Longenbus, London	London General Omnibus Company, 9 Grosvenor Road, Westminster SW. Gerrard	In use 1910

	924	
Lotram London	London County Council Tramways, Tramway Offices, 52 Finsbury Pavement EC	In use 1910
Lotram Lamb London	London County Council Tramways, Tramway Offices, 23 Belvedere Road, SE1. Hop 0321	In use 1933
Mechaneer, Ealux, London	Metropolitan District Railway; Ealing Common Works	In use 1930
Mechaneer Act London	Metropolitan District Railway Co, Chief Mechanical Engineer, Acton Works, Bollo Lane, Chiswick, W3	In use 1933 but used until recently for Acton Works
Metelectro London	Metropolitan Railway	In use circa 1905
Metlectric London	Metropolitan Railway, General Manager, 32 Westbourne Terrace W. Paddington 5340	In use 1910
Metlectric Eusroad London	J S Anderson, General Manager & Chief Legal Adviser & Solicitor, Baker Street Station, NW1. Tel no Welbeck 6688: Tel Add "Solicitor Metlectric Eusroad London"	In use 1933
Metrolito, London	Metropolitan Electric Tramways, Electrical Federation Offices, Kingsway WC; Holborn 2686	In use 1910
Metrolito, Sowest, London	North Metropolitan Electric Power Supply Company.	1930, Head Office
Oligist London	Central London Railway Engineer's Office Queen Anne's Mansions	In use 1908. By 1910 was being used by Sir Benjamin Baker, consulting Engineer, 2 Queens Square SW.
Outnoise London	Baker Street & Waterloo Railway, Hamilton House, EC	In use 1907. Disused by 1910.
Passengers, Sowest, London	UERL Group and then London Transport	1930 and until 1982
Prismoid London	Great Northern Piccadilly & Brompton Railway Holborn – Finsbury Park section. Engineer's Office Belgrave St	In use during 1905. Re-issued by 1910.
Rapidness London	Great Northern & City Railway, 3 Highbury Place N. North 853	In use 1910

Resumption London	Great Northern & City Railway	Circa 1904 (disused by 1910)
Rheomotor London	Central London Railway Oxford Circus station, Argyll Street W. Gerrard 260	In use 1910
Trainist, London	Metropolitan Railway, Traffic Superintendent, 32 Westbourne Terrace W. Paddington 5340	In use 1910
Trainist, Eusroad, London	G Hally, Traffic Manager, Baker Street Station, NW1. Welbeck 6688.	After 1933 was used by Operating Manager (Baker Street); address became formally disused from September 1934
Tubeways, London	London United Tramways (1901) Ltd; 14 Cockspur Street, SW. Westminster 190	In use 1910.
Tunnelling London	City & South London Railway, Finsbury Pavement EC.	In use 1910.
Underground London	Metropolitan Railway, Secretary's Office, 32 Westbourne Terrace W. Paddington 5340	In use 1910
Underground Eusroad London	H S Chapman, Secretary, Baker Street Station, NW1. Welbeck 6688	In use 1933
Underneath London	Underground Electric Railways Company of London Ltd, St James' Park station, SW. Gerrard 5820	Short address subsequently used by London Electric Railway
Undersoil London	Baker Street & Waterloo Railway	In use 1908
Unicon, Feltham	Union Construction Company, Feltham	In use 1930
Vangastow, Southall [and various other places]	Associated Equipment Company	1930 and until comparatively recently
Zonedist London	Metropolitan District Railway	In use 1906. Disused by 1910.

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[110] See http://www.thales-transportservices.com/Workarea/DownloadAsset.aspx?id=10354&LangType=2057