No. 187

**The Institution of Post Office Electrical Engineers.**

# Cabling Problems in Subways and Tunnels

T. G. TURLEY, A.M.I.E.E.

A Paper read before the London Centre of the Institution on the 4th June, 1945, and at other Centres during the Session, 1945-6.

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## CONTENTS.

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## 1. SYNOPSIS.

This paper deals with the laying and jointing of cables in subways and tunnels and the extent to which the latter have been used by the Department to accommodate its cables. As the author's experience of this type of work has been obtained in London the subways and tunnels referred to are those situated there and the practices and methods described are those which have been used in the London Telecommunications Region.

In view of the probability that in the proposed planning of new and redevelopment of existing towns and cities the provision of subways may be an important feature of reconstruction schemes, the present may be an appropriate occasion to review the problems which are associated with their use.

The history of the growth of the plants of public utility undertakings under London streets is traced and the congestion in the sub-soil which has developed in consequence is stressed. Reference is made to the provision of subways for housing utility undertakings' plants and to the extent to which use has been made of them, and also of underground railway tunnels, by the Department. Post Office cable tunnels are dealt with in greater detail and methods of laying cables in them are described.

The conclusion is reached that subways possess some advantage over main duct routes, but that improvement is needed in the design of future subways and particularly in the layout of plant in them.

Deep level cable tunnels for the exclusive use of Post Office cables are considered to be desirable in spite of their limitations and the difficulties in linking them with surface routes.

It appears to be established that the liability of cable sheaths to damage by electrolytic action is small on cables laid in subways and tunnels and certainly much less than is met with in duct routes. This is due in the author's view to the dryness of the tunnels and to the dissipation of sheath currents at points of contact with the cable bearers.

## 2. HISTORY OF THE GROWTH OF CONDUITS AND PIPES IN LONDON.

### 2.1. Water.

The history of the growth of conduits and pipes under London streets begins about the year 1582 when the London Bridge Water Coy. commenced to operate. Later, in 1609 Hugh Myddleton (afterwards Sir Hugh) brought water from Ware, Herts., to the New River Head, Clerkenwell. He used wooden pipes made from elm tree trunks, tapered at one end to form a spigot and having an enlarged bore at the other end to act as a socket ; the internal diameters ranged from six inches to twelve inches. The construction of distribution networks followed and during the next century and a half many miles of wooden water pipes were laid in London. They had a comparatively short life and renewals were frequent ; short sections of them, however, in a good state of preservation have been unearthed during excavations in recent years. Later one company experimented with stone pipes but without success owing to their excessive porosity, weight and bulk. In 1746, iron pipe was used experimentally and later, about 1817, a general change-over to metal pipes was made.

The extent of the subsequent growth was such that to-day the net-work of London's water authority is approximately 8,300 miles of pipes varying in diameter from two inches to sixty-six inches.

### 2.2. Gas.

The advent of the nineteenth century saw the beginning of the use of gas as an illuminant in streets and buildings and the consequent laying of gas mains which increased with the rise in popularity of the use of gas. At the present time there are eight large gas undertakings operating in London, one of which has approximately 6,000 miles of pipe with diameters up to seventy-two inches.

### 2.3. Drains and Sewers.

Drains and sewers began to be laid about 1840. Apparently the development of the system was insufficient to meet requirements and a public demand arose for improved drainage following cholera epidemics ; those of 1849 and 1851 had death rolls of 18,000 and 20,000 respectively. Bazalgettes "London Drainage Scheme" followed some years later and was completed about 1875.

### 2.4. Electricity.

Electric lighting in London dates from 1878, but it was not until 1890 that underground mains were laid with any degree of success. Earlier attempts were experimental as in fact were many later ones, employing a wide variety of conductors and conduits and also making use of the pipe subways where possible.[1]

To-day there are 70 electric light authorities operating in London. Generally they serve separate areas, but considerable overlapping occurs particularly in inner London where the duplication of mains can least be tolerated, but is nevertheless useful in giving alternative supplies at telephone exchanges.

Electricity cables are laid direct in the ground, in iron and steel pipes, in single and multiple way duct and in wood and earthenware troughing. Supplementary plant includes manholes, disconnection boxes and buried transformer chambers.

One undertaking alone which shares a small inner area has a network of over 500 miles of cable and conduit.

### 2.5. Hydraulic Power.

A pipe system of high pressure water mains for operating hydraulic machinery exists in inner London. It supplies water at a guaranteed pressure of 700 lbs. per square inch and was introduced in 1881. To-day the network comprises 180 miles of steel and iron pipe with diameters varying from 2 inches to 10 inches.

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[1] See Bibliography.

