ELECTROLYSIS—TROUBLES CAUSED THEREBY AND REMEDIES WHICH MAY BE APPLIED*

By Albert F. Ganz

Professor Electrical Engineering, Stevens Institute of Technology, Castle Point, Hoboken, N.J.

ELECTROLYSIS is the process of decomposing a chemical compound by means of an electric current.

Electrolysis, in the sense in which it will be discussed here and in which you are particularly interested, refers to the corrosion of underground metallic structures, such as iron and lead pipes, by stray electric currents which reach these structures and flow to surrounding soil. Soil, when entirely dry, practically does not conduct electric current. Pure water likewise has such a high electrical resistance, compared with iron or lead, that it may be considered a non-conductor. Water is, however, readily made conducting by the addition of even very small amounts of salts, and conduction through water is therefore always electrolytic. Soil in its natural state is always moist, and on account of dissolved salts, such as chlorides, nitrates, etc., which are always present, is an electrolytic conductor.

The mass of metal corroded by electrolysis in a given time depends only on the "current," and, with the current densities and other conditions usually found in the case of underground pipes, is equal to that calculated by Faraday's law. Iron is oxidized by electrolysis at the rate of approximately 20 lbs. per year for every ampere of current flowing from the iron to surrounding soil. Under some conditions, particularly with very small current densities, this corrosion may be considerably greater, while with larger current densities than the above, this corrosion may be considerably less than the theoretical rate. The actual rate may vary in practice from one-half to one and one-half times the theoretical rate. Lead is oxidized by electrolysis under ordinary conditions in soil at a rate equal to approximately 74 lbs. for every ampere of current leaving the lead in one year, and this theoretical rate may also vary somewhat in practice. The amount of corrosion produced by electrolysis is independent of the voltage, except in so far as this determines the amount of current flowing, and the smallest fraction of a volt can produce corrosion from electrolysis under suitable conditions.

The rapid corrosion by electrolysis from external currents is usually localized, and results in pitting of the metal. Such pitting may, however, in some cases also result from ordinary soil corrosion, so that the appearance of a corroded metal structure does not by itself afford conclusive evidence as to whether or not the corrosion was produced by electrolysis from external electric current.

Where the direction of current flow between an underground pipe and surrounding soil reverses more or less continually, it has been found that the corrosion occurring during the time that current flows from the pipe is largely offset by a reversed action which occurs during the time that current flows to the pipe. The resultant corrosion by electrolysis from periodically reversed direct current is for this reason much less than when the current always flows in the same direction, and this corrosion decreases with increasing frequency of reversal. Investigations have shown that even if such reversals occur only once in twenty-four hours the actual amount of corrosion for iron is only about one-fourth of what would occur if the same amount of current always flowed from the pipe to surrounding soil.

Sources of Stray Currents which May Produce Electrolysis

Electrical distribution systems which are grounded at two or more points will, by the law of divided circuits, cause currents called "stray currents" to shunt through the earth between the grounded points, and these stray currents frequently reach underground metallic structures and corrode them by electrolysis. In practice, it is found that the most important sources of stray electric currents, which so endanger underground structures, are direct-current electric railways, which use the running tracks in contact with ground for part of the electric circuit.

For such railways, it is the common practice to supply current to the cars from an overhead trolley wire or from a third rail, and to return this current to the power station through the running tracks, supplemented in large systems by return feeders.

In the simplest form of single-trolley railway the rails are connected to the negative terminal of the generator at the power station, and the only path for current to return to the power station is by way of the running tracks. If the running tracks are laid upon wooden ties above ground with broken stone for road ballast, as is common on steam railroads which run on their own right-of-way, the rails do not come in direct contact with ground, and the return current will be practically confined to the running tracks. If, however, the running tracks are laid below ground so that the top of the rails is level with the surface of the street, as is common in cities, then the rails will be exposed for a considerable area to contact with ground. If the tracks are laid on a concrete base, a considerable area of the rails will similarly be in contact with the concrete.

It has been suggested to reverse the usual arrangement of trolley system and make the rails the positive conductor instead of the negative conductor. With the rails the positive conductor stray current flows to underground pipes in the vicinity of the power station, and leaves these pipes over widely scattered areas so that the density of the current leaving will be relatively small. By this arrangement the acute danger which with the usual polarity exists in the neighborhood of each station is removed, but electrolysis troubles are spread over a greatly distributed area. The total amount of electrolysis must, however, be the same whether the rails are the negative or the positive conductor, since the stray currents through earth are simply reversed in direction but not changed in magnitude. This arrangement has been tried in several places and has been used in one large city for about three years. I have had occasion to make tests in this city and have found that trouble from electrolysis is developing in outlying sections, and some trouble from corrosion of service pipes in such outlying sections has already been found.

It must be noted that, while ordinary soil is a conductor of electricity, its electrical resistivity compared with metals is enormously high, being of the order of millions of times the resistivity of iron. Resistance, however, varies inversely as the cross-section of a conductor, and with the large surface of rails exposed to the earth, the cross-section of the path of current through earth is enormously great compared with the cross-section of the path of current through the rails. As a matter of practice, it is often found that where the rails in contact with earth are used alone for the return of current, a considerable portion of the total current leaks from rails through earth.

The leakage of current from the rails of electric railways, producing stray currents through earth and on

*Abstract of paper read before the New England Water Works Association.