THE TUNNEL TELEPHONE SYSTEM

by Antony Badsey-Ellis

EARLY HISTORY

The tunnel telephone system on the London Underground generally consists of a pair of bare wires suspended from porcelain insulators on brackets from the tunnel wall. When pinched together, the traction current is cut. They can also be used for communication: a telephone handset carried by drivers or fitted in the trains can be clipped to the wires via a long flexible lead. For ease of access the wires are at a height such that they can be reached from the cab window.

The wires were first fitted on the City & South London Railway around 1900. They were then installed as standard throughout the underground sections of the three UERL tube railways (the Bakerloo, Piccadilly, and Hampstead Tubes). For the first few years, they were just a method of communication, this being many years before the development of any kind of train radio system. It was used for communicating with the stations in advance of the train. If the driver wanted the traction current to be discharged then staff at the station could connect him to a substation attendant. The quality of speech was not that good, as any electrical interference on the line would cause disruption, and this could come from passing trains and the substation machinery.

When the three UERL lines opened, the tunnel telephone handsets were part of the train equipment, fitted in the cab of driving motor cars. The GNP&BR rule book of 1906 noted that three-car trains consisting of a driving motor, trailer, and control trailer would not have a telephone handset in the control trailer, and that “when it is necessary for a Motorman to use the emergency telephone on a three-car train, and it happens that he is driving from a trail Car he must walk through the train, carefully closing all doors, and must not in any way alarm or disturb passengers in so doing”. The same rule book also noted that portable handsets were provided to tunnel foremen working on night shifts.

As with the C&SLR, there was no direct way of cutting off traction current. This was not seen as a problem by the Board of Trade (BoT), which was responsible for inspecting and approving railways and railway installations before they were permitted to be commissioned, and for regulating railway safety. On 4 March 1907 a question was asked in the House of Commons about “whether there was any automatic arrangement for cutting off the electric current in the event of accident or fire on the tube electric railways of London”. The Parliamentary Secretary to the BoT replied in the negative, noting that “the electrical adviser of the Board of Trade recommends that automatic arrangements for this purpose are not desirable”.

The Central London Railway was fitted with the wires in the years between 1912 and 1914, probably as a result of its acquisition by the London Electric Railway (the name adopted by the UERL from 1 July 1910). The system on the Bakerloo Line was changed slightly from 3 July 1915, in that the northbound and southbound wires were placed onto separate circuits. This was already the case on the line west of Baker Street, so presumably the original decision to have separate circuits for each tunnel was taken in 1906 between the opening of the Bakerloo and Piccadilly lines.

From 30 April 1916 the telephone handsets were not part of the train equipment on the Bakerloo Line, and this was subsequently the case on the other lines as well. Housed in sturdy wooden boxes, they were collected by drivers when booking on, carried between cabs when changing ends, and transferred to any driver who relieved him. When the train returned to its depot, the handset would be handed in by the driver.

The communications passed through the magneto switchboard provided at each station, and so calls could be passed on to other sites, for example substations, if the driver needed the traction current taken off. On 29 January 1914 The LER wrote to the BoT requesting permission to change the system so that the tunnel wires would communicate with the adjacent substations. It was felt that this would enable the traction current to be switched off faster in emergency. The LER also suggested that switches be installed at signals which would immediately discharge traction current without recourse to the substations, although BoT approval for this latter change was not required.

It did not take long for the decision to be made. Exactly one week later the Board approved the change. This system was altered so that the tunnel lines connected instead with the substation ahead, with power coming from batteries, on the following dates:[1]

- Bakerloo Line 29 April 1917
- Hampstead Line 15 October 1917
- Piccadilly Line 7 April 1919
- Central London Line 5 January 1920

At stations, telephones were provided on platform headwalls in sealed boxes, except on the Bakerloo Line, where they were placed in the stationmasters' offices or a special telephone cabinet. They were the same as the handsets on trains, but in a fixed location. A two-way switch allowed the telephone to be connected to the telephone lines in either tunnel.