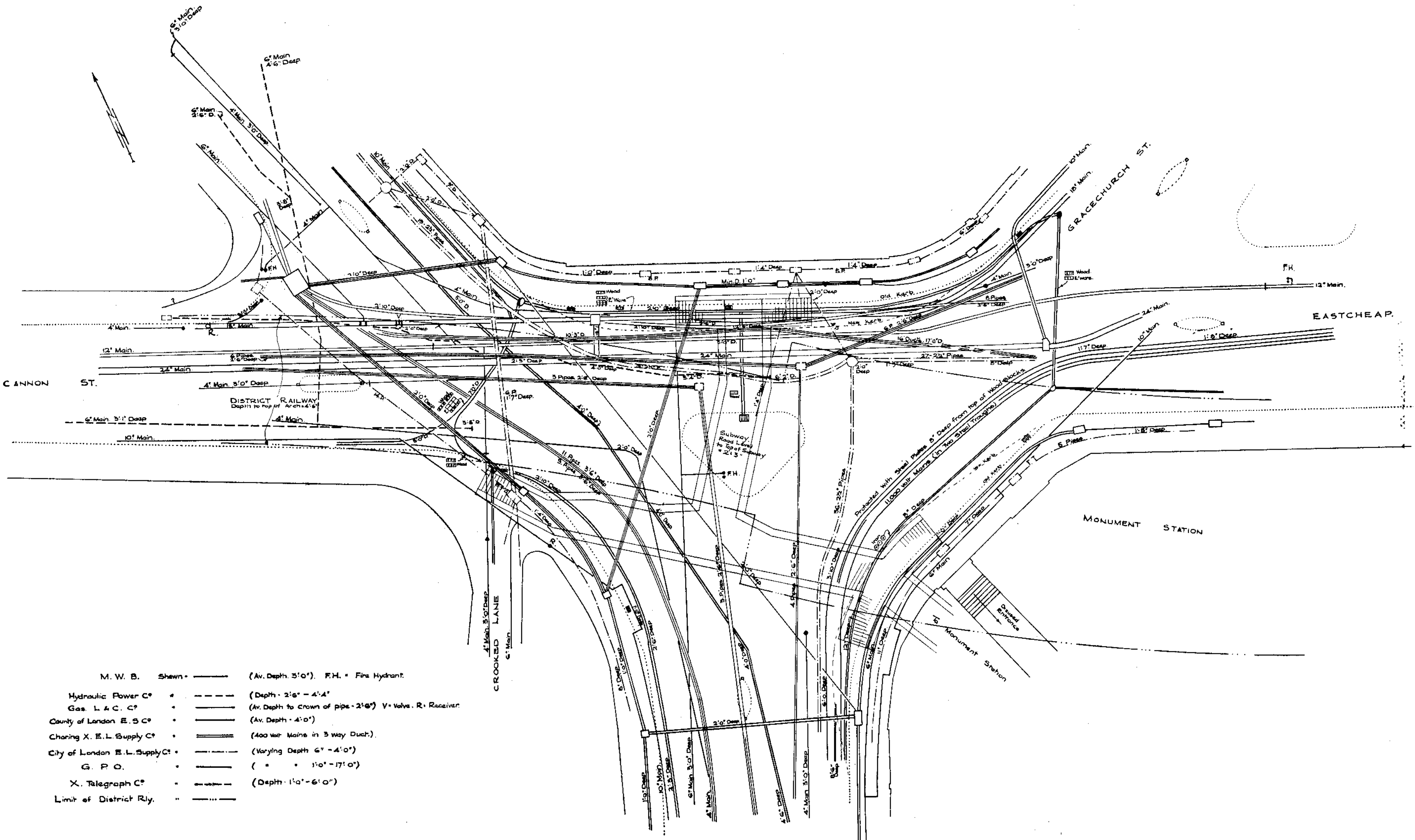


FIG. 1.—PLAN SHOWING PEDESTRIAN SUBWAY, DISTRICT RAILWAY AND CONGESTION OF OTHER UNDERTAKERS' PLANT AT KING WILLIAM STREET AND CANNON STREET.

### 2.6. Pneumatic Street Tubes.

Radiating from the Central Telegraph Office (C.T.O.) is a system of street tubes which serves nearly 70 offices and dates back about 60 years. The mileage of pipe is now approximately 85.

### 2.7. Telegraph and Telephone.

About the middle of the 19th century wood troughing and iron pipes were first used for telegraph cables. There had, however, been many earlier and varied attempts to lay lines underground, without achieving any practical success.[2]

It was not until the approach of the 20th century that underground plant for telephone purposes appeared in large measure, its development having been retarded by litigation and by restrictive and tendentious Acts of Parliament.

The telephone industry was perforce a late entrant into the competition for room in the sub-soil and had in consequence often to accept inferior positions for its conduits. Lateral space was frequently limited, resulting ultimately in cable congestion in manholes. Other utilities' mains, perhaps not accurately charted, were sometimes overlaid, unintentionally of course, by Post Office pipes thus impairing access to the deeper plant.

The growth of this telegraph and telephone conduit network in the London Telecommunications Region (L.T.R.) during the past four decades has been very heavy and it now accommodates, in addition to subscribers' and local cables, nearly 1,300 junction cables linking the 250 exchanges in the Region, and 130 main cables radiating from the trunk, toll and international exchanges at Faraday Building.

### 2.8. Note of Sub-soil Congestion.

The foregoing is intended to convey an idea of the variety and volume of underground plant in inner London and of the resulting congestion.

As might be expected utility undertakings have used for their trunk routes the main thoroughfares, usually the most direct, under which there now exists a complex accumulation of plant. Naturally conditions are worst at main road crossings, under some of which space is either non-existent or too limited to be used for new duct routes.

The presence of pedestrian subways, underground lavatories, tube railways at shallow depths and cellars extending under the footway, and sometimes under part of the carriageway, add to the difficulties as also does the practice of "first comers" laying plant as shallow as safety and the requirements of local authorities have permitted. Figs. **1** and **2** illustrate a typical congested road crossing.

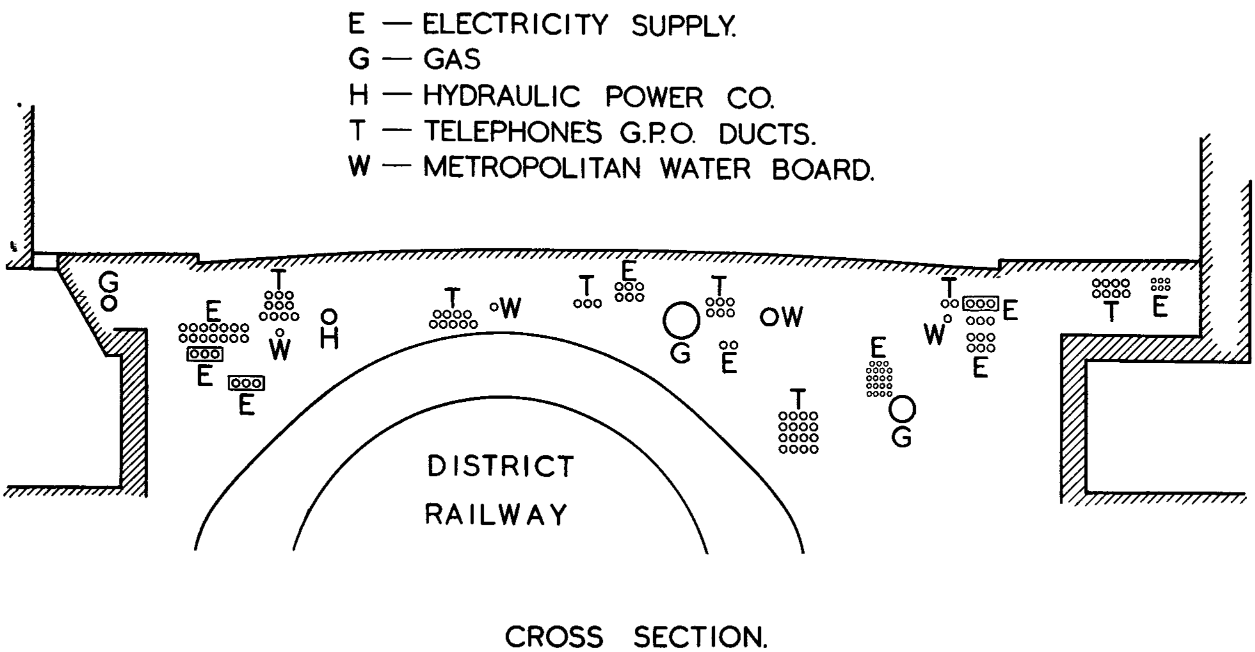


Fig. 2.—Typical Sub-Soil Congestion.

Derelict plant abandoned owing to faults or redundant for other reasons is a frequent source of trouble ; by inspection it is indistinguishable from plant in use. Not all plant is laid parallel with the road and some of the lateral deviations encountered reveal an ingenious but embarrassing interlacing of pipes and cables.

The whole network has obviously grown in a haphazard manner as expediency dictated, without any planning or attempts to utilise the space to the best advantage. Conditions are such that the Department has been compelled in recent years to use for main duct routes, roads of minor importance, less direct, and sometimes to lay plant at considerable depth.[3]

[2] See Bibliography.

[3] See Bibliography.

## 3. SUBWAYS AND TUNNELS USED BY THE POST OFFICE.

Pipe subways for the joint use of public utility undertakings have been in existence in London since 1861. There are two systems in operation, one owned by the London County Council and the other by the City Corporation.

