A New Type of Underground Telephone Wire

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A new type of telephone line is described in which a specially insulated *twin* wire is plowed into the soil. Problems of wire design, splicing and maintenance are discussed and transmission characteristics are given.

IN this day of multi-channel transmission on open-wire lines, lead-covered coaxial and multi-wire cables, and of radio and ultra-high-frequency transmission without lines at all, it behooves the development engineer concerned with line structures to be alert to advanced, even to radical, ideas. Rubber insulated telephone wire placed directly underground is a case in point.

The urge to put telephone lines underground is only a littler younger than the business itself. In large measure, this has been realized by installing lead-covered cables in underground duct systems. An alternative arrangement used more recently is spoken of as *buried cable*.[1] This is lead-covered cable, the sheath of which is protected from corrosion by successive layers of paper and jute flooded with asphalts. In addition, as a provision against mechanical injury or interference from outside electrical sources, a steel tape armoring is sometimes used. Where conditions have been favorable, the practice of burying suitably protected cables directly in the ground has been applied both to toll and to large and small exchange area cables and to one and two-pair entrance cables for underground service connections.

Because, with underground cables in conduits and with buried cables, the costs essentially limit their use to those cases where appearance is an important factor or where a considerable number of circuits can be grouped under the same sheath, these methods are not generally applicable to service on one or two circuit routes, such as those extending to remote subscribers, typical of rural distribution. Particularly in the interest of providing a lower cost type of plant and thereby making possible a more extensive development of service in rural communities, it appeared there would be a considerable incentive for the development of an inexpensive form of buried circuit. Such a circuit would obviously require that an economical means of installation be devised and even more important that the material used be serviceable for a

[1] C. W. Mier and B. D. Hull, *Bell Telephone Quarterly*, Volume 8 (October 1929).

long period under the severe moisture conditions to which it would be subjected in the ground.

Experience with the cable burial problem had led to the development of a cable laying plow, the neat operation of which in plowing cable into the ground at depths ranging up to thirty inches without trenching or backfilling in the ordinary sense has been described elsewhere.[2] The adaptation of this method to the burial of wire at an appropriate depth required that it be simplified so that it would be less expensive, and involved such considerations as the very much smaller size and tensile strength of the wire, its greater vulnerability to mechanical injury, the need for reducing and simplifying traction requirements, and the like.

On the point of serviceability, it remained for our research chemists first to develop a rubber compound that could be relied on to maintain suitable insulating properties over a period of years under the severe moisture conditions under ground.

With these fundamentals in hand, the development engineers undertook to study the mechanical and electrical problems involved and design a wire that would have appropriate transmission and handling characteristics. In addition, they had to devise methods of splicing the wire; to adapt plow equipment to its installation; to develop loading arrangements for use on the longer lengths; to study methods of tracing the path of the wire and locating faults, etc. In short, the job was to develop buried wire as a practicable plant instrumentality.

The Insulated Wire

The wire as actually developed employs 17-gauge annealed and tin-coated copper conductors, insulated in parallel twin construction with a special rubber compound designed to withstand long water immersion without serious deterioration of the electrical properties. The wire is adapted to a continuous process of extrusion and vulcanization.[3]

While the insulation of this wire is very resistant to water absorption, it is, in common with most high grade rubber insulating compounds, quite sensitive to sunlight so that it must be carefully guarded from any unnecessary exposure to direct rays of the sun and from any extended exposure to indirect rays.

