shown by dots, and the positive areas by section lines, instead of by blue and red areas. It will be noted that, in the neighborhood of the railway power station, the pipes are highly positive to the rails, and at points distant from this station they are negative to the rails. The existence of potential differences between pipes and rails is, however, no conclusive evidence of stray currents on the pipes; they indicate at what points current is probably flowing from rails to pipes and from pipes to rails.

Where there are a number of underground metallic structures which may be affected by electrolysis, it is desirable to make simultaneous measurements of potential difference between the rails and each of these structures. The average values of these simultaneous potential measurements may then be conveniently plotted on a diagram in which the

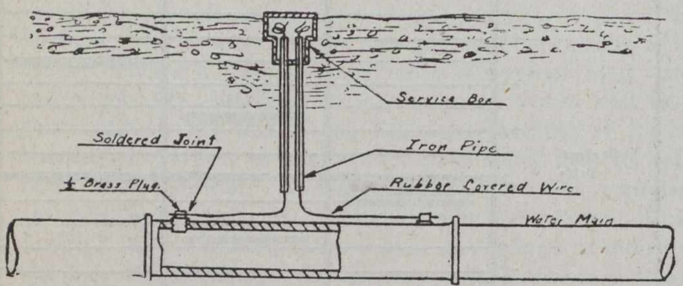

Fig. 5.—Permanent Electrical Test Wire from Surface of Street to Pipe.

potential of any one of the structures is taken as the datum or zero of potential. In Fig. 4 is shown a set of diagrams giving the relative potentials between water pipes, trolley rails and underground cable sheaths, at 3 points along a given street. In this diagram the water pipes are assumed as the datum or zero of potential, and the potentials which are positive to the pipes are laid off above the axis, while those which are negative to the pipes are laid off below the axis, to the scale indicated in the diagram. In the case shown in Fig. 4, the cable sheaths are connected to the railway return conductors near the railway power station. It will be noted that, at the point nearest the power station, the water pipes are positive both to the cable sheaths and to the rails, and that the cable sheaths are also slightly positive to the rails. At greater distances from the power station the rails become increasingly positive to the water pipes, while the cable sheaths become increasingly negative to the pipes. The potential difference between the rails and the cable sheaths increases very rapidly with increasing distance from the power station, as is seen from Fig. 4.

The next step in the survey is to measure drop between drip or service connections, which will indicate the probable existence and direction of current flow on the pipes. Such drop measurements cannot, however, be used for calculating the amount of current on the pipes. To determine the actual current flowing it is necessary to measure the drop between two points on a continuous length of pipe by means of a millivoltmeter. This drop, expressed in volts, divided by the assumed or measured resistance in ohms of the included length of pipe, gives the current expressed in amperes. A convenient table giving the current in amperes for 1 millivolt drop in 1 foot of standard wrought iron, steel and cast iron pipes is appended to this paper. To find the current flowing on a pipe corresponding to a given drop in millivolts for a measured length, multiply the amperes given in the table for 1 millivolt drop for 1 foot by the number of millivolts drop measured, and divide by the included length of pipe in feet. To measure this drop it is necessary to expose the pipe and to make good electrical contact between the millivoltmeter leads and the pipe. A satisfactory method is to use a pointed piece of steel, about the size of an ordinary lead pencil, fastened in a wooden handle, with a flexible connecting wire soldered to it inside of the latter. The pointed steel is then pressed against a bright spot or into a filled notch on the pipe. A still better contact is obtained by soldering the connecting wire directly to the pipe or to a brass plug screwed into the pipe, which is particularly advantageous when readings are to be taken over a considerable time. When such contact wires have been soldered to a continuous length of pipe it is common to use rubber covered wires, bringing them to the surface of the street, leaving the ends in drip or service boxes, which then form permanent test stations for electrical measurements. This is exceedingly convenient, for it is then possible to make current measurements on the pipe without again digging an excavation. Such permanent contact wires for electrical tests are illustrated in Fig. 5.

It should be noted that small potential differences, such as 0.1 millivolt or less, may be caused by local galvanic or thermal action. Where such small values are found in a test for drop on a pipe a careful investigation should, therefore, be made to ascertain whether the observed potential difference is actually drop due to current flow or is due to local causes. The writer has found that such local potential differences are a frequent source of error when such tests are made by persons who are not accustomed to making accurate electrical measurements.

When drop measurements between services and current measurements on pipes have been generally made on a piping system, the results are conveniently plotted on a skeleton

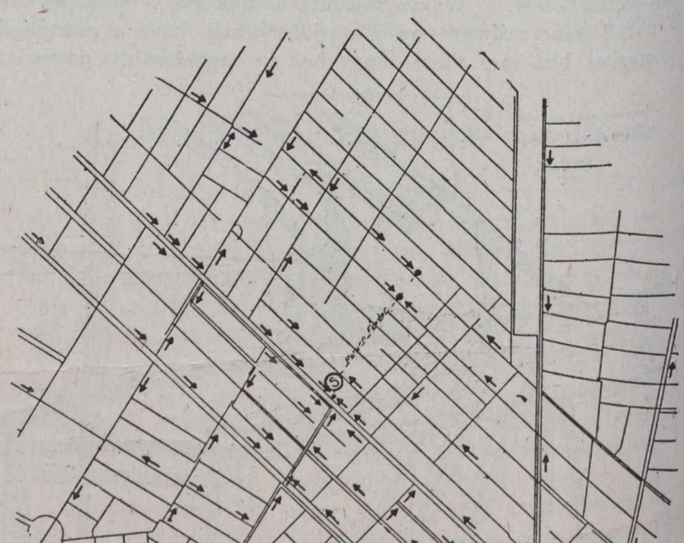

Fig. 6.—Typical Current Survey, Showing Underground Mains and Stray Currents Flowing on Mains.

map of the city in which the pipe lines are shown and the current flowing on these pipes are indicated by arrows. A typical current survey map of a portion of a city is shown in Fig. 6. It is seen that here the currents on the pipes flow in a general direction towards the railway substation.

Since current destroys the pipe only where it leaves the pipe for soil, it is important to know where the current does