### 3.1. L.C.C. Pipe Subways.

" In order to prevent inconvenience to the public by the frequent breaking up of streets and roadways" is the reason quoted in certain Acts which have reference to the 7 miles of pipe subway now vested in the L.C.C.[4] They do not form one continuous network but consist of 22 disconnected sections of varying lengths. Nineteen sections constructed between 1861 and 1904 were associated with street improvements and the remainder with the reconstruction of L.P.T.B. underground stations between 1930 and 1933.

The subways are of brick construction at shallow depth, having an average cover of 3 ft. Water, gas and hydraulic mains are accommodated in them as well as electric light and power cables, Exchange Telegraph Company's and Post Office cables and pneumatic tubes. Entrance is obtained via grids situated either in the footways or on island sites in the carriageways ; the grids also provide natural ventilation. Most of the sections are situated under the centres of the streets with lateral access points to each footway for connection with distribution networks and buildings. Some of the wider roads are provided with parallel subways under the sides of the carriageways giving an advantage of shorter lateral connections.

The Department began to use these subways for telegraph plant in 1880 and for telephone cables at a much later date. They contain approximately 130 miles of telephone cables.

### 3.2. City Corporation Subways.

The City Corporation also possess pipe subways dating back to 1867. They are of similar construction to the L.C.C. subways, and accommodate the same type of plant. They are in isolated sections with an aggregate length of approximately two miles. They were not used by the Department until 1904 and now contain about nine miles of cable.

### 3.3. Old Parcels Tube.

A pneumatic tube known as " The Old Parcels Tube" was constructed to carry parcels and despatches on railed trucks from St. Martins-le-Grand to Euston railway station, a distance of nearly three miles. The first section, North-Western District Office to Euston, was opened for use in 1863 and the remainder completed by 1866. It was owned by a private company who obtained powers under an Act of Parliament. In cross section the tube is horseshoe shaped, most of it being 4 ft. 6 in. wide and 4 ft. 3 in. high with a quarter mile length of 2 ft. 9 in. × 2 ft. 3 in. It is laid at a shallow depth, and its construction is of special cast-iron thought to be of German origin and particularly resistant to corrosion.

It was found difficult to keep the tube air-tight and it fell into disuse in 1874 and remained so until 1890, when the St. Pancras borough council used a section of it for housing electric light mains which have been left in position by agreement with the Post Office.

From time to time other sections which obstructed street works were cut out and in 1922 the Department purchased the remainder of the tube for £7,500[5] as an alternative to laying a large duct route along Holborn estimated to cost £50,000. Manholes were constructed on the tube at convenient points, bearers provided and cables drawn in. Its maximum capacity is 80 cables and at the present time it contains 40 cables at the most congested point. A large section of it was demolished by the Holborn explosion and replaced by a 30-way octagonal duct route.

The tube is provided with a gas alarm installation which detects the presence of coal gas in the tube, operates an alarm, indicates the section affected, and automatically starts a power-operated blower to dissipate the gas.

Fig. **3** shows the routes of the pipe subways and the old parcels tube.

### 3.4. London Passenger Transport Board Tube Tunnels.

As a temporary expedient use has been made in recent years of some of the London Passenger Transport Board's railway tunnels to accommodate selected main cables from inner London to the outskirts, thus providing routes at a safe depth as an alternative to the normal duct routes. Although cable accommodation in these tunnels is limited, approximately 120 miles of telephone cable have been laid in them.

### 3.5. Post Office Railway.

Telephone cables have also been laid in the Post Office railway which crosses London from east to west, the terminal points being Eastern District office and Paddington Great Western Railway station, respectively ; there are intermediate stations en route. A description of this railway system has been given by Major W. G. Carter, M.C.[6]

The length of the railway is approximately 6½ miles and 19 miles of telephone cable have been installed in it. Its capacity to accommodate such cables, however, is very limited.

### 3.6. Post Office Cable Tunnels.

The Department has found it necessary to construct several tunnels in London for the exclusive purpose of housing telephone cables. They are at greater depths than the Council's subways, some being 100 feet below street level.

Their depth gives them freedom from the risks of explosion of coal gas leakages and immunity from the disturbances occasioned by street construction works. It imposes, however, the necessity for using a power-operated ventilation system and of providing

4 & 5 See Bibliography.

6 See Bibliography.

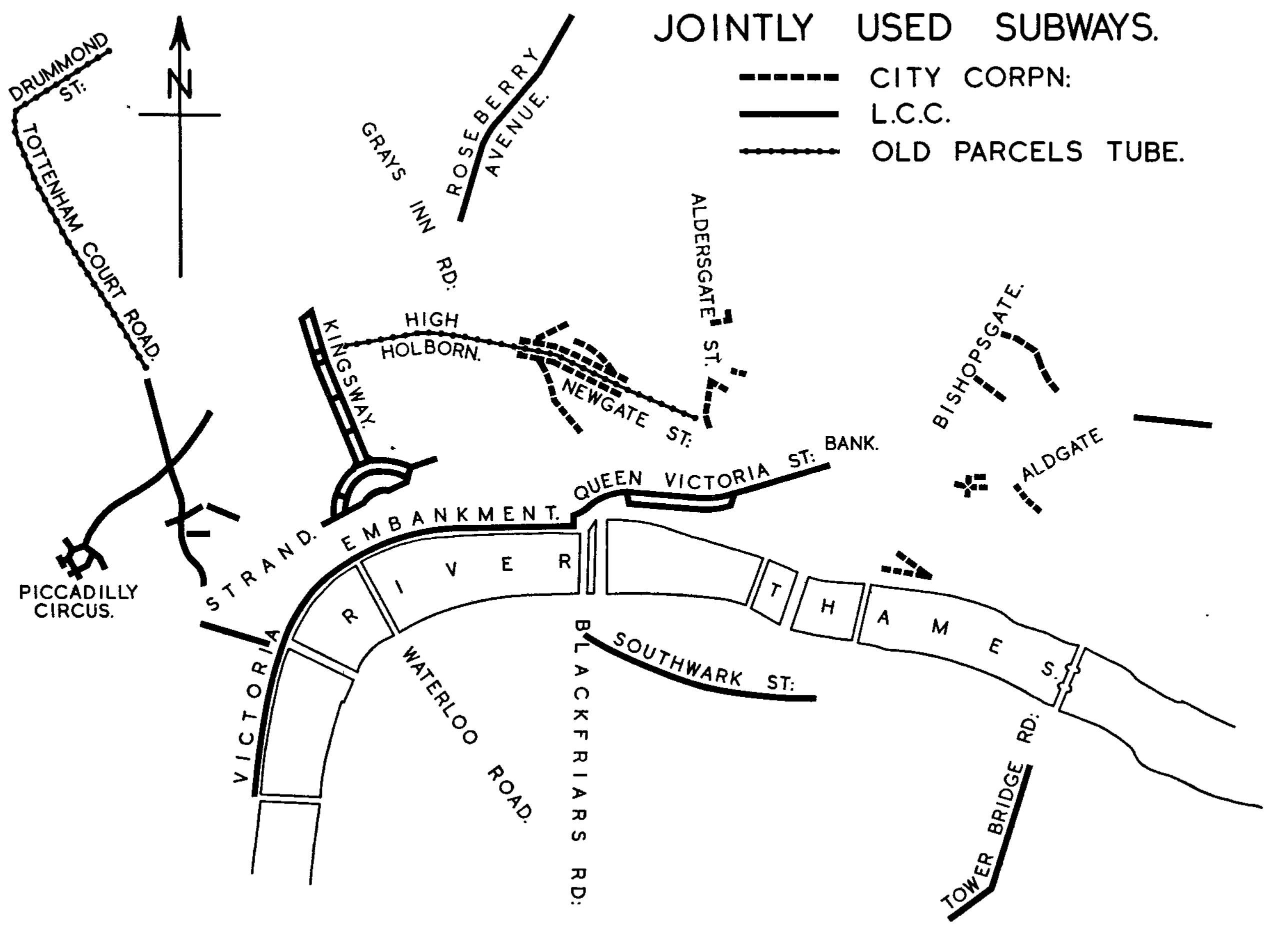


FIG. 3.

cable and passenger lifts in some of the shafts which for practical purposes usually terminate in a building, normally a telephone exchange.

