No. 149.

THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

Recent Developments in Underground Construction, Laying and Loading Armoured Cables.

BY

J. E. Z. BRYDEN, B.Sc. (Eng.), A.M.I.E.E., and
T. HARGREAVES, A.M.I.E.E.

A PAPER

Read before the London Centre of the Institution on the 14th February, 1933, and at other Centres during the Session.

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INTRODUCTION.

The necessity for developing the telephone service of the British Post Office in conjunction with the strictest economy has always been appreciated by Post Office Engineers, but the financial conditions of the last few years have emphasised this necessity and made imperative the exploration of all avenues offering prospects of economical construction and maintenance.

It is well known that the cost of external plant is a large proportion of the cost of providing telephone service, and economies in the provision and maintenance of external plant may therefore be expected to effect substantial savings.

Underground conduit construction is expensive and glazed earthenware ducts afford little protection against electrolytic or chemical corrosion. The possibilities of placing armoured cable direct in the ground are therefore being closely studied by the British Post Office and other Administrations.

The object of this paper is to show that, in certain circumstances, by the adoption of machine methods, underground cables can be laid more cheaply and quickly than has hitherto been the practice.

Under suitable conditions the economics of buried cable provision compare favourably with those of aerial cable construction, in addition to which, wire- or tape-armoured cables may be expected to afford greater immunity from damage by storms, corrosion or vibrational fatigue.

In considering the development of buried cable construction, the following factors must be taken into account.

(1) Type of cable.

(2) Method of laying.

(3) Design of loading coil case.

(4) Accommodation and installation of loading coil cases.

(5) Jointing and protection of joints.

(6) Maintenance facilities.

SECTION I.

Type of Cable.

In deciding the type of cable the factors to be borne in mind are:—

(*a*) Risk of mechanical damage during and after laying.

(*b*) Risk of damage by chemical corrosion during the life of the cable.

(*c*) Cost.

Cable protected only by a lead sheath does not completely eliminate the risks indicated in items *a* and *b*, and an additional protective covering is therefore necessary. There are various types of protection, suitable types being:—

1. *Cable, lead covered, wire armouring.*

Used for crossing docks, rivers, etc., where no protecting conduit can be laid and in situations where cables may be subject to abnormal stress.

2. *Cable, lead covered, tape armouring.*

Now being generally adopted for placing direct in ground, where the tape armouring may be expected to afford reasonable mechanical protection.

3. *Cable, lead covered. Protected with Bitumen and Hessian Tape.*

Suitable in areas where water or subsoil has a deleterious action on the lead sheath. Also laid direct in the ground to serve subscribers' premises in residential areas where ducts are not economically justified.

4. *Cable, lead covered. Protected with "Pernax."*

Used in areas subject to vigorous chemical corrosion.

A brief description of the protective coverings used and the methods of their application is as follows:—

1. *Cable, Lead Covered—Wire Armouring.*

The continuously lead-sheathed cable, after careful scrutiny for defects, is passed through a bath of bituminous compound, after which it is immediately lapped with either (*a*) one paper lapping, with an overlap of at least 50 per cent., or (*b*) two close lappings of paper, one overlapping the other by 50 per cent. The cable is again compounded, and served with sufficient jute yarn to form a satisfactory bedding for the armouring, which consists of galvanised iron wires. The galvanised iron wires are then covered with two coats of compound, consisting of pitch, bitumen and resin oil, and two servings of 3-ply jute yarn, the compound being placed between the two servings and over the outer serving of yarn.

The completed cable is whitewashed to prevent adhesion beween the *coils* of cable on the drum.

(2) *Cable, Lead Covered, Tape Armouring.*

The lead-sheathed cable is first passed through a bath of bituminous compound. It is then immediately lapped with either (*a*) one compounded paper, with an overlap of at least 50 per cent., or (*b*) two close lappings of compounded paper, one overlapping the other by 50 per cent. The cable is again compounded and served with sufficient compounded jute yarn to form a bedding at least 0.060″ thick. A compounded mild steel tape is then applied with a suitable open lay, the gaps being not greater than 25 per cent. of the width of the tape, followed by a similar tape which is applied evenly over the gaps left by the first. The thickness of each tape is 0.02″ for a cable diameter up to 0.75″, 0.03″ for a cable diameter of above 0.75″ to 1.75″, and 0.04″ for a cable diameter above 1.75″. A coat of compound is applied immediately after armouring. The armoured cable is then served with a sufficient jute yarn to form a covering at least 0.060″ thick and again compounded. The completed cable is whitewashed to prevent adhesion between the *coils* of cable on the drum.

(3) *Cable, Lead Covered, Protected with Bitumen and Hessian Tape.*

The lead-sheathed cable, having been cleaned, is passed through a bath of approved petroleum bitumen compound; lapped with Hessian or other approved tape, with a 50 per cent. overlap, or alternatively with two Hessian or other approved tapes, the first laid on edge to edge, and the second being so placed that the centre thereof is immediately over the adjacent edges of the first; again passed through compound, and finally whitewashed.

(4) *Cable, Lead Covered, Protected with "Pernax."*

Pernax consists of Para rubber and Carnauba wax and is impervious to water.

The lead-sheathed cable is first examined and, if necessary, cleaned, after which it is covered with one layer of Pernax to a thickness varying from 0.080″ for a cable having a diameter not greater than one inch, to 0.200″ for a cable having a diameter of 2.25″ or over.

SECTION II.

METHOD OF LAYING.

The first operation in the laying of armoured cable is the excavation of the trench, compared with which the laying of the cable is simple. In fact, the cost of the work and the progress of the scheme are governed almost entirely by the cost and speed of trenching. Speed is essential if advantage is to be taken of the economies to be effected by buried cable construction, and mechanical methods of trenching and cable-laying offer the means of achieving this object. So far as is known, no machine for simultaneous trenching and laying cable has yet been designed in this country, but Post Office Engineers in co-operation with a firm of agricultural engineers have successfully adapted an agricultural machine known as the moledrainer to perform these operations. The use of the machine is described later.

The three methods of trenching and cable-laying which have been practised in Great Britain up to the present time are:—

(1) Open trench, with cable laid by manual labour.

(2) Agricultural plough.

(3) Mole-drainer machine.

(1) *Open trench, with cable laid by manual labour.*

The ordinary and generally recognised method of laying cable direct in the ground is by the excavation of a trench of suitable width and depth; the laying of the cable, and the filling in of the trench—the whole of the operations being carried out by manual labour.

The excavation of a trench 16″ to 26″ deep by 9″ to 14″ wide is familiar to all and does not call for detailed description. Points of importance, however, are that the width of the trench should not be greater than is necessary for the satisfactory execution of the work and that standard depths (to the top of the cable), *i.e.*, carriageway 24″ and footway 14″, should be adhered to as far as practicable.

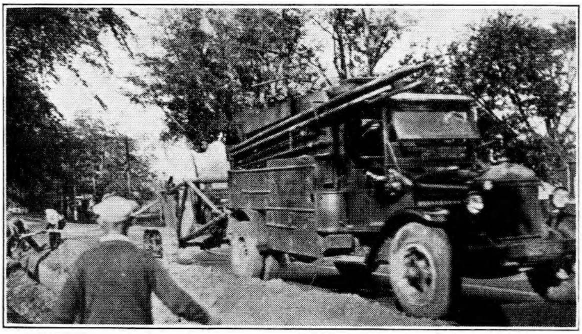
The bottom of the trench should be carefully levelled and any change of level should be gradual.

In laying the cable by hand, two methods may be used:

(*a*) Lay the cable direct from the cable drum into the trench.

(*b*) Haul the cable on rollers alongside or in the bottom of the trench before placing it in position.

Fig. 1 shows the first method. The drum is mounted either on a bogey drawn by a motor vehicle, or on a motor



PLACING CABLE IN SHOULDER OF HIGHWAY.

FIG. 1.

vehicle specially designed for the conveyance of cable drums. In each case the cable is paid direct into the trench by hand, care being taken to see that any tendency to kink and any damage to the armouring is avoided. The trench is then cleared of any stones that may have fallen into it and, after a layer of about 3 inches of finely sifted earth, free from stones, has been placed over the cable to act as a cushion, it is filled in by manual labour.

In the second method (illustrated in Fig. 2), which was employed in the laying of the Ashford-St. Margarets cable, the cable drum, supported on jacks, is placed at one end of the open trench and a motor-driven winch at the other.

A hawser of stranded steel is connected to the cable end by means of a link and swivel and, preferably, a woven wire grip, the end of the cable being suitably dressed to ensure that the pull is taken up by conductors and sheath.

In order to prevent damage to the armouring, rollers are placed across the top of the trench at regular intervals of about 9 ft. The winch is started and the cable drawn along at a speed of about 60 ft. per minute, the loose end of the hawser at the winch end being taken up on a small hand-driven winch. After the length of cable has been drawn along, parties of three men remove the rollers and lower the cable into the trench (two men lifting the cable and one removing the rollers). The trench is then cleared and filled in as previously described. Ten to fifteen minutes is the approximate time required to lay a 182-yard length of cable by this method.

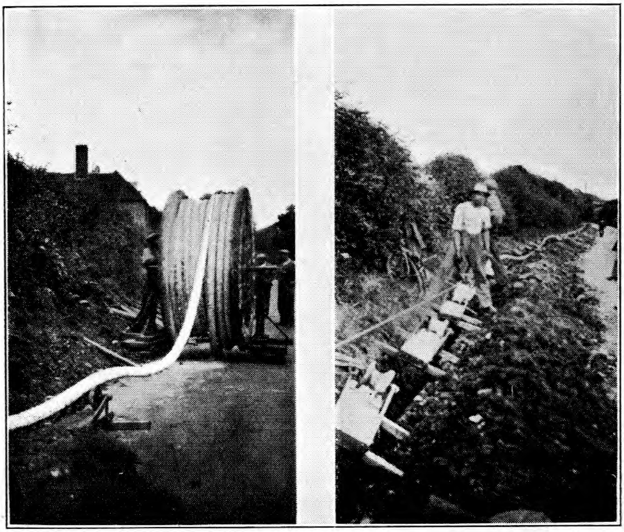


FIG. 2.

The rollers may be placed in the bottom of the trench, but this necessitates a wider trench as there must be enough room for men to remove the rollers after the cable has been drawn along.

When one compares the size of the cable and the extent of the excavation necessary for its accommodation at the required depth, it becomes evident that substantial economies in the laying of buried cable might be effected by the use of machinery which would enable the cable to be laid with less excavation. (Fig. 3 shows relative sizes of cable and trench).

TRENCHES—FOOTWAY AND CARRIAGEWAY.

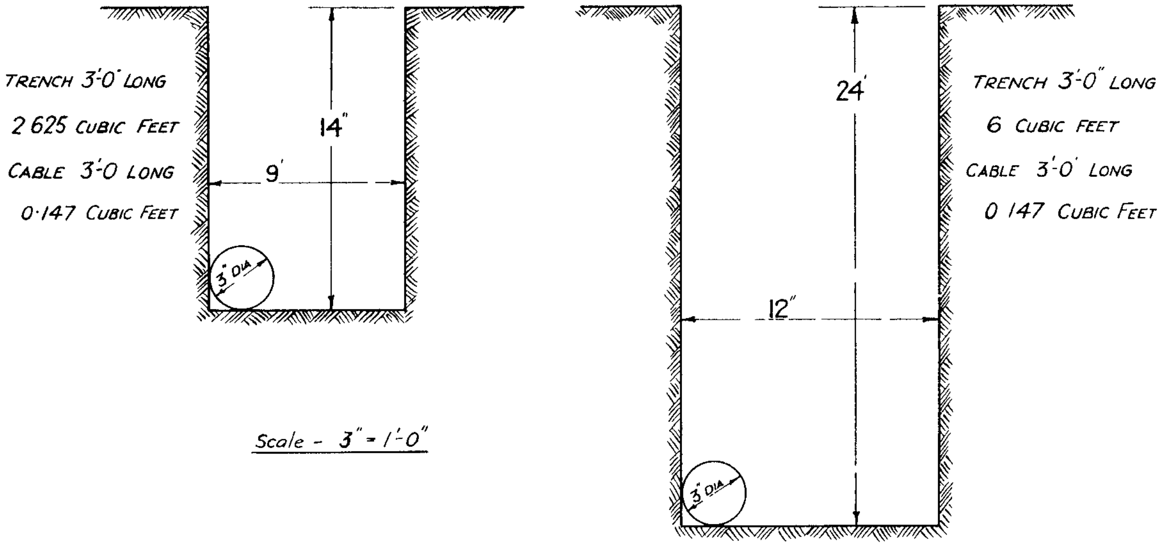


FIG. 3.

(2) *Agricultural plough.*

Where extensive buried cable schemes are being undertaken the use of machinery has received serious consideration, an interesting feature being that machinery developed by the oldest industry, namely, agriculture, is being adapted to meet the needs of modern communication.

The agricultural plough naturally suggests itself as a practical means of excavation where cable is being laid at shallow depth in suitable soil and under gravel or grass. In this respect it is of interest to recall that when 4 miles of underground cable were laid between railway tracks in Massaachusetts, on April 16th, 1882, for the sole purpose of making experimental tests of cable characteristics, the trench was excavated by means of a plough attached to the rear of a truck drawn by a steam locomotive, and was afterwards filled in by means of a stout plank fixed to the truck, at such an angle that when the train moved forward it drew the gravel back into the track like a scraper.