The signal switches were never provided, probably to the regret of the BoT. An internal minute by one of their staff, Major Pringle, noted that this idea was the "main advantage" of the whole proposal.

IMPROVING THE SYSTEM

An incident occurred on 7 November 1920, which caused the system to be permanently altered. It started on a northbound Bakerloo Line train between Piccadilly Circus and Oxford Circus. Some flashing had occurred from the collector shoes on its two previous journeys, and a car examiner had accompanied it from Elephant & Castle as far as Trafalgar Square without anything being amiss. The car examiner had recommended that the driver report the flashing on the car's "trouble card". However, heavy arcing commenced from underneath motor car No.47 at 21.44. The driver attempted to contact the substation by connecting his telephone handset to the tunnel telephone wires, but in the dense acrid smoke he dropped it and could not find it again. He managed to speak to his guard, who had walked up through the train, and instructed him to walk back to Piccadilly Circus to get the current cut off. This actually occurred a couple of minutes before his arrival, as a result of the heavy current flowing being noticed by the substation staff. The passengers were detrained back to Piccadilly Circus by 22.20 – 26 subsequently complained to the LER about suffering from smoke inhalation, and two members of staff were off sick for at least a day.

The cause of the arcing was a fracture in the cable connecting the front left hand (positive) collector shoe. It set up an arc, fed from the rear shoe, which burned through to the negative cable. This created what is known as a positive earth.

There was a second part to the incident. The traction current supply was not divided into independent sections as it is today[2]. A westbound Piccadilly Line train at South Kensington was affected by the heavy current flowing on the Bakerloo Line, and the insulation on one of its negative shoes broke down. A negative earth resulted, and arcing started there at 21.45. The current was not as great as on the Bakerloo Line, and it was not until 22.18 that the substation finally cut the traction current and stopped the arcing.

Unsurprisingly, an inquiry was held into the incidents by the Ministry of Transport (MoT). The conclusion in its report of 13 December 1920 was that the London Electric Railway (LER) needed to provide a more effective method for train staff to remove traction current. It noted that devices for doing this from within the train were under consideration, but in the meantime the use of the tunnel telephone cables was recommended, by getting staff to short-circuit them. This could be effected by connecting the tunnel telephone handset, or by connecting the wires together using a metal chain.

Tests were conducted outside of traffic hours by the LER showed that pinching the wires together resulted in the current being removed in between 15 and 60 seconds. An alternative method of removing the current was provided at the stations: a fixed telephone was connected across the tunnel telephone wires, and the action of lifting the handset would alert the substation. Special Instructions were issued to train staff on 21 January 1921 directing them to pinch together the wires to remove current.

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1 It seems likely that the First World War delayed the scheme, hence the three years between the letter to the BoT and the first implementation.

2 The division of the traction system started in 1948 with the creation of six separate areas, known as Central Line, Metropolitan Line, Northern, Southern, Eastern, and Western.

By March 1921 the LER was able to write to the MoT stating that they had decided that it was not possible to remove the traction current from a device in the cab. All trains were equipped with a short-circuiting device which could be placed across the current rails which would ensure that the current was removed. The main change that had occurred was that pinching the tunnel telephone wires together would alert the substation *in advance of the train* to remove the current. Most sections of track were fed from both ends, and hence the substation attendants would have to alert the substation to the rear of the train to remove the current as well. Private telephone circuits between the substations would allow this to happen.

It was obviously better if both substations feeding a section of line could be alerted simultaneously. An experiment was conducted on the Piccadilly Line between Earl's Court and South Kensington, whereby a short circuit of the tunnel telephone wires would cause an alarm to sound and a visual indication to be made at both substations (in this case, located adjacent to the same two stations). An eyeball indicator was specified, this being a small sphere with two colours on it. It would be rotated by an electromagnet to change the colour on display when the wires were short-circuited. It is a common form of indicator in the electrical engineering world.