Up to date nearly three miles of this type of tunnel have been constructed and house at present 76 miles of cable.

## 4. CABLING OPERATIONS.

### 4.1. L.P.T.B. Tube Tunnels.

Because of the nature of the work and the need for special equipment the Department's cables in the Board's tunnels have been laid by the Board's staff, with the usual supervision by Post Office staff. As cabling work can proceed only during the shut down periods from 1.30 a.m. to 4.30 a.m. the following procedure has been found necessary:—

Loaded drums are taken from a surface siding to underground rail level and stored at convenient stations on the platforms. Later the drums are loaded on bogies and taken to their allotted positions, the cable being paid off directly on to cable bearers on the side of the tunnel.

The longest length of cable which can be laid in the tunnel without joints is determined by the capacity of a 6 feet diameter cable drum, this being the largest drum that can be taken through the tunnel. For small cables this permits long lengths being used and reduces the number of joints. For the larger cables, however, say up to $2\frac{3}{4}$ inches in diameter, the maximum length is approximately only 150 yards.

With the short periods available for work it is possible to complete during one shut down session only the smaller cable joints.

Cable sections through stations are laid in specially constructed cable runways beneath the platforms or through interconnecting subways..

### 4.2. The Post Office Railway.

Cabling operations in the Post Office railway are carried out under somewhat similar conditions to those pertaining in the L.P.T.B. tube tunnels. The method of transporting the cable to the required point, however, is different. The tunnel is too small (7 ft. in diameter) to accommodate a cable drum and a battery train is made up in a station and a cable length of 100 yards is laid thereon. The train is then taken to the required position and the cable transferred to the bearers. Work can be carried out only during portions of week-ends when the traction system is shut down.

A special feature of the cabling in this railway is the restricted space available for the cables and their bearers. There is little clearance between a passing train and the cable bearers and at curves in the tunnel where a lateral inclination of the track occurs it may be as small as $1\frac{1}{2}$ inches. In order to ensure that the maximum clearance is maintained the diameter of the cable joints must be kept small and as a safety measure locking bars which secure the cables in position are fitted on selected bearers. (Fig. **4**.) Without these precautions it is possible for a cable to be displaced by the vibration set up by a passing train.

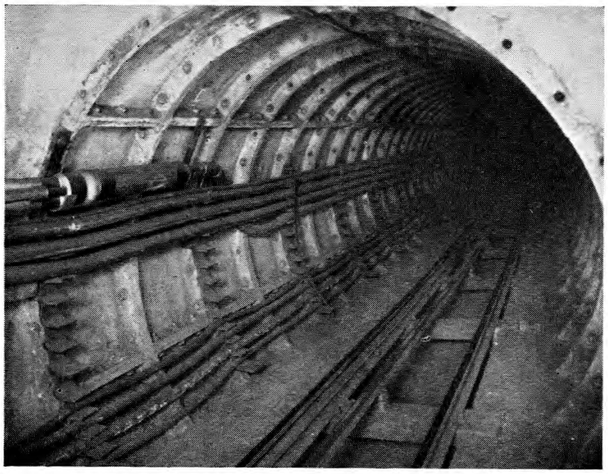

FIG. 4.—VIEW IN POST OFFICE RAILWAY TUNNEL SHOWING CABLE BEARERS AND LOCKING BAR.

### 4.3. L.C.C. and City Corporation Pipe Subways.

Cable-laying in shallow subways consists of three operations: (1) Paying the cable length through one of the entrances, (2) moving it to its allotted position and (3) laying it on the bearers.

The only operation which presents any difficulty is the transportation of the cable from the entrance to its final position and there are two methods which can be used:—

(1) It can be " carried " or transported.
(2) It can be " dragged " or drawn.

In (1), some form of wheeled vehicle may be used but the floor of the subway, being of ballast, is not entirely suitable ; or the cable may be man-handled by a chain of men, a procedure adopted by some of the electric light Companies. In (2), rollers, or other devices to reduce friction, placed at suitable intervals in the subway, may be employed.

A method used extensively over a long period of years by the Department's workmen is to lay wooden battens laterally on the subway floor at intervals of about 4 feet and wedge them to prevent movement. The battens are then greased with petroleum jelly and the cable is drawn over them. Although somewhat crude and unorthodox this method has proved highly satisfactory. It causes no damage to the cable sheath in the form of scratch or flattening and, as the cable rides easily, the sheath is not subjected to undue strain. Rollers have not proved successful in the subways and an account of some experiments with them carried out in the Department's cable tunnel is given later.

Judged by present-day standards the layout of plant in jointly used subways is poor. It should be remembered, however, that they were originally constructed to serve as pipe subways to house water and gas pipes, which apart from drains were the only types of street mains then existing. It was, of course, impossible at that time to foresee the advent and development of electrical (including communication) services and the consequent need for space for cables in the subway ; indeed nearly 60% of the L.C.C. subways had been completed before the first electric cable was laid or the first telephone exchange was opened.

Even where the space in the subways is sufficient for the plant in them, the disposition of the various pipes and cables is such that free access to cable and pipe joints, water and gas valves, etc., is often obstructed by other plant.

At intervals along the walls of some of the subways are short laterals giving access to entrances from the footways or to distribution networks. The positions of these laterals in the sides of the subways reduce the space available for cables and pipes on the wall faces. It frequently happens, however, that the laterals themselves are obstructed by the pipes and cables passing across them. The space on the subway walls available for cable bearers is restricted (in theory at least) to the positions above the laterals.

The cable bearers for Post Office cables are virtually wide shelves containing several layers of cables, an out-of-date arrangement which does not permit of easy access to joints, or removal of obsolete underlying cables.

Some of the gas and water valves in the subways are controlled from street level, a desirable practice in emergency. Connection between the control points in the street and the valves pass vertically through the roofs of the subways and some in so doing pass through the nests of cables immediately above the valves causing undesirable changes in cable formation with consequent congestion.

Jointing conditions are not good, particularly on the cables adjacent to the walls of the subways. There is no permanent lighting nor sockets for hand lamps, and " pot and ladle " plumbing cannot be used, owing to the difficulty of transporting the molten metal along the subways from the entrance where it is heated. Fig. **5** is a view of a typical section of pipe subway.