A more recent experiment, illustrated in Fig. 4, was made at Coneysthorpe, in the North-Eastern Engineering District, where wide grass margins were available. A local farmer, on being approached for the loan of a Fordson Tractor, offered to cut, at a low price, 1,706 yards of trench. The offer was accepted and the trench was traversed twice to a final depth of 18″. The remaining length of trench, about 423 yards, being carriage-way entrances and road crossings, was cut by manual labour. The cable (25pr/10) has a covering of " Pernax " to protect the lead sheath against corrosion.

FIG. 4.

In laying the cable, the cable drum was mounted on the Department's freighter, which moved slowly along the road parallel to the trench as the cable was paid off. Fig. 5 shows the cable being laid in the trench.

FIG. 5.

The experiment was successful and the cost of the work, when compared with the cost of standard underground or aerial construction, leaves no doubt that a similar method should, when possible, be adopted.

(3) *Mole-Drainer Method of Cable Placing.*

Cambridge-Ely-Kings Lynn.

The cable scheme selected for a most interesting experiment was that of Cambrdige-Ely-Kings Lynn.

The scheme provided for 122pr/10lb., 104pr/10lb., 60/10lb. and 74pr/10 Q cable, loaded with 120 mH coils at a spacing of 2000 yards, the total mileage being 45.878 miles. Of this 38.25 miles are armoured and placed direct in the ground.

Over the greater part of the route grass verge is available and suitable for machine methods of trenching and cable-laying. The District staff had been investigating the possibilities of using agricultural machinery for trenching and/or cabling and, after extensive tests had been made, it was decided as an experiment to use the Ransome " Mole-drainer " machine for placing direct in the ground 600 yards of 122pr/10 cable. The experiment was regarded as completely successful and it was decided to adopt the method where practicable along the route of the proposed Cambridge-Kings Lynn cable.

The mole-draining machine, illustrated in Fig. 6, is a well-known and old-established agricultural implement which has long been used for draining land where the soil is sufficiently cohesive to remain in position after the passage of the "mole." The mole-drainer consists of a solid steel cylindrical "mole," wedge-shaped at the leading end and supported from a chassis by means of a knife-edged standard. The depth at which the "mole" operates is regulated by means of the crank handle and screwed rod illustrated, a maximum of 24″ being obtainable.

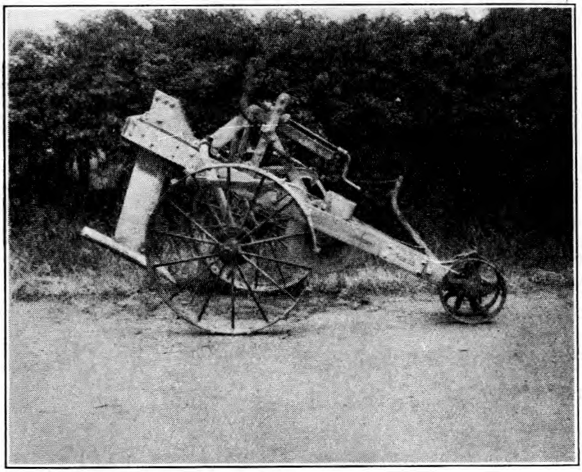


FIG. 6.

The illustration of the machine shows the construction, the main features being the knife-edged standard, the steel "mole," wedge-shaped at its leading end, and the turf-cutting disc. In suitable soils, the "drain" is a perfect tube, and agricultural records show that it remains so for many years.

It is, of course, in its adaptation to communication engineering that it becomes of interest to telephone engineers. There is little doubt that its introduction and successful application on the Cambridge-Kings Lynn underground scheme were due to the initiative of Mr. L. G. Semple, of the Eastern District staff, to whom and to Mr. R. O. Boocock the authors are indebted for description and photographs of methods employed.

The mole-drainer machine can be used coupled direct to a tractor or drawn along by means of a hawser. Figs. 7 and 8

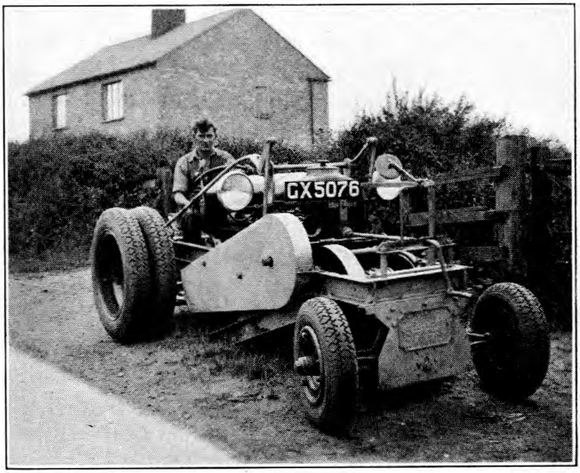


Fig. 7.

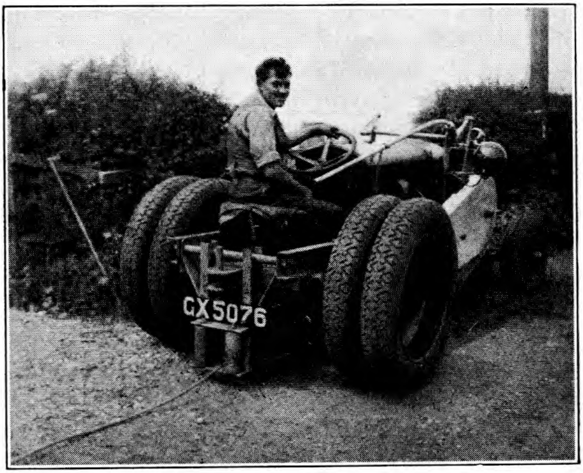


Fig. 8.

show the tractor used on the Cambridge-Kings Lynn scheme. This was a Fordson Industrial Tractor equipped with an auto self-anchoring winch so that, if not of sufficient power to pull the mole-drainer when coupled direct, it could be used as a stationary power winch. Experience showed that one tractor was not sufficiently powerful to exert an effective pull on the mole-drainer when coupled direct. It was therefore used as a power winch.

The winch-hawser was coupled to the front of the mole-drainer *via* a 7/8 G.I. wire mechanical " fuse " having a breaking stress of approximately 4½ tons. This mechanical " fuse " was provided to safeguard the mole-drainer against damage by buried obstacles. A subsidiary " fuse " of 7/14 G.I. wire, with considerable slack, was fixed in parallel with the 7/8 mechanical " fuse " in order to prevent dangerous jumping of the hawser should the 7/8 G.I. wire break.

The coupling between mole and cable consisted of two sizes of stranded G.I. wire linked together, the 7/8 G.I. wire strand being fixed to the rear of the mole and the N/14 G.I. wire being linked with the end of the cable. The N/14 wire acts as a mechanical " fuse " to protect the cable and the number of strands used is determined by the size of the cable. A metal hood with a torpedo head protects both cable end and mechanical " fuse " and prevents premature breaking of the latter should the " bore " collapse immediately behind the mole. Fig. 9 details the arrangement.

A satisfactory method of fixing a woven-wire cable grip to the comparatively small armoured cables, in order that armouring, lead sheath and conductors may all take a share in the stresses during laying, has not yet been developed. The armouring was therefore cut away, the lead sheath and conductors being suitably dressed to take the stress. The cable end was then passed through a thimble, looped back on itself and securely fastened. The method involves scrapping the cable end thus treated.

A hole about 30″ deep by 24″ square was dug at the point where the mole-drainer was to begin its work. The mole was lowered into the hole to the required depth and the tractor driven forward with the winch running free and paying out the steel hawser until suitable anchorage was found at a distance of 70 or 80 yards. The power unit was then disengaged from the tractor wheel drive and engaged with the winch. The hawser took up the load and being held at the distant end by

Mole Drainer and Cable Couplings.

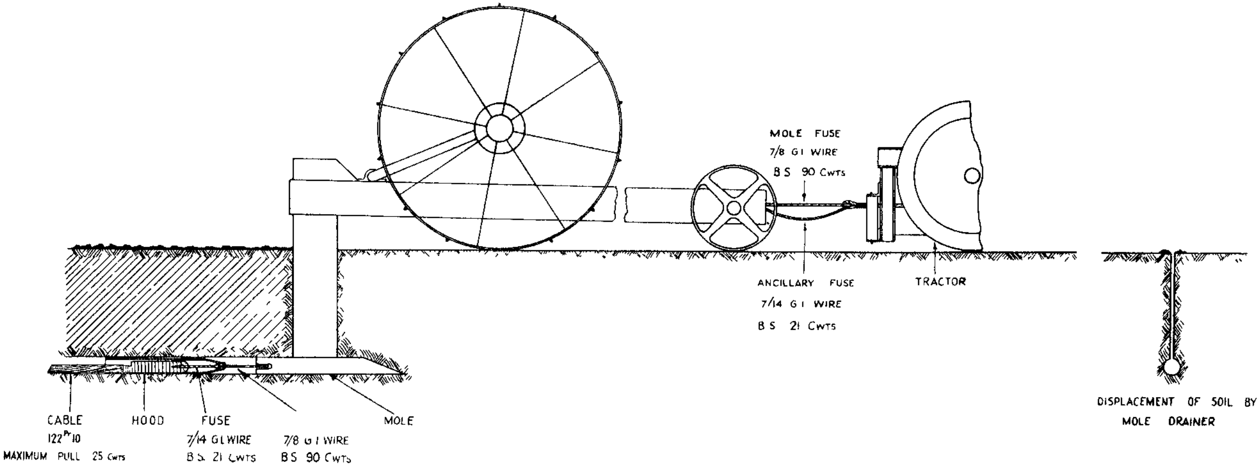


Fig. 9.

the resistance of the earth to the mole-drainer, caused the tractor to move backwards and bury its anchors in the ground. When the anchorage of the tractor became greater than the resistance of the earth to the mole-drainer, the mole-drainer was pulled forward, drawing the cable behind it until all the hawser was taken up on the winch. The winch was then disengaged, the power unit engaged with the wheel drive, the anchor being automatically withdrawn as the tractor moved forward to repeat the operations.

The 122/10 cable was supplied in drum lengths of 522 yds. but, as experiment had shown that 312 yds. was the maximum length that could safely be drawn in, the cable was laid in separate lengths of 261 yards.

The 60/10 cable was supplied in drum lengths of 666 yds., that is, more than double the length that could safely be drawn in. The 666 yds. length was therefore treated as two sections of 333 yds. each and, in order to save two joints, the cable placing operations were carried out as illustrated in Fig. 10. The cable drum was placed at the centre of a 333 yds. section and 166½ yds. paid direct from the drum and pulled in one direction. A further 166½ yds. was then paid off the drum and first "snaked," *i.e.*, coiled in "figure of eight" formation on the ground. The cable was cut and there was therefore now 166½ yds. of cable coiled and ready to be drawn in by the mole-drainer in the reverse direction to that in which the first 166½ yds. had been drawn.

During the time this 166½ yds. was being drawn in the cable drum containing the remaining 333 yds. was moved to the centre of the adjacent section and the operations described above were repeated. The 666 yds. length was therefore laid with only one intermediate joint but took longer than the straightforward method described, and shown in Fig. 10 A.

Fig. 10, A. B. C., also show the movements of tractor, mole-drainer, cable drum and cable, whilst the table at the foot shows the distance travelled and the effective and ineffective time.

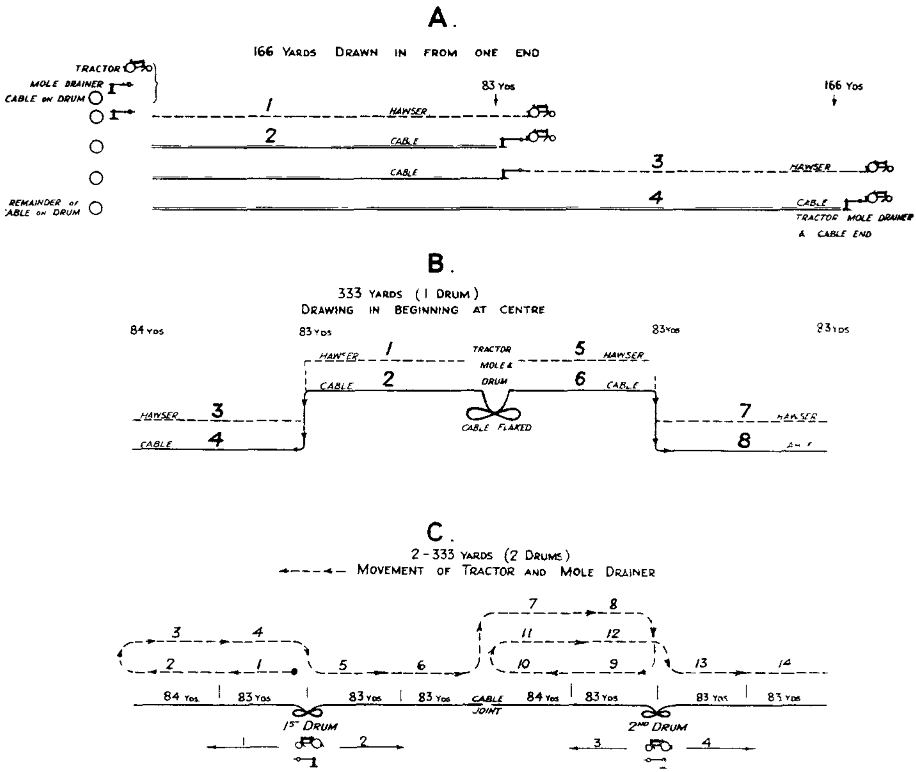
The speed of pulling the cable in was about 60 ft. per minute.

