CABLE TROUBLE.

By R. G. Call, '03.

Although the telephone has long ceased to be a luxury and is to-day recognized as an absolute necessity, there are a great many parts of the huge mechanism which is employed to maintain the service twenty-four hours in the day and seven days in the week which is entirely unknown to those not directly responsible for the maintenance of this service. The large increase of the business has necessitated the replacing of open wire lines with cables which consist of from ten to six hundred pairs of copper wires, each wire insulated its entire length and the whole enclosed in a lead sheath. The insulation of the conductors of these cables is dry paper, and the slightest amount of moisture produces the most disastrous results in the cable.

In underground work, branches, or small cables, are spliced into a main cable and run to a pole either on the curb line or the interior of a block and from this point the subscriber's loops are run to the buildings. In such of the smaller towns where the expense of an underground system is not warranted, cables are placed on pole lines suspended on a steel suspension strand. Taps, or branches, are taken out of these aerial cables similar to those in the underground system. In crossing navigable water it is necessary to place submarine cables which are similar in construction to the underground cable, with the exception that a covering of jute and steel armor is placed outside of the lead sheath.

A brief description of how trouble in telephone cables is actually located and cleared may be of some value to those who are interested in telephony.

All large telephone companies use practically the same methods, but, to be concise, let us take up the method used by the New York and New Jersey Telephone Company, and follow it through from the time the trouble occurs until it is cleared.

First, it will be necessary to know something of the general arrangement of the Company's territory, its various districts, and the organization of its forces. The territory, which includes the entire northeastern part of New Jersey, all of Long Island and Staten Island, is divided into two divisions, and the divisions into several districts of perhaps a dozen exchanges each. The general maintenance work in each district is in charge of an inspector. The headquarters of the Company's construction force for New Jersey and Staten Island are in Newark. This force is divided into several branches; but it will only be necessary to tell here of the work of the Cable Construction and Maintenance force, which, as the name implies, installs and keeps in order all the cables in the Company's territory.

Let us suppose that after a severe storm an aerial cable in one of the districts is found to be defective. The Wire Chief of the exchange affected, or the District Inspector at once calls up the Cable Office in Newark, and reports that cable number one, for instance, is in trouble, and gives the number of pairs of conductors that are defective, the number of trunks and the number of sub-stations that are out of service. This report is at once entered in a log book, with the exact hour and the name of the one reporting the trouble. The Chief Foreman of Cable Construction at once notifies the foreman of the Cable Troublemen, or galvanometer men, as they are sometimes called, and he sends three of his men, a tester and two helpers, to the town or city where the repairing is needed.

It may happen that there is a cable tester working near by, say in Newark. If so, he immediately packs up his instruments consisting of a combination set (which includes a galvanometer, Wheatstone bridge, shunt, condenser and necessary keys), a battery, two magneto test boxes with receivers, and his "junk." This "junk" is the name applied to the tools used in verifying and clearing the trouble, and consists of a double iron block and boatswain's chair, a hand line, a chipping knife, a hammer, a paraffine pot, a gasoline furnace, a pair of climbers and several rolls of tape. Each gang of testers has a locker and their tools are always packed in such a way that they can be carried easily by the three men. While the testers are getting their instruments and tools out, and are packing them into a light two-seated wagon used for trips that cannot be made by rail, this foreman is getting from records kept in the office the length of the cable, the number and location of taps, if any, and also a list of conductors in the cable that were already defective when the new trouble came in. This information he gives to the testers, with, of course, instructions for that particular job, and then they are ready to start.

Immediately upon arriving at their destination the tester sets up his instruments at the foot of one of the terminal poles, sends one man up the pole to the terminal box with his magneto test set, and a long three-ply insulated wire, called a "lead," and sends his second helper to the far end of the cable with instructions to meet the first helper on a certain pair of conductors with his test set, or, as it is usually called, his test box. While the second helper is going to the far end of the cable, the tester makes an insulation test on all the spare wires in the cable, keeping a record of them. In this insulation test only the battery, shunt and galvanometer are used, with a key for opening and closing the circuit. The insulation resistance between the wires and the sheath of the cable is measured by the direct comparison method; a deflection of a certain number of scale divisions being obtained with a constant resistance of say one tenth megohm, and compared with the deflection found when the insulation resistance of the cable is substituted for the constant.