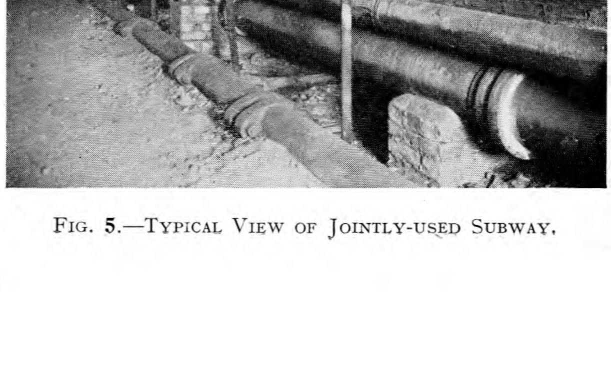

FIG. 5.—TYPICAL VIEW OF JOINTLY-USED SUBWAY.

## 4.4. The Old Parcels Tube.

Cabling practices in the Old Parcels Tube are somewhat similar to those adopted in the Council's subways. There are these differences, however, entrance points (manholes) are more frequent, increasing the number of joints but reducing the distance over which cable lengths have to be transported. Working space is somewhat restricted as the maximum internal measurements of the tube are only 4 ft. 6 in. in height, 4 ft. 3 in. in width with a passageway of 1 ft. 10 in. between the bearers.

Owing to the very considerable air flow which it produces the power-operated ventilating plant is not used whilst work is proceeding in the tube, and as a result the atmosphere becomes vitiated in the vicinity of plumbing operations in which blow lamps are used. The liability to coma, due to fumes, and the difficulties associated with the removal of an inert human body over comparatively long distances in such confined conditions, must constantly be kept in mind during working operations.

## 4.5. Post Office Cable Tunnels.

4.5.1 *Description.*

Fig. **6** is a plan and cross section of a typical Post Office cable tunnel, the salient features of which are as follows:—

4.5.1.1 *Construction.*

The tunnel has a diameter of 7 feet, one section 650 yards long being lined with cast-iron segments and the remainder, 1240 yards, with reinforced concrete segments. The latter have the advantage of lower maintenance costs, periodic painting being reduced, and better lighting is possible owing to the coloured surface. The joints of R.C. segments, however, are less watertight than those of cast-iron which can be caulked, and a R.C. tunnel is therefore not suitable for wet areas. A view of a reinforced concrete tunnel is shown in Fig. **7**.

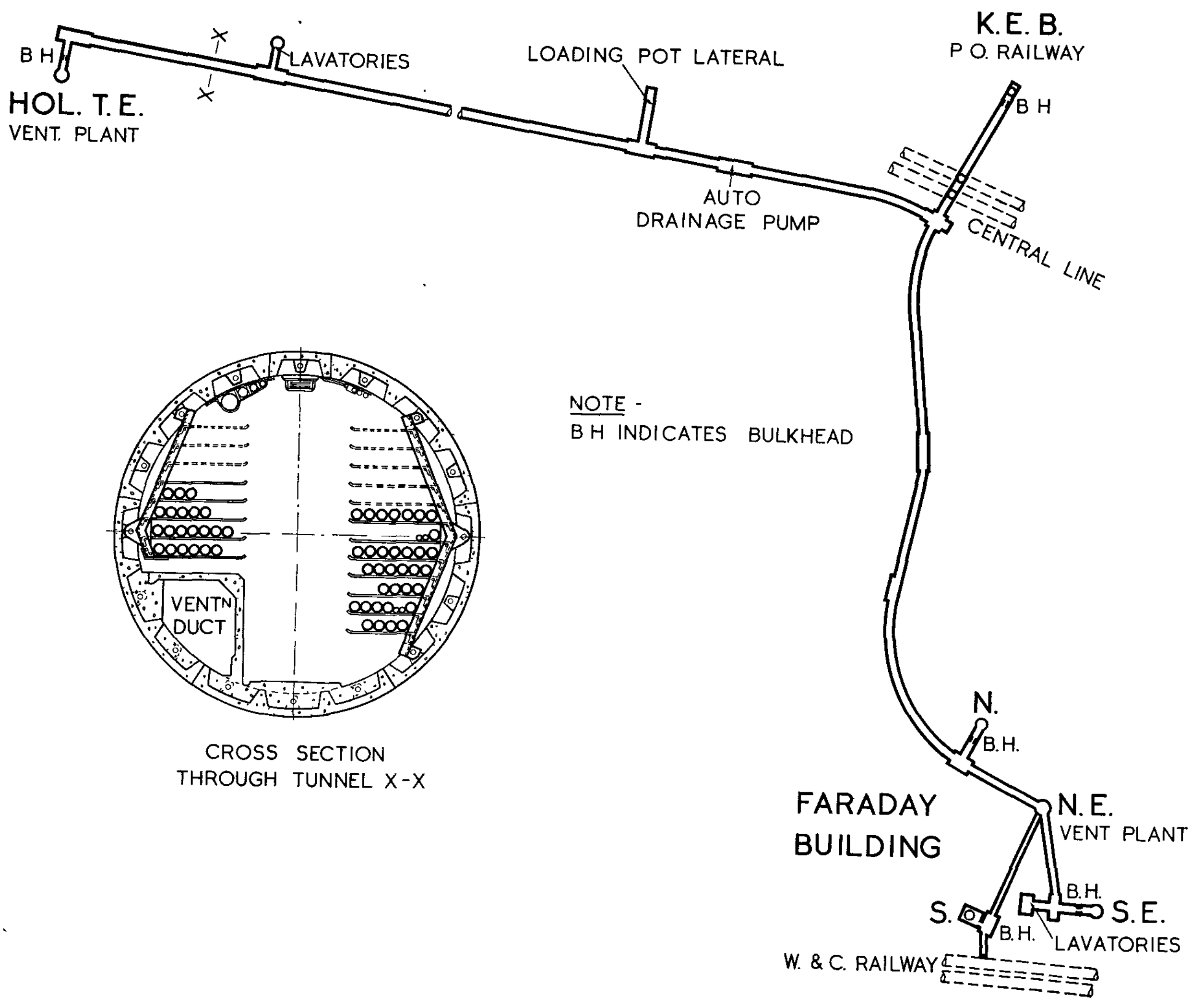

FIG. 6.—TYPICAL POST OFFICE 7′ 0″ DIA. CABLE TUNNEL.

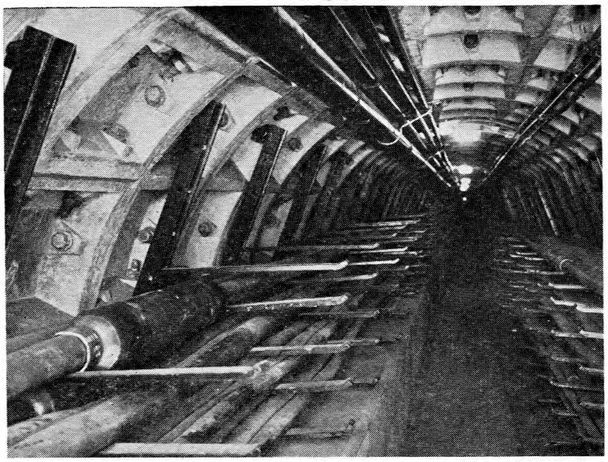

FIG. 7.—TYPICAL VIEW OF REINFORCED CONCRETE POST OFFICE CABLE TUNNEL.