The advantages of the winch-hawser combination are:—

(*a*) Straight and steady pull.

(*b*) Can be used to pull the mole-drainer along sloping banks or along difficult ground.

Cable Placing by Mole Drainer.



	Distance Travelled by - Tractor Yards	Mole Drainer Yards	Cable Drawn in Yards	Effective Pulling Time %
A.	166	166	166	50
B & C.	167	167	167	50
	167	167	—	—
	166	166	166	50
	167	167	—	—
	167	167	167	50
	167	167	—	—
	166	166	166	50
	1167	1167	666	28 5

Fig. 10.

(c) The mole-drainer can negotiate surface obstructions by guiding the hawser through snatch-blocks held by crowbars.

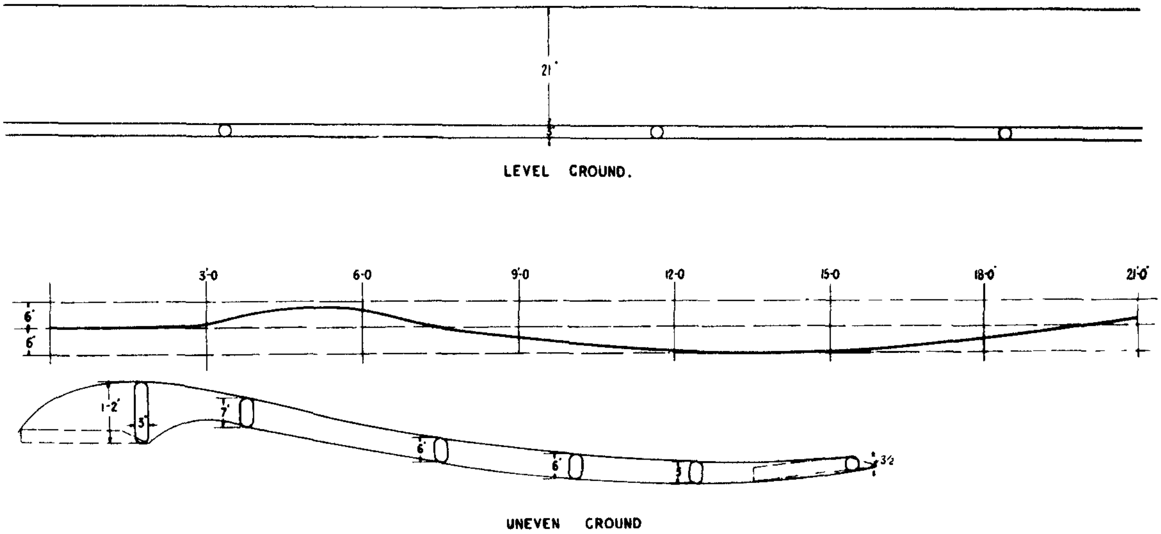


FIG. 11.

The disadvantages are:—

(*a*) The length of cable drawn in at a time is limited by the length of the winch-hawser and the availability of anchorage.
(*b*) Involves frequent shifting of the tractor to new positions.
(*c*) Slows down the work as cable placing is suspended each time the tractor moves forward.
(*d*) Increases ineffective time.

The mole-drainer will be most successful where the ground is reasonably free from irregularities. Undulations, hummocks, etc., are reflected in the "mole" track and more strain will therefore be placed on the cable when drawn through, and Fig. 11 shows the tracking of the "mole" and the effect on the "duct" when the mole-drainer is used on undulating ground.

The mole-drainer described is 4′ 4″ wide and requires at least that width of surface on which to operate.

A mole-drainer known as "The Little Wonder," having a width of 15″, has therefore been developed to operate on narrow surfaces. It is easily controlled by one man and will operate on sloping surfaces as easily as on the level. The principle is similar to that of the standard type except that the maximum depth at which the "mole" operates is 16″.

Where it is intended to place the cable at a greater depth than can be reached by the "mole," a trench 10″ or 12″ deep is first excavated by a deep digging plough, after which "The Little Wonder" can operate at the required depth.

The outstanding features of the mole-drainer cabling method are the ease and the completeness with which all operations normally associated with duct and cable-laying are performed.

The disadvantages are, that the breaking strength of the smaller cables and the weight of large size cables limit both the length that can be pulled in and the vertical and horizontal route deviations.

The machine has proved capable of cutting through grass, gravel, tar-sprayed and asphalt surfaces. Loose stones, roots and small obstacles have presented little difficulty. Unless large stones or other obstructions are encountered the only evidence on the surface of the passage of the mole is a small, slightly raised seam 1″ to 2″ wide. By means of a tamper this is readily restored to its original condition. In road verge or grass land, tamping is not necessary as the seam soon disappears.

It is considered that the mole-drainer machine should be adapted for sub-surface exploration in order to find out the suitability of the ground. Where surface conditions are favourable for machine methods, but sub-surface conditions are doubtful, it is essential that the latter should be determined with certainty. The rejection or the acceptance of the economic advantages of machine methods merely on the evidence of two or three pilot holes, each two or three feet long, in a 6000 ft. loading section, is difficult to justify.

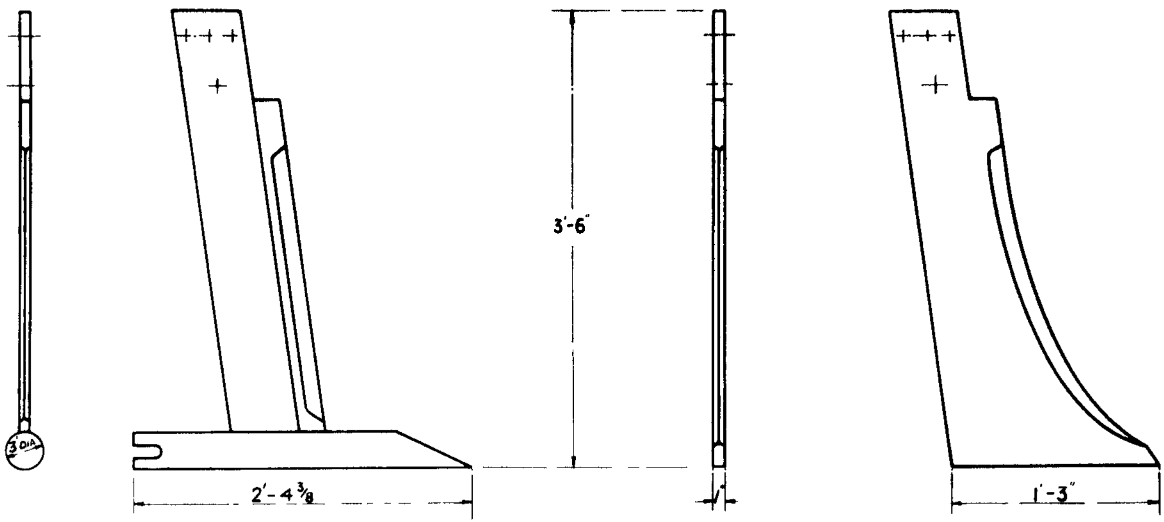
Instead of excavating a few pilot holes to prove the presence or absence of obstructions, and deciding on such slender evidence whether machine methods are practicable, it is suggested that any route where armoured cable is proposed should be traversed by a machine; first at shallow depth if a speedy survey is required, and later at the required depth. There would then be no doubt as to the nature of the sub-surface.

Fig. 12 shows the authors' suggestion for adapting the mole-drainer for sub-surface exploration. The rooter shown would be interchangeable with the ordinary knife-edged standard and " mole " on the same chassis. The mole-drainer would, where possible, be coupled direct to the tractor so that it could be drawn along without stoppages other than those due to obstructions.

Fig. 13 illustrates the idea carried a stage further. In this case, for rapid sub-surface exploration, the cutter is attached directly to a tractor by means of a specially designed fitting. It will be seen that the cutter could be used at any angle, for example, (1) for exploring sloping ground or the foot of a hedgebank, (2) for exploring asphalt, gravel or grass surfaces and (3) for exploring the shoulder of a roadway. (4) Skimming rough or hummocky surfaces.

One or two men would follow the tractor noting or driving stakes at the site of obstructions. Hand digging would later remove the obstructions well in advance of cabling. Such a procedure would ensure the almost uninterrupted progress of cable placing operations, the effect of which will be indicated later in the paper.

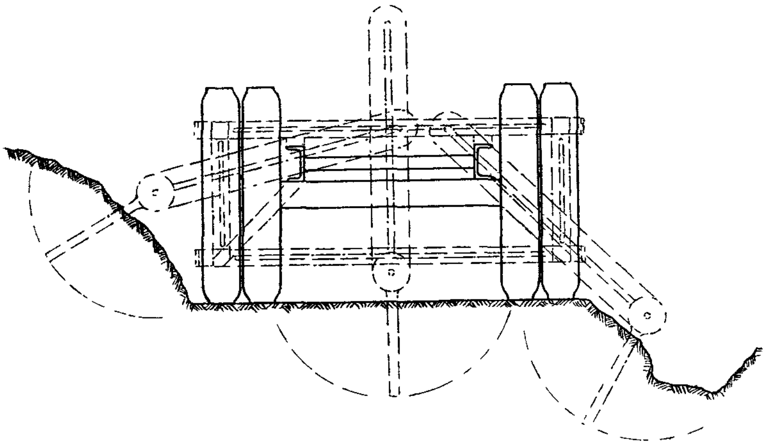
Experience alone will determine the limitations of the



COULTER AND MOLE. ROOTER.

FIG. 12.

mole-drainer method of cable placing in different soils. The nature of the soil may have to be sufficiently cohesive to prevent the walls falling in after the passage of the " mole,"



TRACTOR FITTED FOR SUB-SURFACE EXPLORATION.

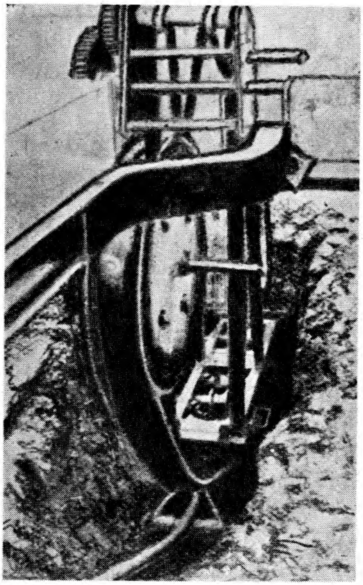
FIG. 13.

unless an interesting development by a German firm makes the use of the mole-drainer practicable in much softer ground. The development, described by Mr. R. Borlase Matthews in the *Electrical Review* of July 17th, 1931, consists of a tube-forming machine (Fig. 14) which forms a strip of sheet steel into a tube drawn along by the mole.

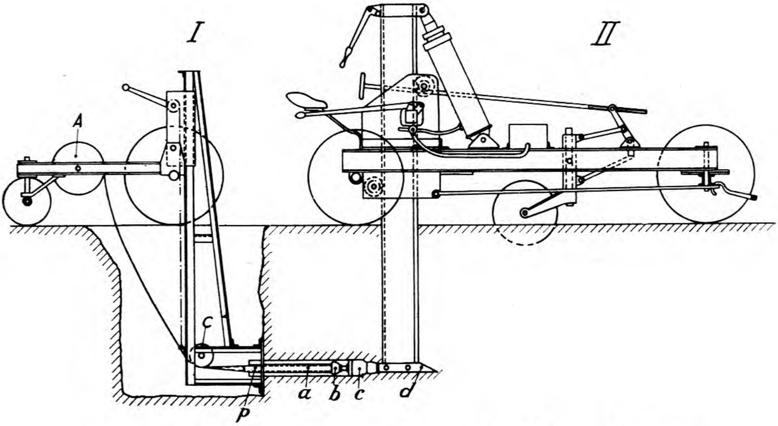
The strip of sheet steel (which may be either galvanised or painted) is provided in 700 or 800 yard lengths. The width of the strip is usually 6½″, forming a 2″ tube with a smooth interior. The tube can therefore act merely as a drain or as a " duct " and be formed in advance of cabling. It is understood, however, that it has been found more practicable to form the tube and draw in the cable simultaneously than to draw the cable into the tube subsequently. Such a method might be successful in ground too soft or peaty for the mole-drainer alone. Sufficient information is not yet available as to whether the development is more than an interesting possibility.

In the diagrammatic illustration of the machine, the mole-drainer is shown on the right and the tube-forming machine on the left.

The grip of the tube is shown at " *b* " and " *a* " is the tube itself. The supply of strip steel is held on the drum at A,



MOLE-DRAINING CABLE LAYING MACHINE.