In a letter to the MoT dated 6 July 1921 the LER's Director of Construction confirmed that the wires could be pinched together, removing the need to provide metal chains (as the inquiry had presumed would be needed). The MoT was also invited to inspect the installation, which they did later that month.

As a result of the inspection some changes were made. The bells which sounded in the substations were replaced with a pneumatic whistle (supplied from the compressed air main) and an electric klaxon, so that the best audible warning could be determined. The substations were noisy places, with rotary convertors creating a din, and the alarm had to be heard over this high level of background noise. A green lamp was normally illuminated – this would extinguish, and a red lamp illuminate if the current needed to be removed. Separate indicators for the eastbound and westbound lines were supplied, and latching relays were fitted so that the audible and visual indications continued even after the short-circuiting of the wires ceased.

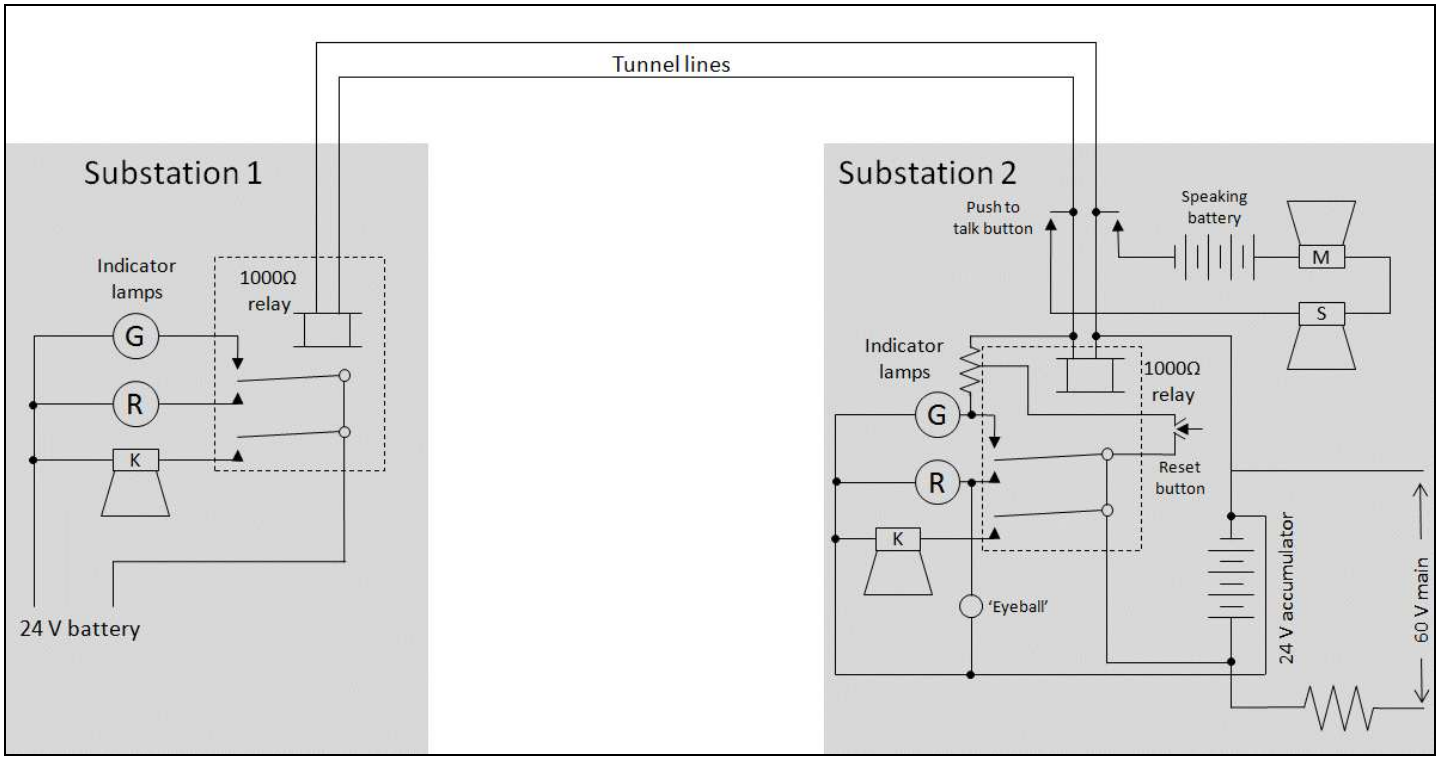
Although the changes required at all substations would take time to implement, it was decided to proceed with the existing arrangement (i.e., short-circuiting the wires to inform the substation ahead). Traffic Notice 44/21, dated 29 October 1921, gave a page of instructions to train staff about the new arrangements. They started by noting that it was now strictly prohibited to use the wires for any purpose other than taking off the current.