By the time the insulation test is completed the second helper has reached the end of the cable and has met the first helper on the appointed pair of conductors or the "talking pair." Let us suppose that the insulation test has shown that there is one well insulated wire, and that all the others are very low, or are grounded By means of the well known Murray Loop, the tester now proceeds to locate the trouble. He has the man at the far end of the cable short circuit, or "bunch" the good wire with the one of the grounded wires, taking care that the wire used for "bunching" touches nothing but the two conductors needed. He then measures the resistance of this loop. We will call this resistance"l". Let "X" be the resistance of the defective wire to the fault. Then (l—X) is the resistance of the good wire and that part of the defective wire between the "bunch" and the fault. By plugging up one of the ratio arms of the bridge and adjusting the rheostat arm a balance is obtained between the two known resistances of the bridge and the two unknown resistances of the wires. We speak of the unknown resistance as being in two parts, since, until the balance is obtained the current divides at the point where the fault lies and returns to the battery through the ground. Calling the resistance of the bridge "M" and "N," we have the following equation when the bridge is balanced; $\frac{M}{N} = \frac{X}{l-X}$, from which $X = \frac{M \quad l}{M+N}$, and since we know the length of cable and the resistance "l" of two of its conductors we can readily obtain the number of feet per ohm and the distance to the fault is obtained in feet.

In locating an open wire, the battery, galvanometer and discharge keys are used, and a capacity test is made. A good wire is first charged for a given time and allowed to discharge through the galvanometer. Then the open wire is charged for the same length of time and discharged in the same manner. The two deflections caused by the discharges are in proportion to the capacity of the conductors charged, and since the diameter of the conductors is the same throughout, the capacity must depend upon their length, providing the insulation is the same, and the length of the open wire is found by the direct proportion.

"The accuracy with which cable trouble is located depends of course upon the nature of the fault. In cases where there are solid crosses and grounds the trouble is located almost invariably at the exact spot, and it is seldom necessary to examine the cable for more than a few feet from the spot calculated. Where the trouble is caused by moisture and the fault itself has considerable resistance, it is more difficult to locate exactly, though as a rule the location is wi.hin fifty feet of the trouble, when the cable is not more than two or three miles in length."

After the tester has made his location, the distance to the trouble is measured off as calculated, and the cable is examined carefully for several yards in either direction. In order to examine the cable thoroughly, one of the men climbs a pole and by means of a hand line pulls up a block and chair, places the block over the suspension wire, climbs into the chair and rides out over the section of cable, moving each suspension clip and looking for any damaged place in the sheath that might cause the trouble. Very frequently a hole is found no larger than a pin, caused by a "blow-out." This in a short time admits enough moisture to ruin the insulation and grounds and crosses appear.

Sometimes a bullet is found half way through the cable and very often a space ten inches long is found riddled with a charge of shot. If the cable is suspended by ma line burns are often found where the sheath has come in contact with the suspension wire. The sheath is sometimes found to be cracked at a point where a sleeve has been wiped on, or has worn through from rubbing on a limb of a tree.

Let us suppose that the cable is found to be badly burned. The man in the chair then cuts away several inches of the lead sheath with his chipping knife and hammer and examines the insulation to see if there is any moisture present. If there is moisture the paraffine is heated to the boiling point and is then poured over the wires again and again until the moisture is entirely boiled out. Often it is found that the moisture has run back several feet, and if that is the case the lead has to be stripped off and the boiling continued until there is no trace of moisture left. If any of the wires are found to be burned through or "open," they are spliced together and a small cotton sleeve is placed over the splice. After the moisture has disappeared the cable is then tested again, and if it is found all right the splice is taped up and left until a splicer can be sent to wipe a sleeve over the part opened up. But if the cable is still in trouble, a few of the defective wires are opened and a test is made each way from the cut to determine whether there is more than one case of trouble, and which direction it lies.

So much for aerial cables, but now suppose a report comes in that an underground cable has "gone up" and fifty or more trunk lines are out of service. The testers are sent at once to the place reporting the trouble, taking only their instruments, and proceed to get a location on the trouble in exactly the same way as described above. Meanwhile the Chief Foreman has ordered the foreman of the splicers to hold a gang in readiness to take up the trouble as soon as word comes tha it has been located. He also has the foreman of the "pulling in" gang prepare to pull in a new section of cable if the trouble is verified in a section and cannot be cleared in a manhole.