4.5.1.2 *Ventilation.*

Power-operated ventilation plant is provided in order to ensure dryness and a suitable atmosphere for cabling and jointing operations. The air flow approximates 2,700 cubic feet per minute, giving $1\frac{1}{2}$ changes per hour. The ventilating duct is necessarily large and reduces the space available for cables by approximately one quarter.

4.5.1.3 *Lighting.*

The tunnels are divided into sections for lighting, two-way switches being provided at the ends of each section. The bulk-head type of fitting is used and hand-lamp sockets are provided at suitable spacing. The supply is on a 50-volt system from transformers giving a voltage of 25 to earth.

4.5.1.4 *Drainage, etc.*

Mains water with a reducing valve to counter the effect of the increased head is available and lavatories are provided with an automatic ejector plant ; there is also an automatic drainage system. The floor is slightly convex with a drainage channel on each side.

4.5.1.5 *Shafts and Interconnecting Points.*

Shafts connect the tunnel with telephone exchange buildings and with the Post Office railway ; two smaller shafts link up with the L.P.T.B. Central Line east and west-bound tunnels by means of sealed pipes through a head-wall. A connection is also made with the Waterloo and City railway by similar means.

4.5.1.6 *Cable Layout.*

The position occupied by each cable throughout the tunnel system is of the greatest importance in securing a satisfactory layout in the tunnel and shafts and requires to be determined before cable laying begins. Layout plans are therefore prepared, showing the positions of all cables in shafts and tunnels and through bulkheads ; a schedule is included showing the designations and codes of the cables and their cable bearer reference numbers.

For a cable tunnel system such as the one under discussion it is necessary to sectionalise the plans for ease of reference and handling. Each section covers a portion of the tunnel system, the extent being shown in plan while cross sections, similar to that shown on Fig. **6**, are given for all points at which positional changes occur. A circle is used to indicate a cable on a bearer and the cable reference number is shown in the circle.

Most of the shafts have two vertical cable runs and the choice of a vertical run and the position therein for any particular cable are determined by its location in the cable chamber at the top of the shaft, while its position in the tunnel is governed by its ultimate destination in the system and whether it is to be loaded in the loading pot lateral. Obviously with so many route-conditions to satisfy it is not always possible to allot straight through routes for all cables, and use has been made of enlargement chambers as cross-over points to effect positional changes of cables from one side of the tunnel to the other, or from one position to another on the same side. Enlargement chambers (Fig. **8**) are a necessary feature in the construction of the tunnel, and although they were not specifically designed as cross-over points, their size was sometimes influenced by cabling requirements.

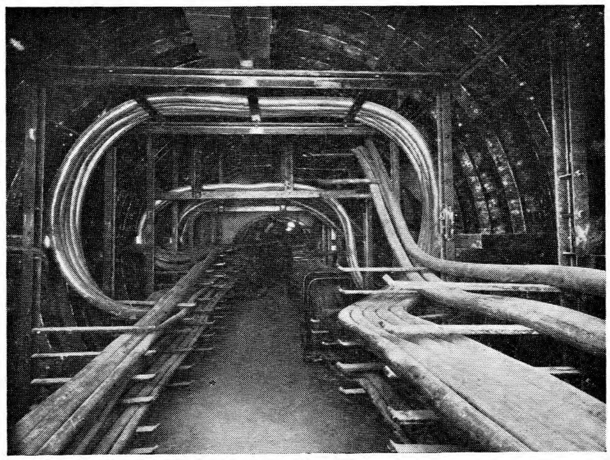

FIG. 8.—ENLARGEMENT CHAMBER, POST OFFICE CABLE TUNNEL.

The problem of accommodating loading pots in the tunnels presented some difficulty and after careful consideration it was decided to provide a separate lateral as an alternative to placing the pots in an enlargement of the tunnel. The method adopted has proved very satisfactory both as regards cabling and loading pot layout.

4.5.1.7 *Cable Bearers.*

The cable capacity of the tunnel is approximately 135 full-sized cables. The type of cable bearer shown utilizes the available space to the best advantage. Several other types were considered, including one having channels bent to the curvature of the tunnel, but they were rejected as being more costly and likely to present difficulties in the alignment of the cantilevers.

Cast-iron bearers have been used where fewer cables had to be dealt with. When needed in large quantities they are cheaper than mild steel types, but weight and bulk restrict their maximum capacity to approximately 24 full-sized cables.

4.5.1.8 *Bulkheads.*

As a precaution against flooding, particularly under air-raid conditions, bulkheads with heavy watertight doors were provided in the short laterals which connect the shafts with the main tunnel. They are of steel and concrete construction and usually about 6 feet thick. Exceptionally the bulkhead was

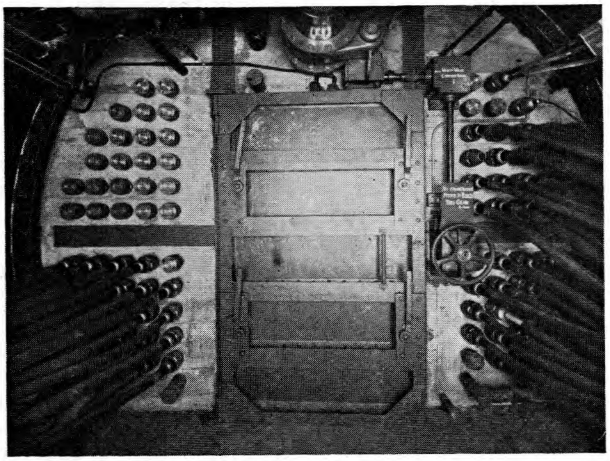

FIG. **9**.—POST OFFICE TUNNEL BULKHEAD "DANGER" SIDE, *i.e.*, LEADING TO SHAFT.

omitted in one case, where the shaft terminates in a specially protected building. Figs. **9** and **10** show respectively the "danger" and "safe" sides of a bulkhead.

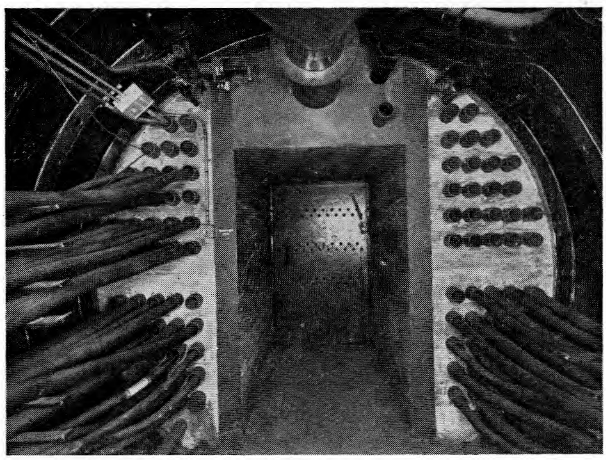

FIG. **10**.—POST OFFICE TUNNEL BULKHEAD "SAFE" SIDE (TUNNEL SIDE).