A second inspection by the MoT in November heartily approved of the changes, preferring the electric klaxon to the pneumatic whistle on account of it not relying on a supply of compressed air. The only hesitation that it expressed was over the reliability of pinching the wires together, and to this end the LER started work to clean all of the wires. The instructions in the Traffic Notice were clear as well: "When it is necessary to get the current taken off in any emergency, the tunnel telephone wires should be short-circuited by pinching and rubbing them firmly together, or by other means – such as attaching the telephone clips – to ensure a good contact. This process to be continued until the current is taken off. If there is any undue delay in current being taken off, the short-circuiting device must be put down. If possible, a second short-circuiting device should be put down".

The headwall telephones on station platforms continued to function as before but, being the same as the motorman's instrument, would also discharge traction current if the handset was lifted.

HOW IT WORKS

The accompanying circuit diagram has been based on one dated 25 August 1921. It has one minor simplification, which does not affect the description below.



The method of operation was fairly simple, and is similar to the operation of track circuits. The telephone wires are bare throughout their lengths in the tunnel. At each end, in the substations, they had a battery connected across them, as well as a relay coil. As long as the circuit was maintained the relay kept power flowing to the green lamp (G – supplied from the same battery). If the wires were short-circuited then the relay dropped, and power was switched to the red lamp (R), which had the eyeball indicator wired in parallel. Separate contacts on the relay would energize the klaxon (K) at the same time. One of the wires was connected to earth, so that an earth fault occurring would also trigger the system.

The battery was to ensure that the tunnel telephone system was always available – the battery was charged constantly from the 60V signal main. A resistance provided a 24V supply to the battery, and this was fed in from the substation at the forward end of the circuit (i.e., the substation towards which the train was travelling). A variable resistance allowed the circuit to be set so that the voltage at the rear substation was 6V. As the relays were in series, the same trip voltage would apply at the forward substation. A separate circuit arranged across the tunnel wires was maintained for the telephony – this was simply a push-button, battery, microphone (M), and loudspeaker (S). When the button was depressed the microphone and loudspeaker could be used to talk with a telephone handset clipped to the tunnel wires (or one of the headwall telephones). The circuit was powered from the independent battery.

On 10 April 1922 the MoT concluded that the experimental section between Earl's Court and South Kensington was a success, and the LER started to make the necessary changes to the substations on the Bakerloo, Piccadilly, Hampstead, and Central London lines[3]. On 18 April 1923 they were able to inform the MoT that this work was complete, and regular testing had shown it to operate as intended. The MoT was invited to perform a final inspection. The report shows that four additional changes had been made to further improve the system:

- An additional relay was included that would trigger the alarm if the current supply to the rails failed; for example, by a short circuiting device being placed on the rails before the tunnel telephone wires were short-circuited.
- The klaxon was replaced by an electric horn, the green lamp by a white lamp, and the red lamp by an illuminated panel stating the section of line on which the wires had been short-circuited.