I. TUBE FORMER. II. MOLE DRAINER.

FIG. 14.

from which it passes over a forming roller and is finally shaped into the complete tubing. The tube-forming machine remains stationary whilst the "mole" is drawn forward. The cable drum is placed immediately behind the tube-forming machine; the cable passing through a guide and under the forming roller. The strip steel can be seen on the reel immediately above. The forming roller can just be seen within the framework.

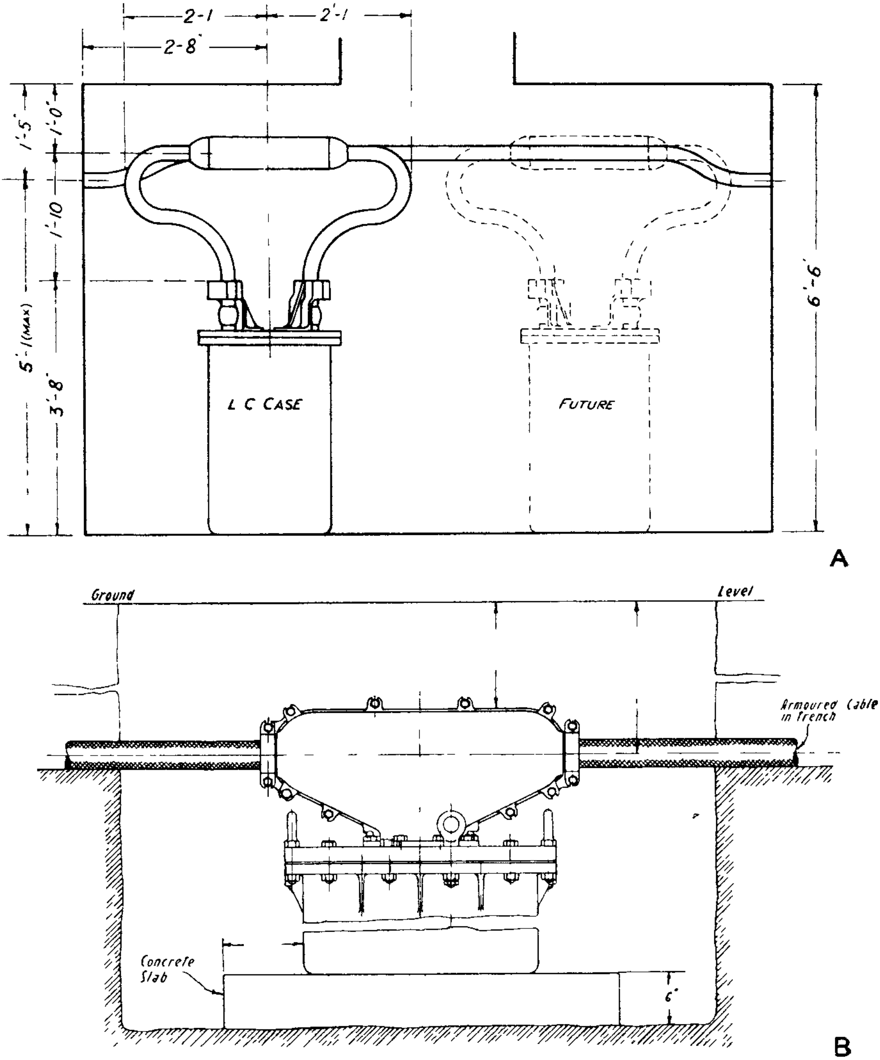
The practicability of using lengths of screwed steel tubing fixed to and drawn in by the "mole" is also being investigated. This method would, however, involve digging a trench at the point of entry, the length of which would be dependent on the length and flexibilty of the tubing used. It may be of interest to note that a mole-drainer was used in connexion with the earth wire system at the Post Office Leafield Radio Station in 1919 but, so far as can be ascertained, a similar machine was first developed for cable-laying by the Philadelphia Electric Co., and described in an article printed in the *Electrical World* of December 1st, 1923. It was developed for installing cable in the grass margins between kerb and sidewalk in residential districts and on private property. Ordinary lead-covered cable was drawn in and the low maintenance costs are said to have justified the use of unarmoured cable.

SECTION III.

Loading.

In connexion with buried cable a new type of loading case has been developed for burying direct in the ground in order to eliminate the expense of building manholes, and two designs were described in the *P.O.E.E. Journal* of July, 1932.

Fig. 15 will help to make clear the difference between the standard type used in manholes and those designed for use without manholes. It will be observed that in the standard type, shown in Fig 15A, the loading coil quads are led out through stub cables which are jointed into the main cable. In the buried type, shown in Fig. 15B, the main cable itself passes through and is jointed in the upper chamber of the loading case. This is the characteristic difference between the two types. It ensures that no unprotected lead sheath is exposed to direct contact with the earth when the buried type of loading case is used.



SECTION OF HOLE.

FIG. 15.

Four variations in design are being installed but further developments may be expected.

The essential characteristics of each are similar.

(1) A lower chamber containing the loading coils, completely sealed with compound and protected by a cover with a flange joint.

(2) An upper chamber in which the loading coil pairs are jointed to the main cable pairs, thus forming a joint box when completely sealed and protected by a strong outer cover.

It is in the endeavour to obtain maximum protection, high insulation and reasonable construction and maintenance facilities that the designs differ in detail.

Fig. 16 shows the loading pot manufactured by Standard Telephones & Cables, Ltd., and installed on the London-St. Margarets Bay Cable.

The lower chamber contains the loading coils, the cable forms from which rise through a central brass nipple to the upper chamber. The lower chamber is sealed with compound, the cover and outer case being bolted together through a strong flange joint.

The removal of the outer casing of the upper chamber reveals a tin canister. This canister is for the purpose of protecting the loading coil cable forms during transport and on completion of the joint is replaced by the beaten lead sleeve to seal the joint. The base of the canister is fixed to the inside of the brass nipple by a thin soldered joint. An upward lift after the application of a blow-lamp enables the canister to be removed. In order to maintain the insulation of the cable forms, the canister is not removed until the cable ends have been prepared and jointing is ready to begin.

Before making the joint the main cable ends are prepared by cutting the wire or steel tape armouring with shears and with the aid of a blow-lamp removing the jute, compound, etc. The lead sheath of the cable should be thoroughly cleaned as the presence of compound would later make satisfactory plumbing difficult.

When the cable ends have been prepared they should be supported in their final position and fixed so that on completion of the joint, one inch of the armoured cable will project inside the flange joint of the outer case, the outer jute serving finishing at the inner edge of the cover. The armouring is bound with four or five turns of tinned copper wire before cutting and is afterwards thumb-wiped to the lead sheath.

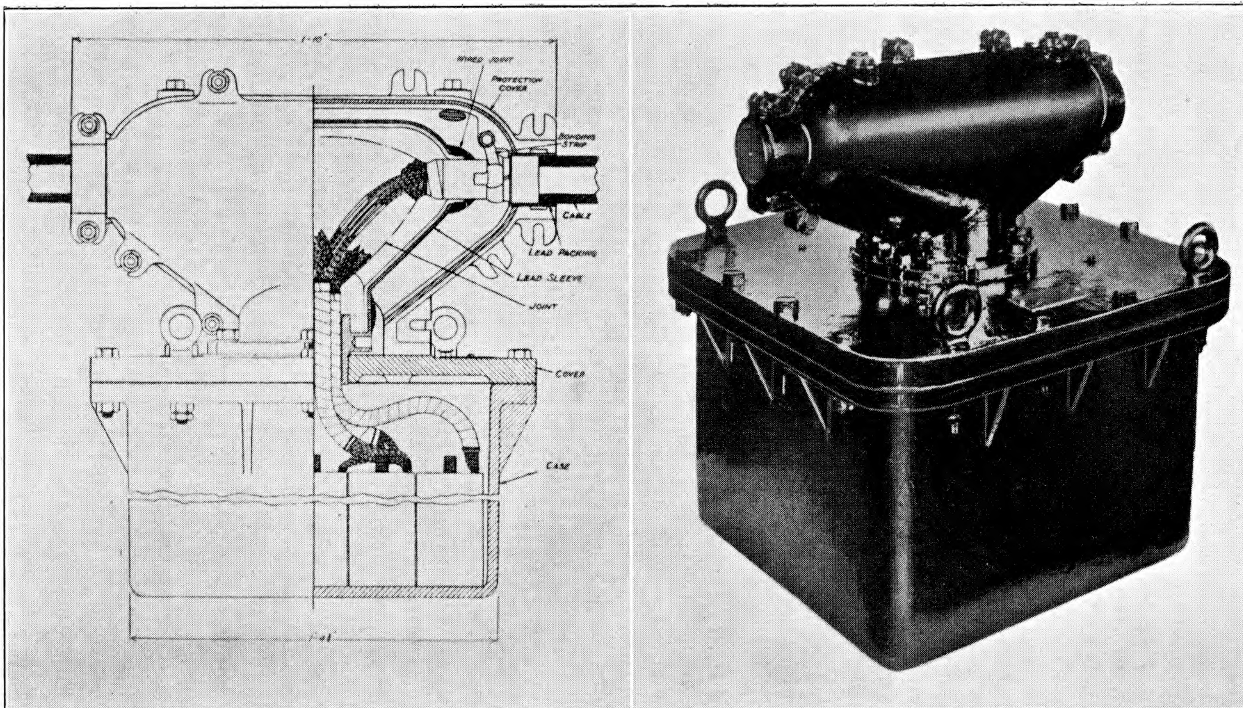

WIRED JOINT
PROTECTION COVER
BONDING STRIP
CABLE
LEAD PACKING
LEAD SLEEVE
JOINT
COVER
CASE

FIG. 16.

To construct the joint, the centre cable form from the loading coils is brought up almost to the level of the main cable, and the outgoing and incoming quads, which are distinguished by a colour scheme, are jointed to the main cable pairs. As the jointing proceeds, subsequent cable forms are jointed to the main cable pairs at a lower level so that an open and accessible joint results. The completed joint is triangular and, after being dried and bound up with linen tape, is sealed by an airtight lead sleeve of similar shape. The lead sleeve is cast in halves and is provided with collars to embrace the main cable sheath on both sides and the brass nipple surrounding the loading coil cable forms. The halves of the lead sleeve are sealed to each other and to the main cable sheaths and brass nipple by wiped joints, air pressure tests being made to prove that the joint is airtight.

Strip copper soldered to the wipe between the armouring and the sheath on each side of the joint is fixed to a lug on the inside of the protective cover.

Fig. 17 shows the jointing arrangements, lead sleeve, cast iron protective cover, the clamping of the armouring and other constructional details. In the case illustrated the cable is not fully loaded and through quads are shown. If the cable is fully loaded, all cable pairs will be jointed to loading coil cable forms.

A cast iron protective cover, which is also in halves, is placed over the whole, each half being secured to the other and to the cover of the lower chamber by bolts and nuts. A means of clamping the armoured cable where it enters the cover is provided.

Before securing the protective cover the cable is lapped with sufficient prepared tape to provide a firm grip for the clamps. The half of the cover carrying the clamps is placed in position and screwed up tightly. The clamps are carefully fitted and the bonding strip screwed down on the bonding lug.

The grooved joint is treated with sufficient yarn and compound to provide a watertight joint. The second half of the protective cover is then secured.

Finally the space between the lead sheath covering the joint and the outer iron cover can be filled with compound.

Fig. 18 shows the design manufactured by the General Electric Co., Ltd., and installed on the Cambridge-Kings Lynn cable.

SKETCH SHOWING JOINT ON STUBLESS LOADING COIL CASE.

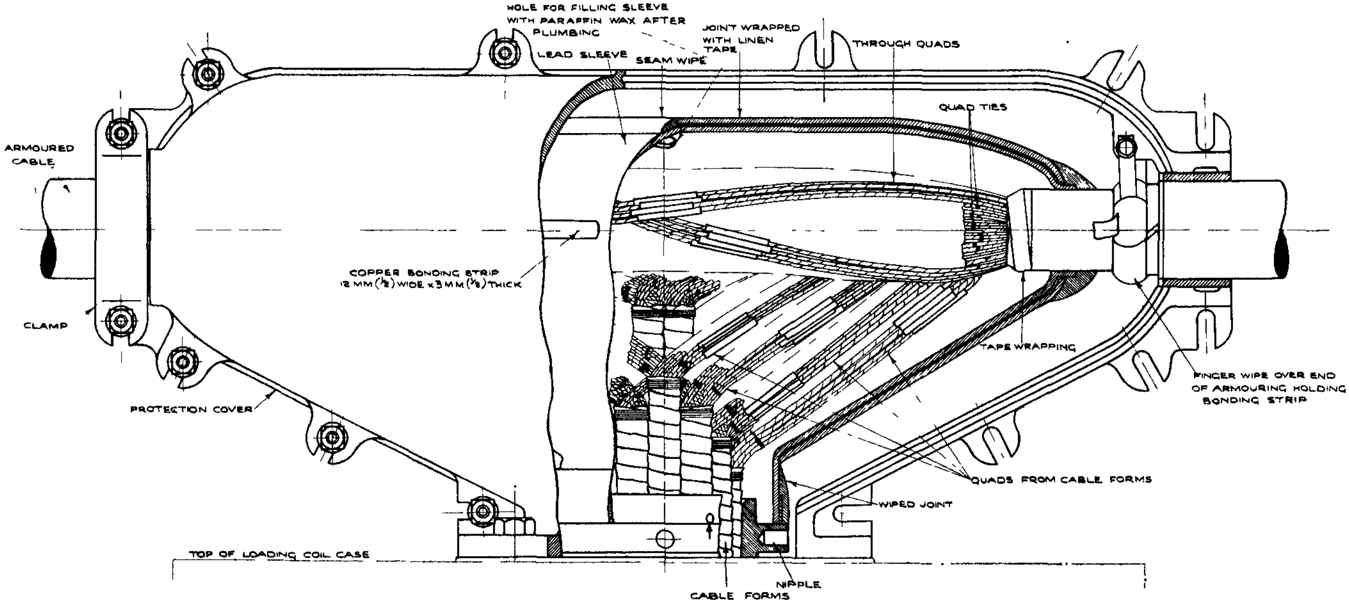


FIG. 17.