The cables pass through the bulkheads via steel pipes which form part of the structure; each occupied pipe is sealed with a phosphor-bronze gland designed to accommodate cables of any diameter up to 3 in., and all spare pipes are sealed with phosphor-bronze caps. (Fig. **11**.)

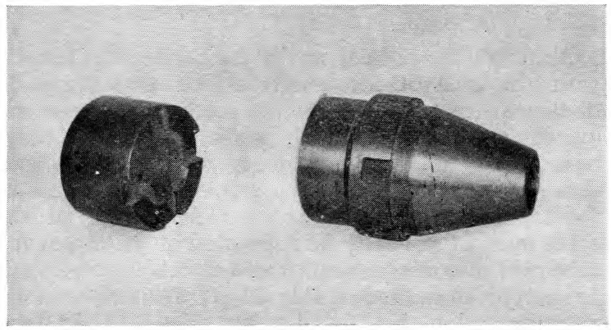

FIG. **11**.—LEFT, PHOSPHOR BRONZE CAP. RIGHT, PHOSPHOR BRONZE GLAND.

The glands are tapered at one end both internally and externally, so that by reducing the length the bore at the tapered end is increased in diameter. To secure watertightness the cables are plumbed to the glands at the points of emergence from the tapered ends. Electric light pipes and conduits, ventilating ducts and other services pass through bulkheads and similarly are made safe. Interlocking valves of simple design ensure that the ventilating plant is shut down before the watertight doors can be closed.

4.5.1.9 *Loading Pot Lateral.*

For the accommodation of loading pots, a lateral chamber was constructed at a point approximately 1,000 yards from the terminal building. The length of the chamber is 63 feet, its diameter is 10 feet and it will accommodate 60 loading pots. The pots are moved from the main tunnel into their position by means of an overhead runway.

4.5.1.10 *Lifts.*

In the tunnel under discussion, two electric cable lifts have been provided, each capable of carrying a 6 feet diameter loaded cable drum. The lifts are approximately 1,900 yards apart so that a cable length required near the centre of the tunnel would have to be transported about 1,000 yards. Turntables are installed in the enlargement chamber near the foot of the lift shafts to assist in the manipulation of the drums.

4.5.2. *Cabling Operations.*

4.5.2.1 *In Shafts.*

Several methods of placing cables in shafts have been tried, but the most satisfactory and expeditious employs a rope through a three-way pulley block for lowering the cable. As the rope is lowered down the shaft, the cable is lashed to it with yarn at intervals of about six feet. After the required length of cable has been paid out, the yarn lashings are transferred from the rope to the horizontal "tacking" bars provided in the shaft, the cable thus being secured temporarily in its correct position in the shaft. The "tacking" bars are of mild steel 3 in. by $\frac{5}{8}$ in. in cross section, covered with sheet lead and fixed across

### 5.3. Tunnel Bonding.

A cast-iron tunnel is of extremely low conductor resistance, and as long as it is electrically continuous it will carry the major portion of the unwanted current. All C.I. tunnels, however, are not electrically continuous. At enlargement chambers where for example a 7 feet tunnel may be continued by a 10 feet section the space between the outer surface of the former and the inner surface of the latter is filled with concrete for the length of the overlap. Similar conditions exist at the junctions of laterals with main tunnels.

In order to maintain electrical continuity the concrete gaps have been bridged by copper bonding strips of suitable cross section. During an extensive electrical survey made by the Department's staff in a tube railway system in which Post Office cables are laid, a number of similar discontinuities in the tunnels were discovered and it was found that the cables bridging the gaps were carrying sheath currents of high values at those points. The fitting of bonding strips, however, reduced the currents to safe values.

## 6. FUTURE OF SUBWAYS AND TUNNELS.

### 6.1. Jointly used Subways.

The future of jointly-used subways in London appears to be uncertain. The published reconstruction proposals[8] while rightly focussing attention on street layouts and architectural features make no reference to any extension of the existing pipe-subways, or to the adoption of the principle of providing subways under all main thoroughfares. It could be assumed inferentially, that the present method of burying plant at shallow depth, which has persisted for more than three centuries, will be perpetuated, with its concomitant disturbances of the amenities of road users.

Sooner or later the increase in the number of sections of streets in inner London where no additional shallow plant can be laid will make necessary the consideration of some other method. Public Utility engineers, in recent discussions[9] have envisaged the construction of new subways, upon the advantages of which however they do not appear to be agreed.

If new subways are to be built, certain fundamental concepts will need revision in order to ensure satisfaction to all users. For example, the policy of crowding the maximum amount of plant into the smallest possible space will require to be reversed and future subways designed on more generous lines ; sufficient room exists under streets to permit of this being done. Again, if the subways are designed as a complete system, a comprehensive layout of plant can also be planned at the outset, but piecemeal construction of course would be necessary. The layout of all pipes and cables together with their bearers and supports will need approval by the subway authority, and the disposition should be such that inspections and remedial maintenance work can be effected without interference with other plant.

In the author's view all cables should be laid on cantilever bearers fixed in channels secured to the subway walls, the lowest bearer being placed so as to allow access beneath it to laterals.

Pipe mains could best be accommodated down the centre of the subway on suitable supports, the vertical portion of which would form part of the subway structure. Suitable separating distances between pipes would enable attention to be given to joints. By this arrangement the pipe mains would divide the subway longitudinally, leaving a passageway on either side of them. Access from one passageway to the other would exist but could be facilitated by recesses in the floor beneath the pipes, spaced at convenient intervals. Connections with buildings or with distribution plant in the footways could be made through the subway walls above the highest cable bearer, this portion of the wall being reserved especially for the purpose. Enlargement chambers would be needed at subway junctions to allow room for plant deviations and crossings.

Regarding shape and type of construction, a rectangular cross section and reinforced concrete are favoured, service exits being formed during construction and sealed so long as they remain empty ; alternatively brickwork walls and a reinforced concrete roof allow of new service exits being made more readily. The provision of electric lighting and suitable hand-lamp sockets should be regarded as normal practice.

Fig. 13 shows the principles of a suggested design for a jointly-used subway. The measurements given, including the roof and wall thicknesses, are not arbitrary ; actual dimensions would require to be determined by local conditions.

It is difficult to make a comparison between the cost of providing a jointly-used subway and a duct route of similar capacity. The subways in London were constructed by the local authorities out of public funds, and each utility undertaking using them pays an annual rental based upon the space occupied by its plant.

In the event of further subways being constructed the responsibility for the cost of transferring to them the plants now buried in the soil would need to be settled. It seems reasonable, however, to expect the utility undertakings to contribute having regard to the improvement factor.

### 6.2. Post Office Cable Tunnels.

The limitations of deep level cable tunnels are confined to the need for terminating them in exchange buildings and the practical difficulties of connecting them with surface duct routes. They are, however, particularly suitable for trunk and junction cable routes and their adoption is likely to be warranted in cities with a large number of exchanges within a comparatively small area, where heavy junction cable networks normally obtain.

London is a peculiarly favourable example. An attempt to convey an impression of general subsoil congestion was made earlier in the paper and it might be well to consider in more detail one locality where the congestion is especially acute. The City telephone manager's area embraces the City of London

[8] & [9] See Bibliography.