Splicing

One of the principal problems in using a wire of this kind is that of splicing, as it is quite obvious that the splice must be essentially as

[2] C. W. Nystrom, *Telephony*, Volume 98 (June 21, 1930).
[3] S. E. Brillhart, *Mechanical Engineering*, Volume 54, pages 405–9 (1932).

resistant to water absorption as the wire itself. The splice actually developed (see Fig. 1) has two features of interest: the joints in the conductor proper and the method of patching the insulation. The

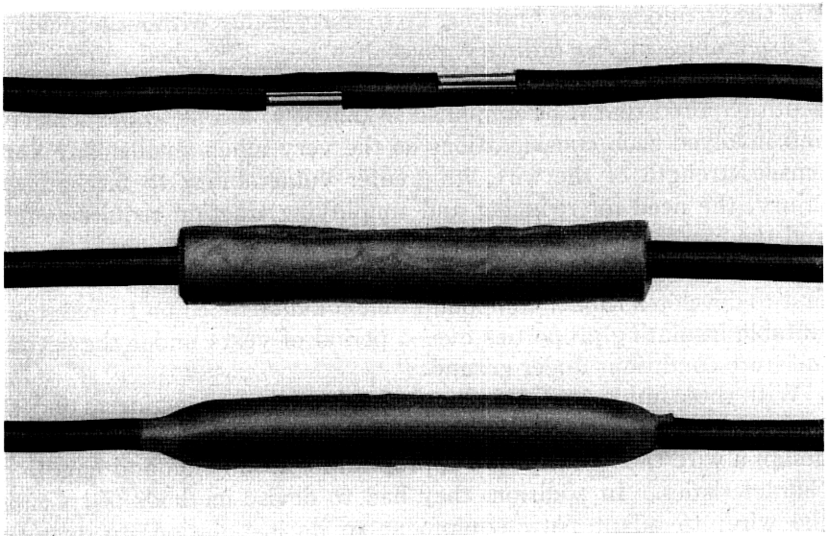

Fig. 1—Splicing buried wire. Top: pressed sleeve joints in conductors. Center: unvulcanized rubber pad in place. Bottom: after vulcanization.

conductor joint is made by pressing a cylindrical sleeve on the abutted ends of the wires to be joined, in this way producing a tight joint of high electrical efficiency and relatively immune to corrosion. The joints in the two wires are staggered and the whole encased in a pad of unvulcanized rubber which is pressed in place and vulcanized in an electrically heated mold, shown in Fig. 2. The vulcanizer is equipped with a thermostatic device to insure proper control of the temperature. This splice is intended for burial directly in the ground without other protection and tests indicate it to be the equivalent of the unspliced wire.

Electrical Properties and Loading

In cross-section, the insulated twin is an oval having a major diameter of about .33″ and a minor diameter of about .165″. The cross-section has been designed to give optimum electrical characteristics for the amounts of copper and rubber compound employed per unit length. The average mutual capacitance per thousand pair feet after seven days water immersion is about 0.022 mf. with an average loop resistance per thousand feet of about 10.2 ohms. While the trans-

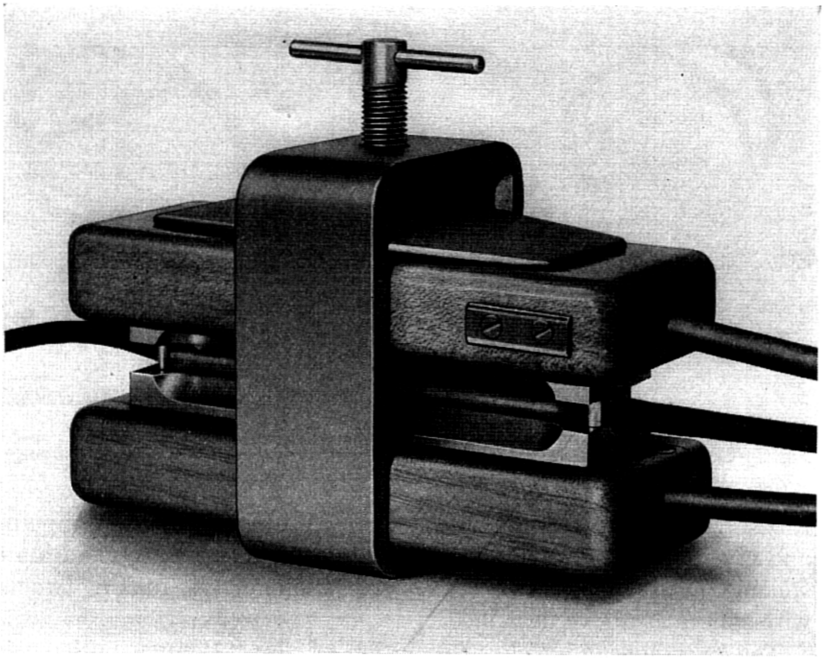

Fig. 2—Vulcanizer for buried wire splice. The buried wire is in the center and storage battery leads for heating vulcanizer are above and below on right.