BURIED LOADING COIL UNIT.

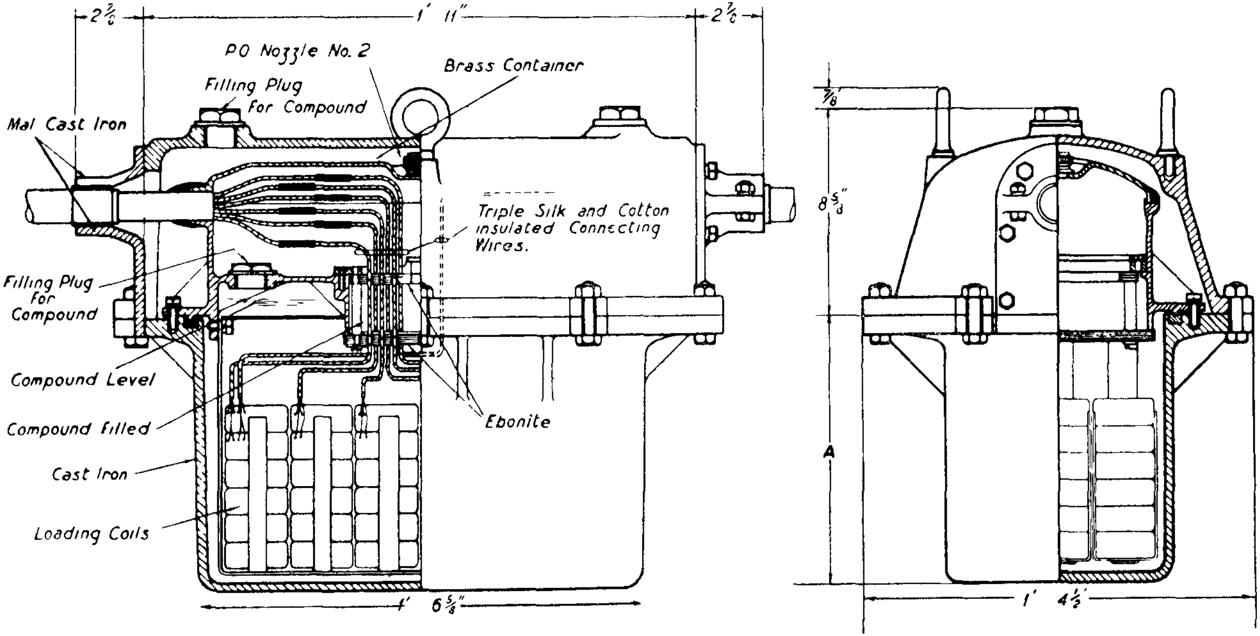


FIG. 18.

The lower chamber contains the loading coils, the textile-covered leads from which rise in quads to the upper chamber through two perforated and numbered ebonite plates. The space between the ebonite plates, as well as the lower chamber containing the loading coils, is sealed with compound. The outgoing quads from the loading coils pass through the numbered holes in one of the ebonite plates and the incoming quads similarly through the other. The numbered holes fix the numbers of the quads and therefore facilitate jointing.

The lower chamber is closed by a strong cover, the flange joint being secured by means of bolts and nuts. This cover is cast in brass to include a rectangular-shaped joint box as part of the upper chamber, which is revealed when the end plates and the upper casing are removed. When supplied the brass cover is lightly soldered in position.

An interesting feature of this loading case is the provision made for testing the insulation without removing the brass cover.

The A, B, C, and D conductors are bunched in separate groups, each group being jointed to a heavier gauge insulated conductor which is soldered to the inside of the sealing disc fitted in the centre of the brass cover. The disc is easily removable after the application of a blow-lamp. The connecting wires can then be withdrawn for testing. The main cable ends are prepared for jointing, as previously described, before the brass cover is removed.

The removal of the brass cover reveals the loading coil quads and numbered plates, as illustrated in Fig. 19. It will be noted that the numbering is arranged so that the lower numbers are on the outside and therefore in the best position for jointing to the lower cable pair numbers. To facilitate jointing it has been found advisable to make each row of joints somewhat higher than the position they will finally occupy, afterwards placing them neatly in the lower half of the brass container before jointing succeeding rows.

The quads are jointed to the main cable pairs by means of twisted and soldered joints, a bight being made to allow sufficient spare should the loading case be changed or the joint have to be re-made.

The completed joint is sealed by means of the brass cover which meets the sides of the rectangular-shaped casting at the same level as the main cables enter the upper chamber. Wiped

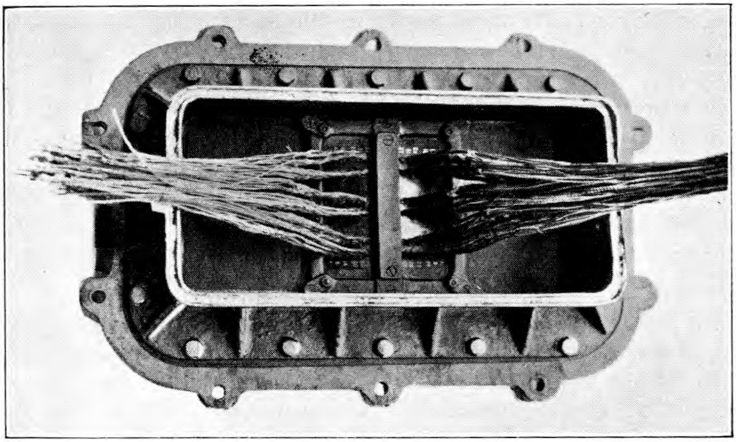


FIG. 19.

joints are made along the seams and over the cable sheaths at the point of entry, air pressure tests being made to prove the plumbing.

The brass container, cable armouring and cast iron protective cover are bonded together by means of strip lead.

The armoured cable is lapped with prepared linen tape at the point of entry to ensure a tight fit when clamped.

The outer cast iron protective cover is now fitted overall and secured by bolts and nuts. Split end-plates that clamp the armoured cable are then fixed and all external joints treated with compound.

Provision is made for filling the spaces between the brass joint box and the outer protective cover with compound.

Fig. 20 shows the loading case designed by Messrs. Siemens Bros. & Co., Ltd. The complete loading case does not differ in its essential characteristics from those previously described. It is, however, in the accomplishment of its purpose that it differs. The lower chamber containing the loading coils is of standard design and the use of a stub cable for the coil connections follows standard practice. The necessity for protecting the stub cable has led to the adaptation of the general tee box pattern to the requirements of this special purpose.

The internal structure of the loading coil case is identical

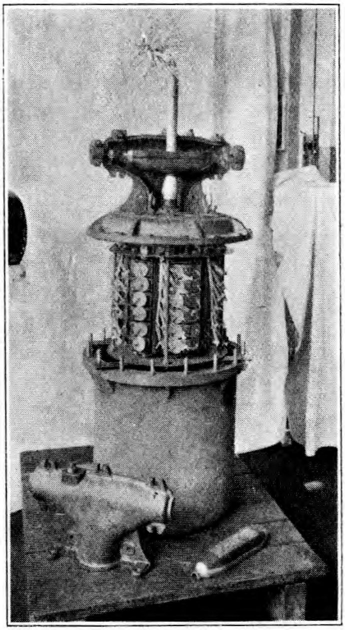


FIG. 20.

with that used in the standard loading cases of the same firm. Each coil is contained in an hermetically sealed copper case filled in with insulating compound under vacuum, the copper cases forming screens between the coils. The copper cases are arranged in columns on what may be termed ladder supports which are in turn hung from a plate carried by the cover of the case. The rungs of the ladder are made of steel plates, the projecting tongues on which are bent up, after the copper cases are inserted, to retain the cases in position.

The stub cables are opened out and the quads are led down the sides of the ladder frames to the individual coils, jointed with copper ferrules, and insulated with paper tubes. The accessibility of these connections can be seen from Fig. 20. All connections are made and tested before the whole assembly is lowered into the cast iron chamber.

The whole of the space inside the pot is then evacuated and filled with insulating compound.

When supplied, the stub cable is protected by a returnable cast iron cover screwed to the cover of the lower chamber.

This cover forms a platform for the support of the outer protective tee cover, and on removal reveals the single lead-covered stub rising from the centre of the stub. After the preparation of the cable ends the bottom of the lead sleeve should be threaded over the stub cable until it is in its final position. The sheath is then marked at a point $\frac{3}{8}''$ within the sleeve. The sheath should be cut to this mark and the cut blacked in.

The sheath should be tinned where the sleeve is to be sweated to it; the sleeve replaced, dressed down, and bound with tape to prevent solder running through. The sleeve is then sweated to the cable by running in the solder from the inside, as shown in Fig. 21.

FIG. 21.

On the larger sizes of pot this joint is made with an ordinary solder wipe after the wire jointing has been completed, the bottom half of the sleeve having previously been threaded on the stub cable.

Before commencing jointing two sheets of paper wide enough to cover the completed joint are placed inside the sleeve. It is advisable to bring up the quad or pair from the loading coils on the opposite side to the cable end to which it will be jointed and double back horizontally across the sleeve, as shown in Fig. 22, in order to obtain a satisfactory jointing length and also to provide for slack, should it be necessary to work on the joint later. On completion the jointing paper previously placed in position is used to wrap over the wires.

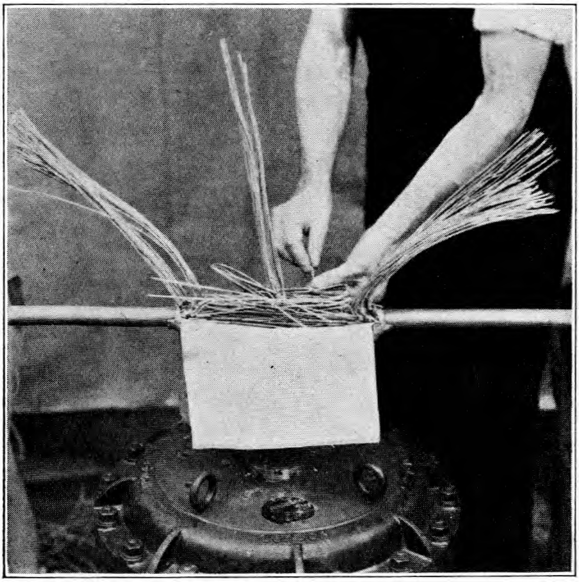


FIG. 22.

The finished joint is dried out as usual, care being taken not to overheat the soldered joint at the bottom of the lead sleeve.

The top half of the lead sleeve is placed in position and tacked to the lower half with solder, after which the complete sleeve is plumbed to the cable at each end and the sleeves properly wiped. Fig. 23 shows the joint almost complete.

The back half of the protective cover is next placed in position and the armouring clamps carefully fitted to secure the cable, the bonding clips being placed round the steel tapes and screwed to the bonding lugs. A strip of 1″-8lb lead is connected across the joint from one clip to the other, and is

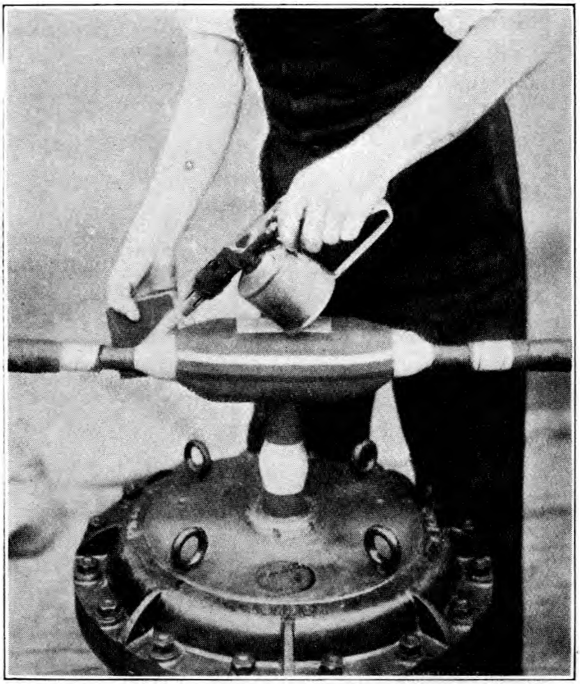


FIG. 23.

soldered to the lead sleeve at the centre. Fig. 24 shows the completed joint with the back half of the cover in position.