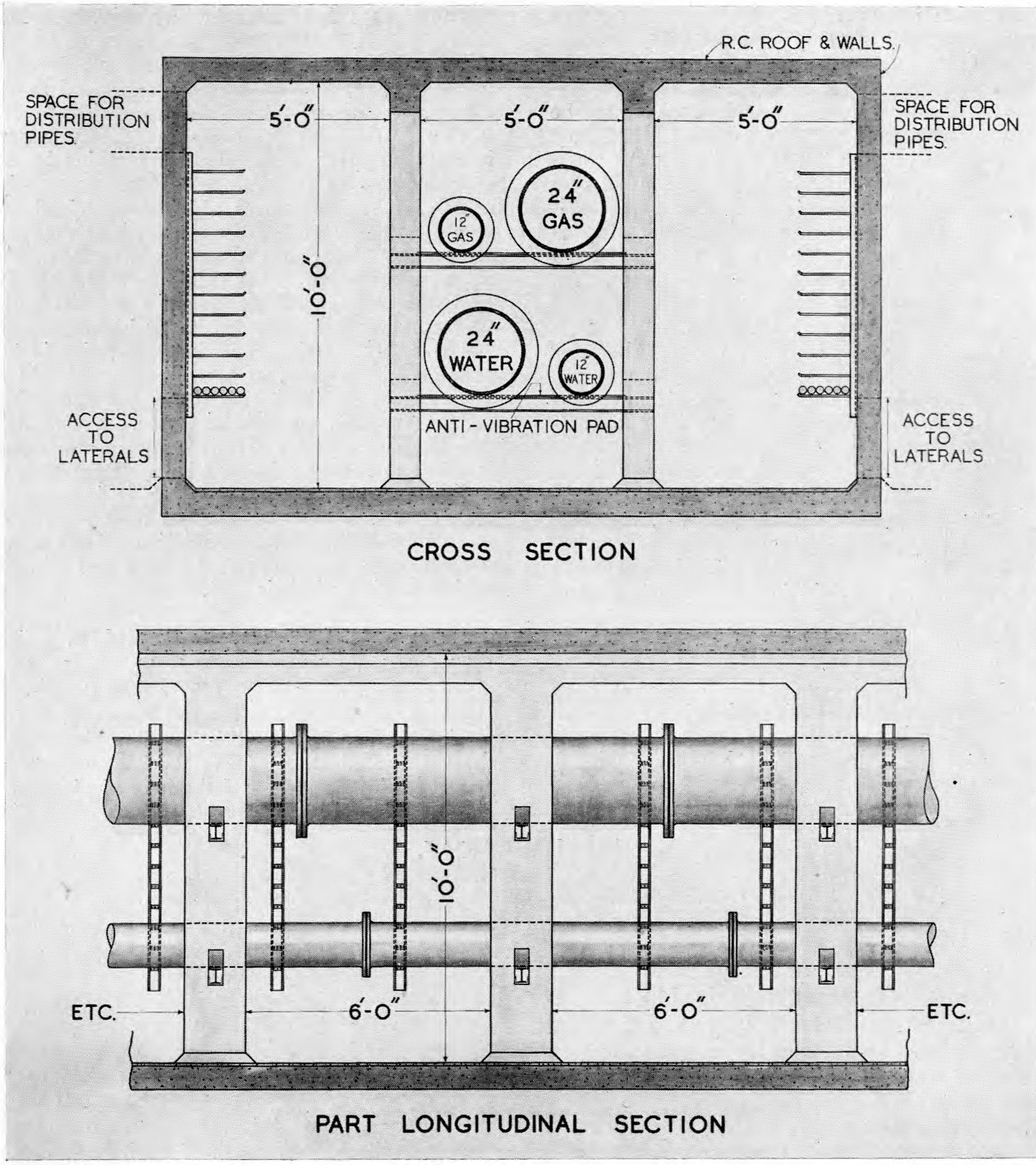


Fig. 13.—Suggested Design for Jointly-used Subway.

and some contiguous territory. In extent, it is only nine square miles and it includes some of the oldest parts of London with narrow streets and most types of obstructions inseparable from old and historic towns. Bridges, subterranean rivers and water-bearing strata at comparatively shallow depths, influence the choice of routes for new duct work, and in one area of about 42 acres in the vicinity of St. Paul's Cathedral ground excavation and water pumping are controlled by Act of Parliament.[10] The narrow streets with their heavy volume of vehicular traffic impose restrictions on the extent of the disturbance which may be allowed by ground works. Inevitably the rate of progress of the work is slow.

Some idea of the volume of the external plant in this small area may be gained from the following statistics. There are more than 1,100 manholes, over 1,800 joint boxes, 214 pipe miles of distribution pipe and duct, 83 route miles of multiple way duct of from 2 ways to 100 ways, 500 miles of trunk and junction cables and 122 miles of subscribers' cables from 100 pairs to 1,400 pairs. The replacement value of this plant approximates £5 millions.

Many of the trunk and junction cables radiate in the direction of the four cardinal points of the compass and they have automatically created heavy duct

[10] See Bibliography.

routes on north-south and east-west lines. Some of the routes are of unwieldy size and it becomes impracticable to secure an orderly layout in the associated manholes.

The area under review would appear to be eminently suitable from the standpoint of expediency for the provision of cable tunnels. How far it could be justified on economic grounds as a result of cost comparisons with duct routes of similar capacity is difficult to determine at present as it is too early to compute all the charges which will be incurred in the maintenance of cable tunnel systems. An approximate comparison of the available annual charges, however, might be of interest.

The annual charges per mile of a 7 feet diameter cable tunnel, 80 feet deep, including electric lighting, lifts, sewage, bulkheads, cable bearers, etc., are:—

Cast-iron lined tunnel £7,200 per mile, excluding maintenance costs.

Reinforced concrete tunnel £6,200 per mile, excluding maintenance costs.

The annual charges of a duct route with approximately half the capacity, including, however, maintenance costs are:—

1. 72-way duct route laid in open trench 10 feet deep under average carriageway surface—£5,800 per mile.
2. Three 24-way duct route provided at one and the same time, laid in open trench 10 feet deep under average carriageway surface in a congested street—£7,500 per mile.
3. Either of the above provided by tunnelling—£8,670 per mile.

The author feels that in any relevant economic study special consideration should be given to the "irreducible data" which with cable tunnels are many, varied, and not readily expressed in money values. Such items as freedom from risks of damage due to road works, gas leakages, faulty water and hydraulic power mains, electricity mains burn-outs, and electrolytic corrosion cannot accurately be assessed. The value of this immunity, however, would probably be greatly in excess of the amounts recoverable from offending Undertakings. As an example the value of lost calls due to the breakdown of cables carrying long distance circuits although problematical will undoubtedly be high.

The better working conditions obtaining in tunnels compared with those in surface routes should prove advantageous to the health of the staff and ultimately reduce the cost of sick absences. Economic conditions apart, a policy of improving working standards in order to enhance the well-being of the staff would be in line with the present trends in industry where higher levels of working comfort have been provided and are being included in the designs of new industrial undertakings, as a matter of course and without too critical a view of their cost.

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