mission requirements to be placed on a buried circuit will, of course, depend upon the facilities with which it is associated, it is expected that buried circuits up to about five miles in length will, in general, not require loading. Where loading is required, provision has been made for it in the form of a permalloy dust [4] core coil having 44 millihenries inductance which is individually potted with rubber insulated lead-out wires. It is intended to be spliced into the wire at 8,000-foot intervals and buried directly in the ground with the wire.

The potting arrangement for the buried wire coil has several features of interest. The loading coil is first potted in a small metal container which is vacuum impregnated with a moisture resistant compound. The lead-out wires from this container are then spliced to stub lengths of the buried wire, as shown in Fig. 3. This container is then placed in a larger sheet copper container, the rubber insulated wires being brought out through tubes soldered into the copper container and pressed down into intimate contact with the rubber insulation. The lead-out wires are taped for reinforcement at the outer ends of the

[4] G. W. Elmen, *Bell System Technical Journal*, Volume 15 (January 1936).

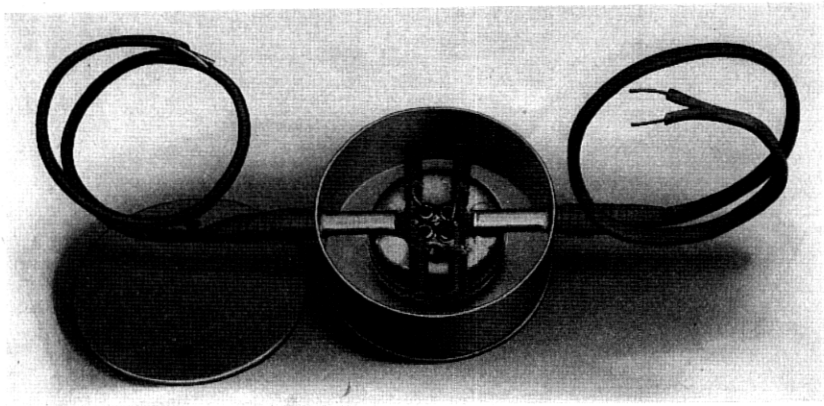

Fig. 3—Loading coil for buried wire before filling outer case, showing the splicing of the rubber covered stubs to the lead-out wires from the inner case.

tubes. This outer can is then filled with a moisture-proof compound and given a dip coating of moisture-proof enamel. The operation of splicing the loading coil into the line wire then involves making two line wire splices as above described.

The one-thousand-cycle attenuation of this 17-gauge buried wire after seven days water immersion and at 70° F. is about 1.1 db per mile for the non-loaded line and the corresponding attenuation of the loaded line is about .49 db per mile. The characteristic impedance of the non-loaded line at one thousand cycles and under the same conditions as above would be $275/\overline{40^\circ}$ and of the loaded line would be $525/\overline{8^\circ}$. The nominal cut-off frequency of the loaded circuit is 3600 cycles.

Layout of Buried Circuits

At the present time, the most promising use of buried wire in the telephone plant appears to be for rural distribution on routes requiring one or two pairs. These routes would commonly have a number of party line subscribers, each subscriber being bridged on the buried circuit. For the most part, it has been found preferable to follow the route of existing public roadways, laying the wire in the shoulder of the road. Installing the wire on right-of-way across private property is advantageous under some circumstances, however. At points where a service connection is to be made, there is the alternative of bridging a service lead across the through circuit or looping the circuit into the subscriber's house, the latter being preferred where the house is a short distance from the through route. Where a bridged connection is to be made, it has been found desirable to bring the wires up above ground for binding post cross-connection so as to provide a test point rather than splicing the bridging wire in permanently and burying the splice in the ground. A small terminal has been provided for this purpose. The buried wires are brought up into the terminal housing through a galvanized iron pipe in order to provide protection of the rubber insulation from sunlight. The terminal is mounted on any convenient pole or post or on a short stub set for the purpose.