The grooved joint of the cover is packed with the lead tube packing provided, and the front half is brought into position. All nuts and bolts, and also the studs on the top of the case, are then added, and everything screwed up tightly. Fig. 25 shows the completed case being filled with compound.

The pattern manufactured by the Automatic Electric Co., Ltd., is illustrated in Fig. 26. It follows the general design although differing in detail. The lower chamber containing the loading coils is extended so that the completed joint is wholly enclosed when the cover is secured.

The jointing chamber consists of a gunmetal sleeve into which the loading coil cable forms are led and jointed to the main cable pairs. The lower half of the gunmetal sleeve is fixed to the cast iron partition which separates it from the loading coil chamber.

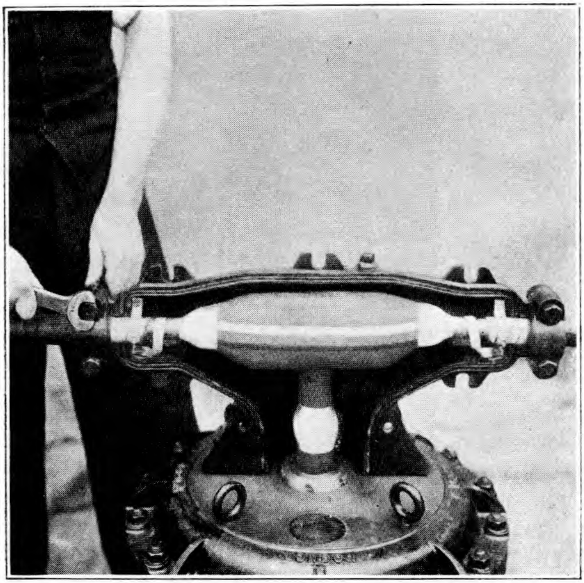


FIG. 24.

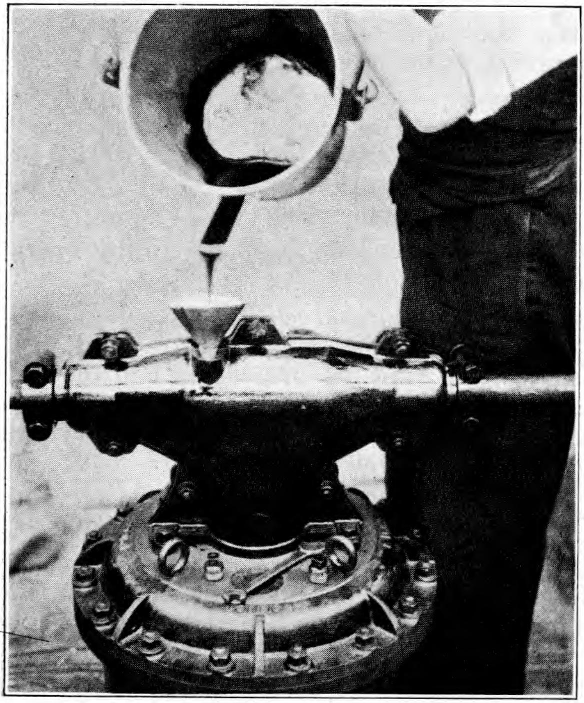


FIG. 25.

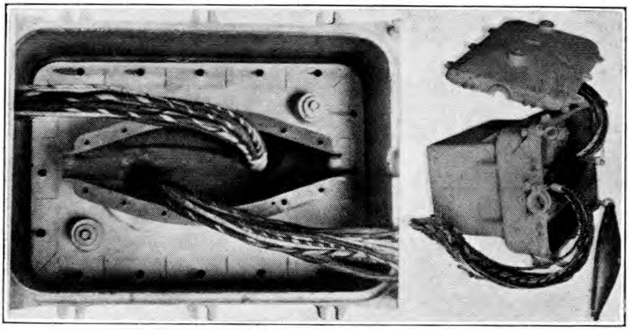


FIG. 26.

The two sections of the gunmetal sleeve are secured together by means of countersunk screws in blind holes, the heads of the screws and the whole of the seam being finally wiped over. To facilitate soldering and to obviate the risk of molten metal falling into the sleeve, the flange of the lower half of the sleeve projects beyond that of the upper half.

A standard air nozzle is fitted for desiccating purposes.

For cables up to 150 pr/20, all dimensions remain the same except the depth of the loading coil chamber, which varies according to the number of coils.

For transport purposes the gunmetal sleeve is assembled and the seams lightly soldered to enclose the loading coil forms. The cable entrances are effectually sealed by means of metal caps. The cast iron cover overall affords the necessary mechanical protection.

The sequence of installation and jointing operations is as follows.

After removing the outer cover, fixing the main cable in position and preparing the cable ends for jointing, the temporary lead sealing caps are unsoldered and the upper half of the gunmetal sleeve removed. The cable pairs are jointed to the loading coil pairs on the opposite side from which they enter and thus fall naturally into position.

During the jointing operations the usual precautions are taken to ensure that moisture is excluded.

Jointing is facilitated by means of a special colour code, each column of coils having its cable and code, the latter being the same for both " up " and " down " stubs. On completion of the jointing the upper half of the gunmetal sleeve is screwed down and wiped to the main cable. The edges of the sleeve and the heads of the screws are also wiped.

Finally, after the outer cover is bolted down, sealing compound can be run in to fill the space between the jointing chamber and the outer cover.

A later development by the same manufacturers in collaboration with Post Office engineers is shown in Fig. 27.

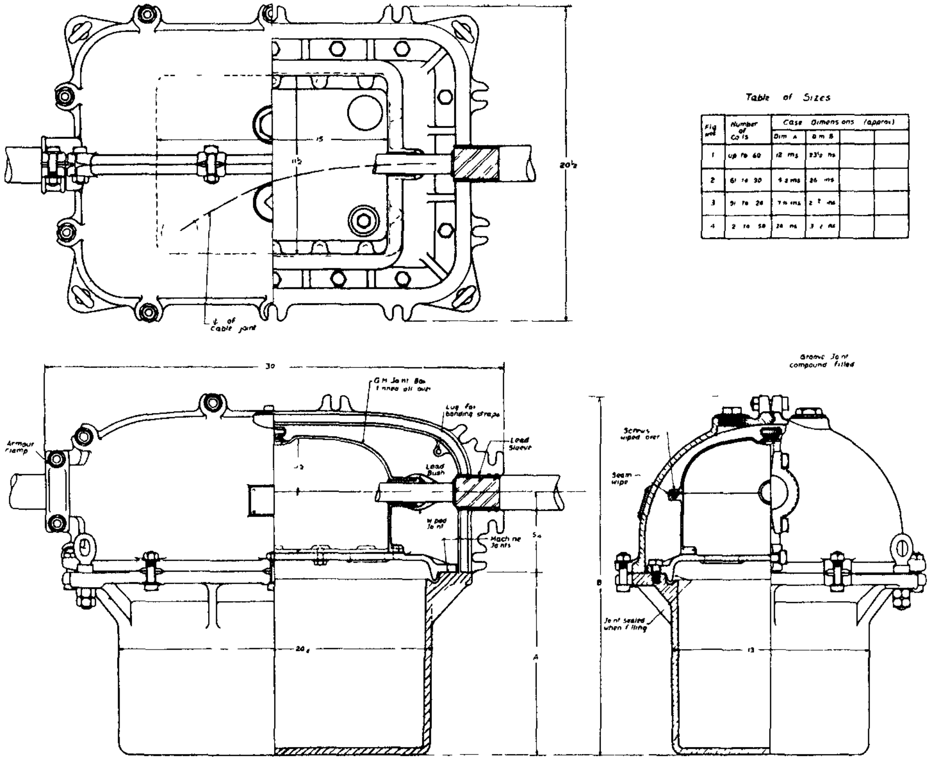


FIG. 27.

The essential difference between the new design and that described .is the replacement of the gunmetal sleeve by a rectangular brass chamber of greater height and breadth and having the holes, through which the loading coil pairs pass, placed at the corners diagonally opposite to facilitate jointing.

In all designs any unloaded pairs in the cable are joined straight through in the jointing chamber.

All the designs named are of very robust construction to withstand handling and risk of mechanical damage. In order to make them resistant to corrosion also, the external surfaces of cast iron are treated with special compounds and the joints wih red lead and linseed oil.

Each is designed to provide complete sealing of the actual joint by filling with compound the space between the outer protective cover and the lead sheath, or jointing chamber. Where, however, the joint is enclosed in a plumbed lead sheath it is not proposed to fill in the space but simply to smear the surface of the lead sleeve and the cable sheath with petroleum jelly. In the G.E. Co. and A.E. Co. types the space between the inner brass cover and the outer protective cover may, however, be filled with compound when the cases are installed.

SECTION IV.

Accommodation and Installation of Loading Cases.

As loading manholes are not normally built to accommodate the buried (" stubless ") type of loading case, an excavation of minimum size is made, and is shown in Fig. 28. The depth must allow a cover of 2 ft. between the top of the loading case and the surface, after a concrete raft 6″ thick has been constructed on the floor of the excavation to provide a firm foundation for the loading case. The length and width should be such that all jointing and testing operations can conveniently be carried out. A suitable excavation for an 8 ft. concrete raft would be 9′ 6″ long × 5′ 6″ wide × 5′ 0″ to 5′ 6″ deep and for a 4 ft. raft 5′ 6″ long × 5′ 6″ wide × 5′ 0″ to 5′ 6″ deep.

Where the capacity of the loading case to be installed represents the ultimate loading of the cable, the size of the concrete raft is 4′ × 4′ × 6″ thick. Where the cable is not being fully loaded at the outset, the size of the concrete raft is 8′ ×

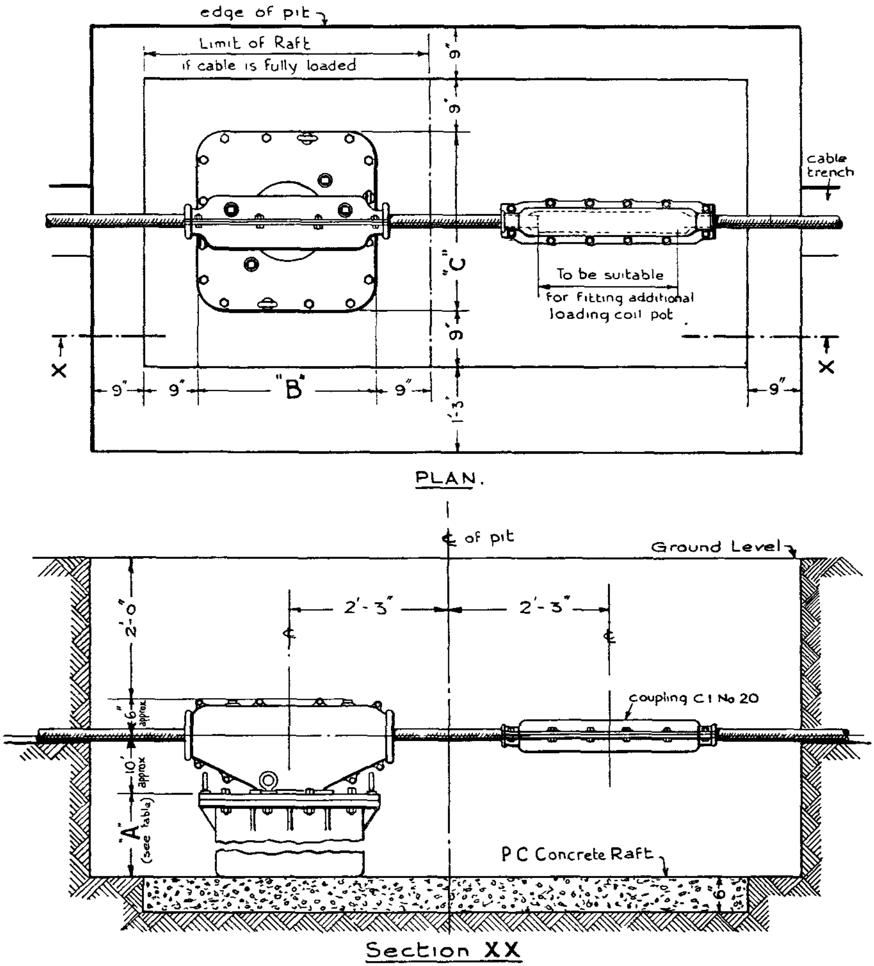


Table of Dimensions,

No of Coils	Dimensions (approx)		
	A	B	C
432	2 - 5"	2'-6"	2 - 6"
324	2' - 0'	"	"
216	1' - 7"	"	"
108	1' - 2"	"	"
54	1' - 2"	"	1' - 6"

POTS LOADING COIL, BURIED. METHOD OF INSTALLATION.

FIG. 28.

4′ × 6″ thick, thus providing accommodation for present and future loading cases.

The construction of concrete rafts on site for heavy loading cases is undoubtedly justified. With lighter cases for smaller cables, however, experience may prove that a support which could be placed in the excavation at the installation of the loading case would be equally satisfactory and more economical. In chalk, heavy clay or rocky ground rafts might even be dispensed with.