[3] The City & South London Railway was not included, even though it was part of the Underground group. Major reconstruction of the tunnels started in 1922, and it seems likely that the changes were postponed and introduced when the C&SLR reopened.

- Additional indicator panels were fitted in some substations so that the attendant would be alerted wherever he happened to be.
- A push-button was added to reset the circuits once the incident was resolved.

A further experiment was occurring at Earl's Court substation. A tripping device on the traction current overload cut-outs was connected to the tunnel telephone system, causing traction current to be cut automatically as soon as the wires were short-circuited. This was another significant improvement, and by 1926 had been fitted to the substations across the network. This was commissioned on the following dates:

- Piccadilly Line 28 June 1924
- Bakerloo Line 25 April 1925
- Hampstead & City Line 27 June 1925
- Central London Line 23 January 1926

About the same time it was arranged that discharge of the traction current would automatically illuminate the tunnel lighting. It must be noted that resetting the tunnel telephone circuits did not restore traction current – this had to be done separately by resetting the traction current circuit breakers.

NOT JUST FOR TUBE TUNNELS

Tunnel telephone wires only made it onto the sub-surface lines in the 1930s. As part of the Underground group, the District Line was first, starting on 14 July 1930. A recent article in *Underground News* has described how Metropolitan Railway drivers were issued with telephones when operating Inner Circle trains over the southern part of the Circle[4]. The Metropolitan sections were equipped after the formation of the LPTB, and commissioned on 26 January 1936. Prior to this, wires on the Northern City Line (ex-GN&CR) started in use on 17 March 1935. The East London section of the Metropolitan Line was equipped and operational from 4 September 1938.

Possibly the most unusual place that 'tunnel' telephone wires were installed was alongside the South Acton branch of the District Line, which is entirely on the surface. The wires were installed as a safety precaution when one man operation was being considered for the shuttle and were commissioned on 22 January 1933. One man operation was introduced five years later, in 1938, and the telephone wires remained in operation until the withdrawal of the service in 1959.

When the Central Line was extended eastwards from Liverpool Street the short tunnels north of Leytonstone and west of Grange Hill were fitted with telephone wires, in addition to the tube tunnels from Leytonstone to Newbury Park.

The one other London railway that used tunnel telephone wires was the Waterloo & City, owned by the Southern Railway. When new rolling stock was introduced in 1940 a tunnel telephone wire system similar to that on the Underground was provided, with handsets fitted in the cabs of the new trains.

DRICO

One of the main problems with the system was that drivers could not communicate directly with their line controller. All messages needed to be relayed via the substation attendants, causing delays and risking messages being garbled. In the late 1940s a new and most significant change to the tunnel telephone system was developed: Drico. Short for **Dri**ver-**Co**ntroller, Drico provided a different telephone handset which did not short-circuit the telephone wires when connected to them.

Messages arrived in the control room via a loudspeaker. It was not intended for general use (e.g. delays at a signal), but to keep the controller informed if a train became defective and was likely to take more than five minutes before getting back on the move. The box in the cab containing the speaker and Drico leads was normally sealed – after use the driver had to make a note on the trouble card requesting that the box be re-sealed.

Drico worked on the existing system without preventing its operation, but if the telephone wires were shorted out then Drico would not work. Instructions to staff stated (in capital letters, no less) that the

[4] See "District Electric Trains No.18", *Underground News* No.584, August 2010, pages 386-387.

tunnel telephone hand-set must not be left connected to the wires to ensure that the traction current remained off, for this reason. In the event of an emergency requiring traction current be discharged, the tunnel telephone was to be used first, and then the telephone was to be disconnected and the short circuiting devices laid at both ends of the train. Drico was then to be used to let the Controller know (i) why current had been switched off, and (ii) what the situation was. If Drico became inoperative in a section then a square board bearing the letters 'DC' on a white background, crossed through in red, would be displayed.