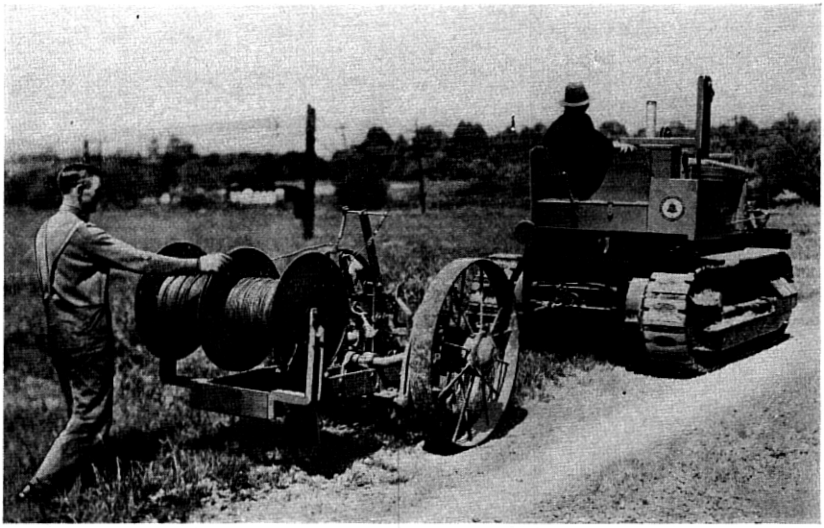

Fig. 4—Plowing-in two pairs of buried wire along roadside.

As buried wire will, in general, be associated with exposed wire circuits, it is planned to provide the same type of electrical protection at subscribers' premises for buried circuits as for drops from open wire or exposed cable circuits. It is also planned to provide protection for buried wire at junctions with open-wire lines over one-half mile in length.

Plowing-in Operations

The success of buried wire is in considerable measure dependent upon the efficiency of the equipment provided for plowing it into the ground. This problem has therefore been studied carefully with a view to reducing the traction requirements to a minimum for the desired depth of placing, so as to permit the use of readily available tractive equipment. Experiments have indicated that in a given type of soil the tractive load on the plow increases approximately as the square of the depth of setting. The choice of depth is, of course, a matter of judgment and is influenced somewhat by the local conditions. In general, it is felt that depths between 16″ and 20″ are adequate and that more shallow installations are justified only under special conditions.

The plow equipment that has been developed for this purpose is shown in operation in Fig. 4 and in more detail in Fig. 5. The plowshare is a vertical blade with a tube fastened to the back edge through