The loading pots are lowered into position either from a lorry equipped with a crane or with skids, block and tackle, or by means of shear legs and block and tackle.

In cases where unloaded pairs are left for future loading, special provision is made for an additional joint in the cable at the point fixed for the second loading case. The unloaded pairs will be jointed straight through in the upper chamber of the loading case originally installed. In order that they may be accessible and readily identified when the second loading case is installed, without the necessity for opening the first case, the cable is cut and sufficient overlap allowed for a second joint, commonly referred to as the "future" joint. At the "future" joint, the loaded pairs are numbered and put straight through in the centre of the cable. The unloaded pairs are numbered, jointed on the outside, and ballooned to provide sufficient slack for future loading. Fig. 29 shows a "future" joint and a loading joint on the Ashford-St. Margarets Cable.

The completed joint is protected by means of a cast iron coupling, as illustrated in Fig. 30. To provide a tight joint a wrapping of prepared linen tape is made over the jute serving of the cable to an overall diameter sufficient for the coupling to clamp tightly over the wrapping at each end. The joints between the flanges of the two halves of the coupling are packed with lead strip, the ends of which are pressed tightly against the tape wrapping at each end of the coupling.

The steel tape armouring of the cable projects about 2 inches into the coupling at each end and is wiped to the lead cable sheath after being bound with a few turns of tinned copper wire.

The electrical continuity of the armouring is maintained by lead strip soldered to the wipe at each end and bolted at one end to the bonding lug provided on the cast iron coupling.

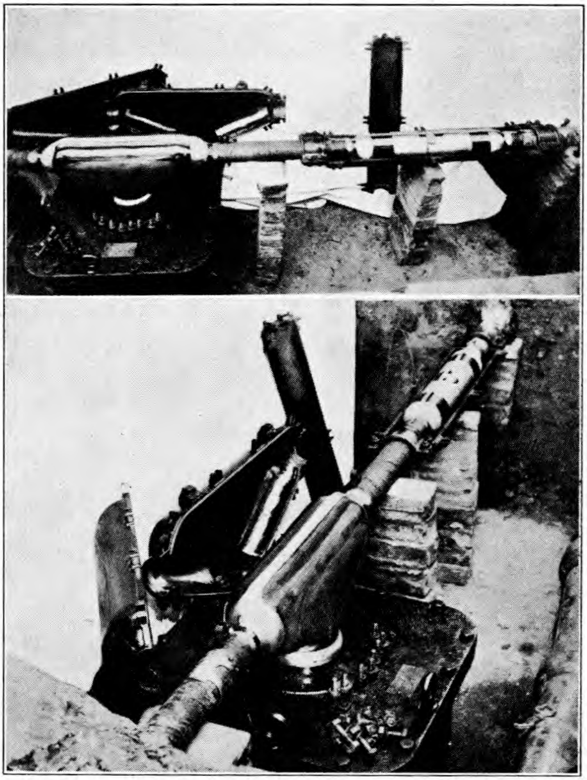
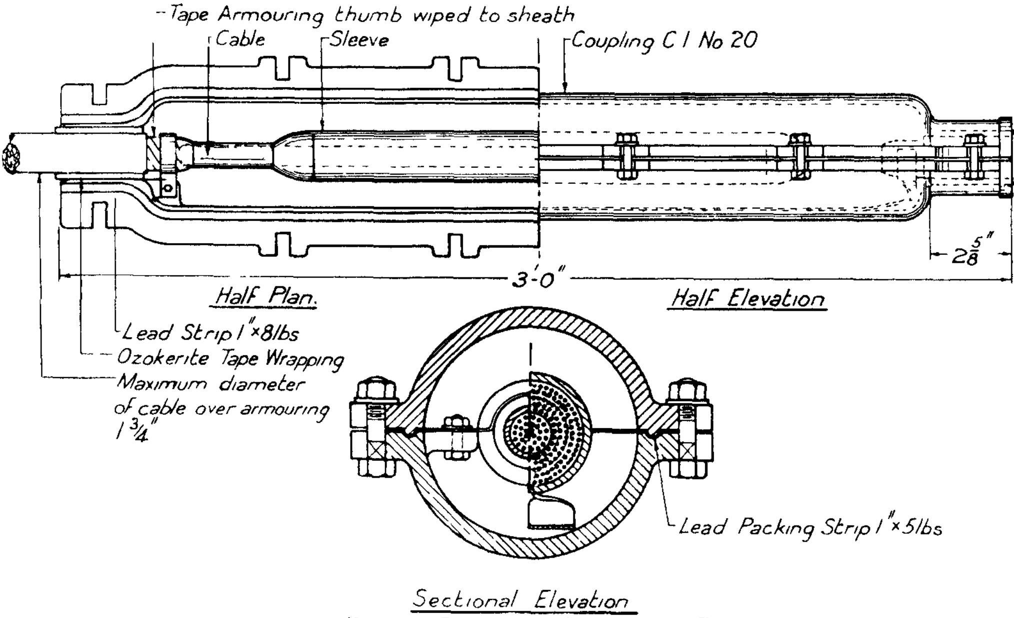


FIG. 29.

The provision made for additional loading involves considerable expense and experiments might show that future additional loading could be carried out without the necessity for making a joint in advance.

Except in the case of large size cables a slight offset (dip) of a few inches might allow sufficient slack for future additional loading. The proposal to work 4-wire circuits within quad should in future make it unnecessary for a jointer to have to search into the inner layers of a cable to find widely separated " goes " and " returns." Where possible, the centre and inner layers could be loaded initially and the present and projected extensive use of cables having conductors of uniform gauge would facilitate such a method. Each scheme would be treated on its merits.



BURIED JOINTS IN ARMOURED CABLE.

FIG. 30.

SECTION V.

JOINTS AND PROTECTION OF JOINTS.

The position of buried joints should be such that they are easily accessible both for construction and maintenance. In the event therefore of any cable length ending in a roadway or similar difficult position, the cable should be cut and the ends sealed so that the joint can be made clear of the road crossing and maintained without difficulty, at all times.

Jointing operations on buried cable begin by the removal of the armouring, compound and jute yarn, before stripping the lead sheath. The wire or steel tape armouring is cut with shears, after which the application of a blow-lamp burns the yarn or tape and softens the compound sufficiently to ensure its removal. The lead sheath is then thoroughly cleaned to facilitate plumbing later.

The jointing of the conductors follows standard practice, and is illustrated in Fig. 31. The electrical tests are fully

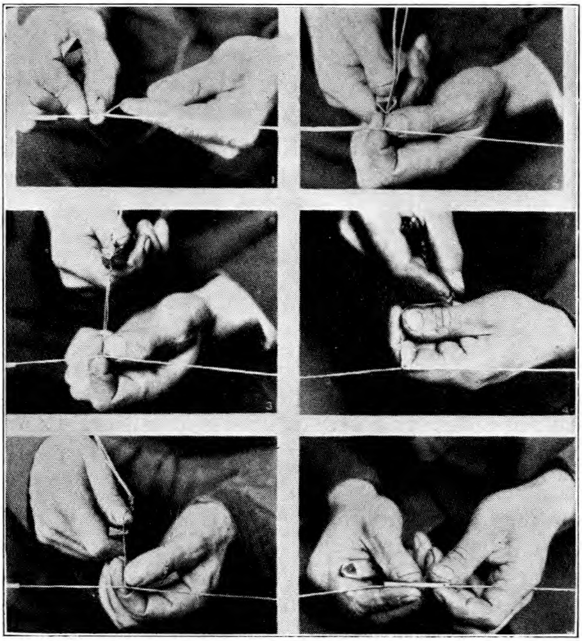


FIG. 31.

described in Technical Instructions and Circulars. All wire joints are soldered. If the cable contains screened pairs the continuity of the screening should be maintained. When the joint is completed, air pressure is applied and soap suds tests made to prove the plumbing.

The completed joint is protected by a cast iron coupling, as previously described in connection with the " future " joint.

Where cables are buried in waterlogged ground or ground subjected to the action of contaminated water, the cast iron coupling must be watertight in order to protect the lead sheath against corrosion; and the following method, devised by The Standard Telephone & Cables Co., has been found satisfactory.

(*a*) The cable ends entering the coupling are lapped with " Ozokerite " Tape and served liberally with compound before clamping up.

(*b*) The joints between the top half of the coupling and the separate collar pieces are caulked with lead wool.

(*c*) Between the flanges of the top and bottom halves of the coupling is packed with 4 lb. lead strip placed between thin layers of plastic cement.

The position of each joint should be indicated by a marking post and a post should also be set where the cable changes direction and excavation is possible.

SECTION VI.

Corrosion.

Properly treated armoured cable is believed to be practically immune from corrosion. In addition therefore to economy in laying, there is the equally important advantage of greater service reliability.

Extensive research has been carried out upon the protection of cables against the effects of stray currents and manufacturers can now provide a protected cable that may be regarded as immune from corrosion. The armouring can be treated with special compounds which are impervious to moisture and inert chemically, so that the lead sheath is electrolytically insulated over its whole length.

In corrosion areas it has hitherto been the practice to draw protected cable into duct, the protective covering consisting of compounded paper tapes. This type of cable, however, cannot be drawn over existing cable without risk of damage to the protective covering, and for the same reason other cables cannot be drawn over it. It is also very difficult to draw out. The result is that unless a large size protected cable is laid in the duct initially, much of the duct space is wasted, whilst if a large size cable is provided merely to fill the duct the provision may be uneconomical. In such localities there is little doubt that buried cable should be more extensively used in the future.

The Comité Consultatif Internationale (C.C.I.) has laid down " Rules Relating to the Installation of Cable Circuits," in which it is stated :—

(*a*) " Cables in the earth.—Unless they are covered with a protective coating or with chemically inert material, lead cables should not be placed directly in the soil.

(*b*) "Cables in conduits.—The choice between different kinds of conduits (iron tubes, concrete, sand, stone, wood, etc.) is made chiefly from technical and economic considerations; cables in conduits are sufficiently well protected against chemical action from constituents of the soil.

" A thick coating of petroleum jelly applied at the surface of the cable sheath at the moment of installation will assist in preventing chemical corrosion.

" The conduits should be made as watertight as possible without incurring unjustifiable expense.

" If it is impossible to protect the conduit against infiltration of harmful fluids, it is necessary to place the cables in a sheath which has been covered with a protective layer impregnated with a preservative compound.

" All necessary arrangements should be made to guarantee and maintain this layer perfectly watertight."

Regarding " Principal causes of chemical corrosion," the C.C.I. state : " Lead can be attacked by bases as well as by acids. Nevertheless it is one of the most resistant metals from a chemical point of view.

" The lead should not be allowed to enter into direct contact with pure cement, with water containing lime, or with alkaline bodies. Cinders are equally dangerous. Chemical corrosion can also be produced in certain soils where there exist organic acids resulting from the decomposition of wood or other vegetable matter. Certain kinds of wood appear to attack the lead: it has been noticed that oak in particular produces corrosion. Sewer water is harmful. Lead does not dissolve in hard water, but soft water, in particular, marsh water containing organic acids, attacks it."

Wire-armoured cable should also be less liable to damage in mining areas where subsidences may be expected, as it will take a considerable strain without stretching. Tape armouring adds little to the tensile strength of a cable and under stress would tend to tighten and squeeze the lead sheath.

Lengths of steel tape armoured cable laid in 1901 and 1902 have recently been recovered from the Tunbridge Wells area. The cable is still in good condition and does not appear to have depreciated. It is reported that no fault has so far been found in any joint or section of cable except where damaged by road contractors. The joints were enclosed in wood boxes filled with bitumen.

SECTION VII.

MAINTENANCE.

The extensive use of armoured cables may present new maintenance problems. Being direct in the ground, surrounded generally by moist earth, they would, when damaged, be more liable to complete breakdown. Protected by steel tape armouring and placed in ground not normally disturbed by other undertakers it is, however, reasonable to expect little cause for anxiety. Good as the Post Office Engineering Department's testing methods are it will be necessary to develop precision tests which will locate faults with the greatest possible accuracy in order to obviate extensive excavation.

At present a length of the smaller size cables can easily be withdrawn and replaced, but with the large cables now being laid this will be very expensive.

There is little doubt that in those cases where cables are not easily withdrawn and replaced the possibility of service interruptions will necessitate accuracy in fault location.

If an exact localisation cannot be obtained a joint must be opened and further tests made.

Those who have examined the constructional details of buried type loading cases will appreciate the difficulty of opening and closing the loading joint compared with the opening and closing of the joint on the " down " side of a standard manhole type loading case. It is evident that the loading case should not be opened unless a fault has definitely been proved to exist in the loading case. Where " future " joints exist they form convenient points at which to test, particularly as they are straight joints.

Where the cable is fully loaded, it will be necessary to open and test from an intermediate joint in the loading section.

As future loading sections may need only three intermediate joints between loading points, the joint to be regarded as the testing joint, and the means of identifying the respective quads, will have to be determined before the cable scheme is completed.

