underground piping, does not constitute a source of loss to the railway company, as, for instance, would be the case with leakage of gas or water. On the contrary, by allowing the current to return by earth and underground pipes as well as by way of the rails, the total conductivity of the return circuit is increased, and the voltage loss in the return of this current is decreased, so that there is an actual saving of power for the railway company.

Alternating currents have been used for some years past in a number of electric railways employing the running tracks as a part of the electric circuit, and where these tracks are in contact with earth, stray alternating currents through earth are produced. Where an alternating current flows from iron or lead to surrounding soil, corrosion from electrolysis may also be produced, but this proceeds at a relatively very slow rate, as already explained. With alternating currents, electrolysis is, however, produced at the two electrodes, instead of at one electrode only, as with direct current. So far as the writer is aware, no damage from electrolysis due to such stray alternating railway currents has been reported to this date. This may be due to the slow rate at which corrosion is produced by alternating currents, together with the fact that most of these railways are of relatively recent installation. It may also be due to the fact that stray direct currents are nearly always present with the alternating currents, and the effects of these direct currents may have inhibited or masked the effect of the alternating currents. It is therefore not possible at this time to draw a positive conclusion as to the danger from stray alternating currents.

Where current leaves a wrought-iron or steel pipe for earth, the oxide of iron resulting from electrolysis becomes diffused through the earth, and streaks of iron oxide can generally be found in the surrounding soil. Electrolysis of wrought-iron or steel pipes usually results in pits which eventually go entirely through the wall of the pipe. It has frequently been found, in practice, that where a gas service pipe lies in clay or other tightly packed soil, it may be pitted through in many places without giving any external sign of leakage, because the soil surrounding the pipe maintains it gas-tight. When cast iron is corroded by electrolysis, the oxides of iron mixed with graphite usually remain in place, leaving the outside appearance of the pipe unchanged. This material, resulting from the electrolysis of cast iron, usually has the consistency of hard graphite, and can be cut with a pocket knife. There have been many cases in which a cast-iron main was carrying gas or water without any apparent leak, where a light blow with a hammer drove a hole right through the pipe. Here the electrolytic action had corroded the iron entirely through the pipe, and the oxide of iron had remained in place, and, together with the surrounding soil, had prevented the pipe from leaking. Whether or not the mixture of iron oxide and graphite resulting from electrolysis remains in place so as to maintain a pipe gas or water-tight, depends upon the surrounding soil conditions. It is therefore seen that an underground piping system may be suffering severely from electrolysis without giving any outward sign of the damage. A physical examination with a test hammer is required in the case of cast-iron pipe to establish definitely whether or not it has been damaged by electrolysis.

Remedial Measures Applied to Pipes

Attempts have been made to protect underground pipes from electrolysis by insulating them from earth by paints or dips. Practical experience as well as a large number of tests have, however, shown that no dip or paint will permanently protect a pipe against electrolysis in wet soil. The first difficulty is to apply the paint so as to form an absolutely perfect coating, and the second one is to prevent mechanical damage to the coating during shipment and installation of the pipe. In the case of paints which are applied with a brush, these afford only a very thin coating over the metal, and where stray currents are present, the effect of these currents and of the moist soil is to cause the coating to disintegrate and disappear rapidly. A large number of experiments which I have made have shown that such paints will disintegrate not only where the current flow is from the metal to earth, but also where the flow is from earth to the metal. Experience further shows that even where coatings of paints or dips are apparently intact, electrolytic action is not always prevented, and, in fact, very serious electrolytic pittings have been found under apparently good coatings. It has been found that in most cases the applied coatings have either been completely destroyed by the effects of the wet soil and the electric currents, or defects in the coating have developed, causing concentrated corrosion at such defective spots. Where it is attempted to apply a heated material like pitch or asphaltum to a cold pipe, it is impossible to completely cover the pipe. Pitch and similar compounds have been applied to pipes with wrappings of jute or of some similar material. A number of layers can be applied in this way so as to build up any desired thickness of insulating covering. Such covering, if sufficiently thick, will afford protection against electrolysis, provided that it is mechanically perfect. The great difficulty in practice is to apply such a covering without leaving defective spots through which moisture will have access to the metal of the pipe.

Pipes which are covered with imperfect insulating coatings or coverings exposing bare spots of metal, are in much greater danger from electrolysis where positive to earth than are bare pipes, for the reason that the stray currents will leave only from these bare spots, and here produce concentrated corrosion. The writer has seen cases where a pipe coated with an imperfect insulating covering was pitted nearly through in one year, whereas a bare pipe in the same locality was very much less affected, because the corrosion was distributed over a larger surface.

Summary

Experience shows that an increasing amount of damage by electrolysis is occurring on underground piping systems in many localities throughout the country where adequate measures have not been taken to reduce this damage. The principal and generally the sole sources of stray electric currents causing this damage are the single-trolley direct-current electric railways employing the running tracks in contact with earth as part of the return circuit. Experience extending over many years in foreign countries and over ten years in this country has shown that practicable and economical methods of construction can be applied to such electric railway systems which will remove acute dangers from stray currents to underground piping systems and which will greatly reduce the electrolysis danger in all cases, and in most cases will make this danger negligible. Mitigating methods applied to underground pipes fail to attack the source of the trouble and should be applied only in special cases, if at all, and then only after adequate methods of minimizing the production of stray currents have been applied to the railway system. Metallic connections from underground water pipes to the railway return circuit which cause these pipes