Just over a year after its introduction on the Northern Line (9 March 1952) London Transport was urged to roll it out across the network following an accident on the Central Line. This was done, but took until late 1956 to be completed on the tube railways. It was not installed on the Victoria Line, which instead used a system called the Carrier Wave Telephone[5]. The dates are as follows:

- Bakerloo Line 31 January 1954
- Central Line 1 September 1954
- Piccadilly Line 5 February 1956
- Northern City Line 18 March 1956
- District Line[6] 13 January 1957
- Metropolitan, Circle[7] and East London[8] lines 2 March 1959

Another innovation of the 1950s was a train that could clean the tunnel wires. Previously they were regularly cleaned by hand, with emery cloth being rubbed along them to remove dirt and corrosion. This was a time-consuming and slow activity. The train was hauled by a battery locomotive, and used two ballast wagons. One man would degrease the wires, two men operating power-driven circular brushes would clean the wires, and a fourth man would re-grease the wires. The train driver and a supervisor completed the crew of six, which could travel slowly along the tunnels during engineering hours. The only difficulty reported was the inability to reach wires in a low position, which occurred on some lines, and use of a flat-bed wagon (with a lower floor than the ballast wagons) was contemplated to overcome this.

Left: The two Tunnel (Telephone) Line Cleaning wagons TLC1 and TLC2 are seen in Ealing Common 'Alps' depot sidings shortly before being scrapped. They were converted in June 1948 from Metropolitan Railway Ballast Wagons – TLC1 from BW108 (built 1904) and TLC2 from BW248 (1893). After being stored out of use for some years they were cut up on site at Ealing Common on 16 September 1978 by Cashmores.

Photo: Brian Hardy

Tunnel telephone wires were added to tunnel reversing sidings on the Northern, Piccadilly, and Central lines in 1966, and commissioned on 3 December. The Kennington loop was also included. Additional telephones were installed in the nearest headwalls for communicating with a driver in the siding when they connected their tunnel telephone. Drico was also provided, but would not work

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5 Carrier Wave Telephone transmitted signals via the current rails. One problem with it was that it stopped working when a short circuiting device was placed on the tracks.

6 Drico commissioned on tunnel sections of the District Line for R and Q Stock trains only but excluding South Acton branch, East Putney – Southfields tunnel and between High Street Kensington and Edgware Road.

7 Including High Street Kensington to Edgware Road.

8 From 6 December 1965 portable Drico equipment was provided for Eastern Region train drivers over the East London Line.

after operation of the telephone wires. In the event of current being taken off a bell was arranged to ring at the nearest station to alert staff. When it was safe to recharge the current the driver would have to inform the station staff, who would pass the message on to the controller.

Whilst on the subject of headwall telephones, some of these are provided with ‘section ahead’ and ‘section in rear’ plungers if there is a conductor rail gap either side of the station. If a train is stalled across the gap then it could allow current to flow from the live side to the dead side, with serious consequences. The plungers allow the current to be switched off from the section distant from the station, by in effect shorting out the tunnel wires. This was partly fail-safe, as the operation of the telephone wires by both a motorman and a guard (who were at each end of the train) should ensure that current is fully discharged, even if the train sits across a rail gap.

CHANGES FOR THE VICTORIA LINE

The tunnel telephone system had a small change made for the Victoria Line. One man operation was to be used, and hence there was no guard to operate the telephone wires at the rear of a stalled train. A short section of tunnel telephone wire after each rail gap was therefore arranged to take off current from both current sections: in effect, it was tripping relays at three substations (in front, to the rear, and both relays in the adjacent substation).

The tunnel telephone circuit had some other wiring changes made to it, and this was trialled between Burnt Oak and Hendon substations, in the Burroughs Tunnels (north of Hendon Central, which had been equipped with tunnel telephone wires since opening).