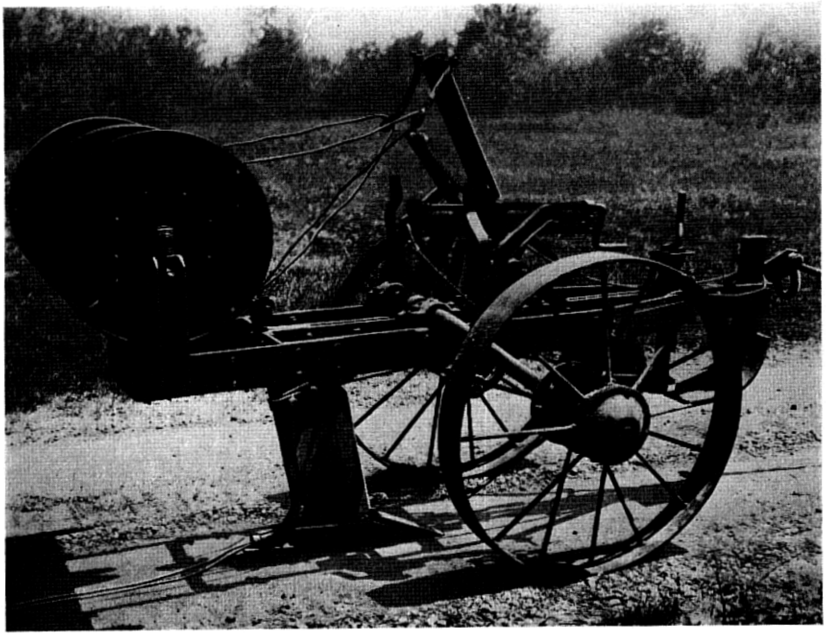

Fig. 5—Wire plow in elevated position, showing duct for wires at back of plow-share.

which one or two pairs of wires may be fed into the soil. The depth of the blade in the ground is readily adjustable to meet local conditions. It has been found that in fairly hard soil with a liberal supply of rock, an equivalent of a 40 or 50 hp caterpillar tractor is required to draw the plow. Across stretches of private right-of-way or at other locations where it is not convenient to use tractors or trucks in direct traction, however, alternative methods have been employed, such as using the winch line of a construction truck to pull the plow. The speed at which the plow may be operated is controlled largely by the number and character of obstacles encountered. Under favorable conditions, the plow may be operated at a speed of three or four miles an hour but a much lower average is to be expected under the less favorable conditions commonly found.

One consideration of some importance in installing wire of this type is the possibility of the insulation being crushed by boulders displaced by the plow, particularly where the trench with wire in place is to be rolled down or subjected to heavy traffic. This danger is, in fact, of such importance that buried wire of this type is probably not a serviceable form of construction through a terrain where nested boulders are frequently encountered.

While it is generally possible to plow across gravel highways, this method can not be used when hard-surface highways are encountered, and in such cases it becomes necessary either to use a pipe pushed under the roadway or to span the highway with open wire. Where conditions are such as to require routing the wire through or over culverts, across ditches, streams and the like, involving actual or potential exposure of the wire as by soil erosion, iron pipe or equivalent protection against mechanical injury and light will generally be required.

Interference

As in the case of other types of telephone circuits, the problem of avoiding noise and crosstalk must be considered. Where more than one pair is buried at a time, there is a crosstalk problem but experience has shown that the introduction of twists every few feet, either by twisting the wire in the process of laying or by having it pretwisted on the reels, is sufficient to reduce the crosstalk to low values.

Special care must be given the wire in manufacture to assure a good degree of balance between the capacitances of the two conductors to ground. This is important in order to avoid noise in the buried wire circuits when they are exposed to power circuits or when the connected open wire is exposed. Under severe exposure conditions, even with the best balance obtainable in manufacture, it may be necessary to resort to special balancing measures in the field to assure satisfactorily quiet circuits.

Maintenance Questions

The introduction of a new type of plant such as buried wire will naturally involve some new maintenance problems. Although records will, in general, be kept of buried wire routes, it will at times be desirable to have fairly precise methods of tracing the underground path. Experiments have indicated that this may be done with considerable precision by putting a tone current on the wire and following along the surface of the ground with an exploring coil device. The location of faults in buried wire also involves some problems which are different from those experienced with cable circuits but experiments have indicated that established methods may be adapted to this new use with an acceptable degree of precision.

Conclusion

As less than fifty miles of buried wire circuits of the type described have actually been installed and put into service, it is recognized that many problems may yet arise and that this type of plant should still be considered as in a trial stage. It is, for example, not known to what extent burrowing rodents such as gophers might cause difficulties. Soil erosion may also introduce problems not as yet clearly visualized. On the other hand, many wind, ice and tree interference troubles peculiar to open-wire construction, involving such things as broken insulators, broken poles, wires crossed or broken, etc., should be avoided by placing the wire under ground. Buried wire should also, in general, be free from lightning troubles when properly protected at junctions with open-wire lines. Considerations of this kind will be largely controlling in determining the eventual field of use for the buried type circuit. Present indications are that in any event many locations may be found where this type of construction will prove economical.