In locating trouble in an underground cable all tests and measurements are made from the vertical side of the main distributing frame in the terminal room of the exchange; a man being sent out to the terminal pole where the defective conductors appear. After making his calculations the cable tester reports that he has located the trouble near a certain point. The splicers then go to a manhole nearest this point and proceed to unwrap the sleeve on the cable and slip it to one side. Before this sleeve is removed a bond or "jumper" is securely connected to the cable sheath on either side of the sleeve. This is done to prevent an arcing between adjacent cables, due to the sheath carrying a foreign current. This foreign current is generally due to the use of street railway rails as one side of the trolley circuit. The rails are seldom, if ever, properly bonded, and the return street railway current leaves the rails at this point, returning to the power house by the path of least resistance, which is usually a water main, gas main or lead sheathed cable.

If no trouble is found in the splice a few of the defective wires are opened and cleared and a test is made on them from the office. If these wires test all right it is evident the trouble is beyond and the wires are closed through and the splice is taped temporarily. The splicers then go to the next manhole and open up the splice there in the same way. If the same wires are tested in the second manhole and are found defective it is known that the trouble lies in the section between the two splices opened and that a new section is needed to replace the one in trouble.

As soon as the trouble is verified in this way the Chief Foreman is notified and he sends the "pulling in" gang, which has been held in readiness, and the section of cable is replaced. If there is a spare duct in the conduit the new cable is pulled into it, but if there is no spare duct the old cable has to be entirely cut away and pulled out and the new one pulled into the same duct. In the latter case the work is done at night so as not to interrupt the service during the busy hours of the day.

In handling a case of submarine trouble the work is proceeded with in a similar manner to that in which underground trouble is taken up. One of the "pulling in" gangs is made up entirely of deep sea sailors. Upon notification that a submarine cable has been damaged this gang is ordered to the cable boat, which in turn is ordered to the nearest point for embarkation. This boat is equipped with a short, heavy mast forward of the pilot house, on which is swung a heavy boom. This boom is arranged so that it can be raised or lowered on either side of the boat and at any angle. A large snatch block is hung on the end of this boom. On the forward deck of this boat are two steam winches and the side rails, which are of very heavy construction, are equipped with steel rollers.

On arriving at the crossing where the cable has been damaged, a grapnel is dropped overboard, and the boat backed up until the grapnel picks up the cable. The cable is then hoisted by means of the steam winches until it can be reached from the deck of the boat. Lines are then secured to this cable, and the boat moved backward and forward until the numbering band on the cable is found. A numbering band consists of a brass or copper band secured to the armor of the cable and on which the number is stamped. The right cable being picked up, the boat is then turned lengthwise of the cable and the cable hooked into the snatch block at the end of the boom, which is swung over one side of the boat, according to the direction of the tide and the wind. When the cable is placed in this snatch block it is within easy reach of the deck of the boat and can be carefully inspected. The boat is then started ahead and the cable is raised while passing through the snatch block until the point where the damaged part is reached. Anchors are then put out fore and aft to hold the boat in position, and the cable is swung, by means of the boom, over the deck of the boat and securely fastened to prevent either end, when the defective part is cut away, from slipping overboard. The armor and lead sheath is cut away and such repairs as are necessary are made. The splice is then covered with a lead sheath and the armor and jute laid back in place and the cable at this point is seized with hambroline.

The causes of trouble in underground and submarine cables are almost as varied as those in aerial cables. Probably it is caused most often by high potential currents and lightning entering the cable and burning out the insulation, in spite of the fuses and protective devices. Occasional trouble is caused in underground cables by electrotlytic action in places where cables are paralleled or near trolley lines or other high potential circuits using a ground return. In time this electrolytic action decomposes or eats away the sheath of the cable, often for a space of several feet.

At first one might think that an underground cable would be free from mechanical injuries, but this is not the case. Careless workmen in opening a street for sewer or water pipes often drive a pick or bar through a duct and into a cable, or a bar driven to detect gas leaks strikes and injures a cable or perhaps the ducts and cable are crushed by a pile being driven near them. Considerable trouble is sometimes caused by water freezing in the iron pipes, which terminate the laterals, and crushing the cable causes crosses and short circuits.

The time required to locate and clear a case of trouble necessarily varies greatly, owing to the different conditions existing, but a fair average would be about one half a day for each case of aerial cable trouble and about the same for underground trouble that can be cleared in a splice. When a new section is required, a day is taken to locate and verify the trouble and the following night is taken for pulling in and splicing the new section. In all cases the work of clearing the trouble must not be stopped for any reason whatever until it is entirely cleared. Meals and sleep are dispensed with and the work is continuous from the time of arriving on the job until the cable is tested by the Wire Chief and reported O. K.