A 1968 document describing the system stated that a standard LT relay was used in a circuit designed to trip the traction current circuit breakers when the voltage in the tunnel wires fell below 3V. These relays have four sets of contacts used in the system, as follows:

1. Stick circuit, to ensure that the system remains tripped even after the short circuit is removed from the tunnel wires.
2. Switches the illuminated visuals in the substation to show where the short-circuit is.
3. Trips the traction current circuit breaker, to remove the current from the rails, and
4. Triggers the audible alarm.

The tunnel wires were 10 SWG (3¼ mm diameter) cadmium copper or phosphor-bronze. This has a resistance of 3.4Ω per 1,000 yards. One change since the 1920s was that the 24V batteries for the system were charged from the regular 240V mains electricity supply (via a transformer and rectifier), rather than from the signal main.

Another feature was a test push-button and telephone handset provided at the rear substation. The button would be used regularly at the end of the traffic day to remove traction current, and the telephone to speak to the forward substation. This would confirm that the system was operating correctly. As substations were converted to remote control, and no longer had attendants on site, the circuits had an additional relay in which transferred the indications and the substation telephone to the line control room.

A more modern circuit was developed around the 1950s. It is far more complex than that described earlier, and only an overview can be given here.

Essentially, each section of tunnel has a dedicated relay in both the substations feeding it, and another in the control room. The circuits were arranged so that any one of the relays tripping would disconnect the traction current. One of the key advantages was that only a single wire was needed back to the control room for each section of tunnel; five common wires linked all the substations with the control room. This allowed an eight-pair cable (i.e., a multi-core cable containing eight pairs, or sixteen wires in total) to connect ten tunnel sections back to the control room. This simplified the control cabling.

Another advantage of this type of circuit was that it used standard 50V telephone relays and was fed from mains electricity in each substation and at the control room. Unlike the earlier system, the substation components were installed in special relay rooms in the substations.

THE CURRENT PROCESS[9]

Although operation of the tunnel telephone wires should fully remove the power, when the alarm sounds in the control room the controllers first contact the power control room to ensure that traction current has been completely discharged. They will then attempt to contact the train operator, using the Connect radio in the first instance.

If contact cannot be made with the train, an attempt to restore traction current will be made after seven minutes. Of course, if the wires are still short-circuited, or a short circuiting device has been placed across the current rails then this will fail. The controller will first attempt to reset the tunnel telephone system. If this is successful then the traction current circuit breakers will be reset, thus restoring current.

The headwall telephones also feature a red plunger which acts in the same way as lifting the handset. Staff instructions state that this must be pressed for three seconds.

If a fault is found on a section of the tunnel wires they can be cut out of the circuit using a device known as an override. When this is done a 'T' board is placed on the platform headwall at the station before the faulty section. This is a red square with a black T, crossed out with a white X. Even if a fault is repaired during the traffic day, the override is often left in place until the close of traffic to prevent possible disruption to the train service. If a train needs traction current off in such a section then a short circuiting device can be placed directly on the rails – carefully.

The system is tested very frequently, as the wires or headwall telephones are often used at the end of the day to remove traction current for engineering hours. At the start of the traffic day the line controllers ensure that the tunnel telephone system has been reset, and then contacts the power control room to request traction current be switched on.

RECENT TIMES

When the Heathrow Terminal 4 loop was constructed in the mid-1980s tunnel telephone wires were not installed. Instead, telephone units were provided every 60 metres along the tunnel, with their location shown by a dimly lit lamp. This system was extended to Terminal 5 when that branch opened in 2008. The north side of the Circle Line, between King's Cross and Moorgate has the same system. The Jubilee Line extension was provided throughout with conventional tunnel telephone wires.

The Thames Tunnel retains its tunnel telephone wires, even though it is no longer part of the London Underground. These are used to discharge traction current in emergency, but it is not believed that the class 378 trains carry handsets that can be used on them for communication purposes.

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Thanks are also due to Brian Hardy and MRFS for reading and commenting on the text, and supplying dates and other facts, and to Ken Joiner for reference material.

[9] Pun intended!