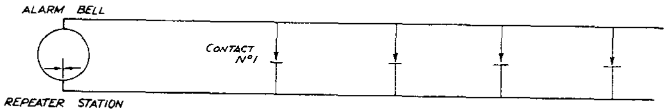
In order to assure the integrity of the buried cable sheath when first placed in the ground, the Bell System of America have adopted gas pressure testing as a means of indicating faults. The cable is tested with nitrogen gas under pressure at the works; on arrival at its destination; during laying operations; after placing; and after jointing. The entire cable is maintained under continuous gas pressure with an alarm system operating when a break occurs in the sheath. In the Syracuse-Watertown cable, alarm contacts are placed at loading points at intervals of 6000 yards, *i.e.*, three loading sections, along the route. The contacts are connected throughout to a pair of wires, and at the repeater station an alarm bell rings if the pressure falls below a minimum. A speaker pair is also terminated at the alarm contacts so that a lineman can communicate with the test desk. Lead pipes are brought up from the cable to valves mounted above the ground at each loading point in order that the gas pressure can be tested or gas introduced into the cable.

Fig. 32 illustrates Alarm Contact Circuits described by Mr. C. W. Nystorm in the *Electrical Engineer* of March, 1932.

It will be seen that the operation of an alarm contact renders the alarm circuit ineffective to the subsequent operation of any of the other contacts, until the first alarm contact is disconnected or the gas pressure is raised in the section affected.

The difficulty has been overcome by the design of the second circuit based on the Wheatstone Bridge principle. Alarm contacts on the cable pair operate on reduced gas pressure and short-circuit known resistances. Equal resistances and break jacks are placed in the bridge at the repeater station. As each pair of resistances has a different value, the

CAS PRESSURE ALARM CIRCUIT.



CIRCUIT OF IMPROVED CAS PRESSURE ALARM.

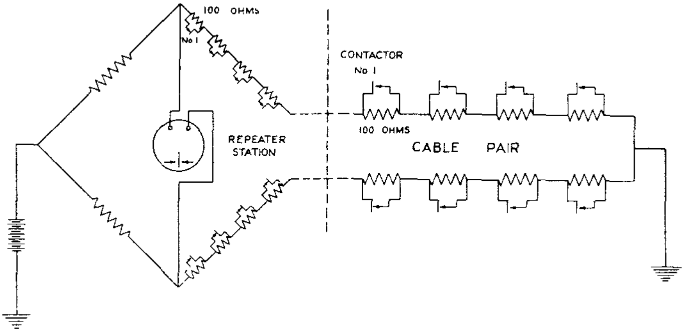


FIG. 32.

attendant at the repeater station merely inserts a non-metallic plug in each jack, until the silencing of the alarm indicates the correct one. The bridge is thus automatically rebalanced and remains so until another contact operates.

In order that the condition of the cable may be under observation during the absence of gas pressure, *i.e.*, when the gas has escaped owing to a large sheath break or repairs, a low insulation resistance alarm is used. Several pairs in the outer layer are connected to a relay mechanism in the repeater station which automatically and in regular sequence switches these conductors to a sensitive insulation measuring device. The small currents flowing through the moistened insulation are amplified by thermionic valves; a decrease in the insulation resistance below a predetermined value causes an alarm to operate.

SECTION VIII.

Replacement and Recovery.

In the economics of underground conduit construction the value assigned to existence of additional ducts for future cables and for the replacement of existing cables, plays an important part. These facilities, however, are not always as readily available as actuarial calculations presume.

Under suitable conditions, cables can now be placed directly in the ground as cheaply as they can be drawn into duct. It is generally assumed that there are difficult engineering problems in recovering or replacing buried cables, but those familiar with the mole-drainer machine and its use for draining have reason to believe that the " duct " remains and that there should therefore be little difficulty in drawing out a cable. Engineers who have had experience of its cable placing capabilities and have studied the matter closely, point to the ease with which the cable can be pulled through the " duct " by hand, to support that view. Experiment alone will settle the question and lengths of cable are to be pulled in by the mole-drainer with the intention of attempting to withdrawn them at some future date.

With regard to larger cables placed in the ground by such a machine as the cable laying plough, Fig. 33 illustrates the authors' suggestion for their recovery. The equipment consists of a tractor, a modified cable laying plough, and a cable drum trailer.

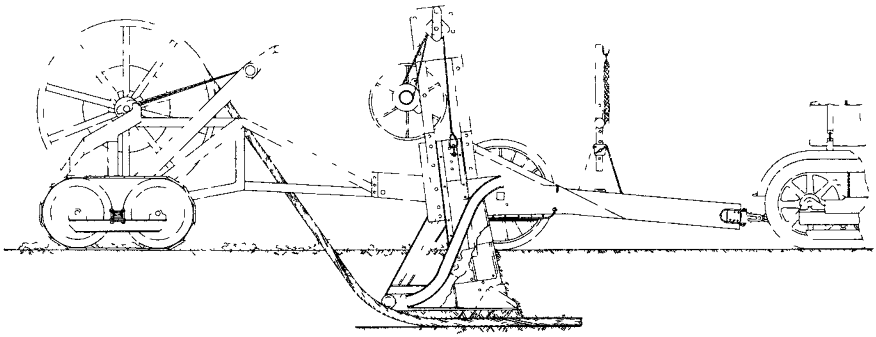


Fig. 33.

The precise position and depth of the cable being known from the records, the end of the cable is dug up until it can be secured on the drum. The plough blade is set to a depth of two or three inches above the cable and as the equipment is drawn along the cable drum, which is revolved by suitable gearing, lifts the cable out of the slot made by the plough. The earth thrown out of the slot is then scraped back and consolidated as described in the case of cable laying.

With both methods of recovery it will be necessary to dig open the jointing pits by hand. When a cable recovery is intended, protective couplings would be removed and joints cut out in advance of actual recovery operations.

SECTION IX.

Route. Public or Private Wayleaves.

It will be obvious that the methods of laying cable described owe their success to the nature of the ground surface and subsoil and are therefore only completely satisfactory where suitable land, grass verge, or gravel is available.

In the main, methods of underground construction in this country have changed very little, apart from improvements in the type of conduit. Until quite recently little use had been made of machinery.

Underground construction, either footway or carriageway, is expensive. Obstructions due to other undertakers are numerous. The length of trench that can be excavated and left open is often limited, or additional expense for watching is incurred. By thus restricting the contractor's output the cost of the scheme is increased. If vehicular traffic is limited to one half of the roadway during the trenching operations, claims may be made due to alleged damage by the excessive traffic conditions.

Abnormal cost of underground construction due to expensive reinstatement often renders it advisable to provide additional ducts at the commencement of a scheme. The nature of the reinstatement also affects the size of the cable.

The cheaper the construction the more economical is it to provide cables for a shorter period, and the more nearly the size of cable coincides with immediately prospective traffic requirements the more economical will be the provision.

The Postmaster-General's statutory powers regarding wayleaves are too valuable to be regarded lightly, but it can safely be said that the use of powers in all circumstances is not necessarily a sign of sound administration.

Security of tenure with its implication that, once in possession always in possession, does not in practice mean undisturbed possession. It may be regarded too literally.

During the last few years the shifting of overhead and underground plant, due to road reconstruction and bridge-widening operations, has cost the Department more than £660,000.

The new roads, with their wide grass verge, offer a suitable medium for the machine placing of cable. In other cases, the roads are bounded by hedgebanks and there appears to be no good reason, apart from the question of wayleave, why the foot of a hedgebank should not afford a suitable place for cable laying by machine methods, instead of trenching expensive footway or roadway as at present.

A comparison of the costs of different classes of reinstatement indicates that for each mile of underground construction undertaken on a public road the equivalent of a substantial wayleave charge per mile per annum is incurred where the Department is forced to lay its plant under expensive footway or roadway.

The economies to be effected by the machine placing of cable are substantial and future cable routes may be determined by the practicability of that method of construction. It would, in many cases, mean crossing private property, but there are numerous by-roads, intersecting footpaths, railways, canals and suitable land in all parts of the country, where machine trenching and cabling would be practicable and where there would be little risk of damage both during and after laying.

The experience of wayleave officers shows that wayleaves for underground plant may often be obtained where strong objection would be taken to the erection of poles.

Careful consideration would be necessary, but a direct and suitable cross-country route offers such advantages in the rapid laying of buried cable that a meticulous survey is justified. By ploughing-in the cable each length would be limited only by the size of the drum and the capacity unbalance characteristics of the cable. It is considered that cable lengths of 500 yards could be placed without difficulty and joints in a 2000-yard loading section therefore reduced to three.

In open country, cable ends could be left near the surface awaiting the jointers, whilst in suitable positions excavations might not be necessary for loading cases.

SECTION X.

Buried Cable v. Standard Underground Construction.

Having described the method of laying and loading, the advantages and disadvantages of buried cable compared with aerial cable and standard underground construction may be summarised, and are indicated below.

Advantages of buried cable.

- Cheaper to lay.
- Can be laid quickly.
- Therefore :
  - Expenditure on new cables can be deferred until a later date.
  - Existing plant can be used to a larger percentage of its capacity.
  - Excess provision can be reduced to a minimum.
  - Size and type of cable can be more accurately determined.
  - Minimises the possibility of modification of design between the conception of the scheme and actual manufacturing.
  - Provision and traffic requirements can more nearly coincide, thus effecting the greatest economy.
  - Reduces the risk of electrolysis or other corrosive damage if its protective covering is properly treated. Makes unnecessary the scheduling of corrosion areas for special treatment.
  - If armoured, the cable is thereby shielded against power circuit interference and mechanical damage.
  - Longer lengths of cable can be laid without jointing.
  - More flexible in avoiding obstructions, in being diverted and in following contours of the land.
  - No creeping.
  - Less liable to vibrational fatigue.

Disadvantages of buried cable.

If damaged may quickly become completely faulty.
Might not be so easily recovered.
Ground must be opened for each new cable.

Buried Cable v. Aerial Cable.

Advantages of buried cable.

Less objection on æsthetic grounds.
Longer life and less maintenance.
Wayleaves should be easier to obtain.
Negligible temperature changes, therefore practically constant transmission equivalent.
Less risk of damage by storm, fire, vibration or creeping.
If steel armouring is used, the cable is thereby shielded against power circuit interference and mechanical damage.
No routine inspections necessary.
Does not need removal when crossing or in close proximity to high pressure circuits.

Disadvantages of buried cable.

Not so accessible at any point.
Not so easily recovered or replaced.
May be damaged by excavation operations.
If armoured, is more expensive.

Observations.

The experience gained on the Cambridge-Kings Lynn scheme has been invaluable. Our Eastern District colleagues have set a performance rating for underground construction for which they deserve warm congratulations. Good as that performance is, there is little doubt that, partly as a result of that experience, figures for future schemes carried out under similar ground conditions will show a decided improvement. How then is the improvement to be brought about? Is it by sending a machine to a District and leaving that District to "carry on," or is it by giving each District the benefit of accumulated experience? There is only one satisfactory answer if maximum economy is to be effected. The services of those who have so successfully carried out the Cambridge-Kings Lynn scheme should be placed at the disposal of any District considering the practicability of laying armoured cable. Experience alone in these early stages can determine with certainty whether surface and subsoil conditions are suitable for machine methods.

By virtue of his position the Efficiency Engineer is the officer who should take the initiative in developing and applying progressive methods in his own District. Upon him therefore should be placed the responsibility for seeking the advice and co-operation of an officer—presumably an Efficiency Engineer—from another District who has successfully applied machine methods.

The two officers should first inspect the proposed route or routes. Once the route is decided upon a meticulous survey should be made in conjunction with local engineers. Obvious obstructions should be noted for removal and any feature likely to present difficulty should be carefully considered for special treatment. The character of the ground and the need for sub-surface exploration should be studied closely. The precise methods to be adopted on each section of the route should be decided. The number of men detailed for each operation, the supply of machinery, tools, stores and transport should all be satisfactorily arranged before any work begins. The officer to be placed directly in charge and the foremen engaged on the scheme should be fully informed. In this respect the precise and detailed instructions issued by the American Bell System are worthy of emulation.

As the work proceeds the organisation set up should be constantly reviewed and any defects remedied.

Substantial economies can be achieved only by a thorough organisation of every stage, particular attention being paid to keeping the cable placing machine fully engaged placing cable.

Using the mole-drainer and the auto-mower winch equipment the speed of cable placing is approximately 60 ft. per minute.

The maximum length of cable laid in one day on the Cambridge-Kings Lynn scheme was 1300 yards, a length which at the speed stated represents an effective cable-placing time of only 65 mins., or 13.5% of an 8-hour day.

The organisation set up should therefore be such that cable will be placed in the ground at a speed of 60 ft. per minute for a maximum number of hours per day; a problem the solution of which will repay serious study.

Conclusion.

It is hoped the paper has shown that buried type cable construction is a practicable proposition and that the adoption of modern methods of machine placing would result in substantial economies.

Finally the authors wish to offer their thanks to the manufacturers concerned for details and photographs of loading cases and trenching implements; to the P.O. Engineers named in the paper; and to the draughtsmen of the Lines Section of the Engineer-in-Chief's Office, particularly to Mr. W. J. Fletcher, without whose valuable assistance and enthusiastic co-operation the preparation of many of the illustrations would not have been possible.