in the same or in the opposite direction as the current. It has been assumed by some writers in the past that no corrosion from electrolysis can take place if the voltage between two metallic conductors in soil, such as between pipe and rails, is less than 1.5 volts, because this is the dissociation voltage of water. This, however, is entirely wrong, and it has been proven by many investigations, also by practical experience, that 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 that the smallest fraction of a volt can produce corrosion from electrolysis under suitable conditions, and this is now generally recognized by electrical engineers.

A large number of laboratory tests have been made to determine whether electrolysis is produced when an alternating current flows from a metal to an electrolyte; for example, from a pipe to surrounding soil. These experiments indicate that a slight amount of electrolysis may be produced by an alternating current, which is generally less than 1 per cent. of the amount of electrolysis produced by a corresponding direct current. It must be remembered, however, that, in the case of alternating current, electrolysis would be produced wherever there is a flow of alternating current between a metal and soil, while with direct current metallic anodes exist only at ½ the points where current flows between metal and electrolyte; namely, where current leaves the metal.

Sources of Stray Electric Currents.—Stray currents are electric currents which have leaked from grounded electrical distribution systems and flow through ground and through underground structures. Grounded telephone and telegraph lines produce electric currents through ground of such very small magnitudes that their effects upon underground piping systems can be neglected. Direct current, electric lighting systems, in which the distribution is on the Edison 3-wire plan, with the neutral conductor grounded, are in American practice provided with such large neutral conductors of copper that practically no stray currents are produced from such systems. This grounding of the neutral in Edison 3-wire systems is to serve as a safety measure, and is not for the purpose of using the ground to carry current.

The secondaries of transformers are also frequently grounded to underground pipes for the purpose of preventing a high and dangerous voltage from existing between the secondary circuit and ground. Such ground connections, however, do not produce flow of current from pipes to ground and, therefore, such grounding of transformer secondaries does not cause danger from electrolysis.

Electric railways, using the running tracks for return conductors, often produce comparatively large stray electric currents through ground, and these are the only sources of stray currents which need be considered in practice. Direct current is very generally used for such electric railways, and it is the common practice to supply current to the care from an overhead trolley wire or from a third rail, and to return this current to the power station through the running tracks, supplemented where necessary by return feeders. A single-trolley electric railway is shown diagrammatically in Fig 1, in which the path of the electric current, from the positive terminal of the generator through the circuit and back to the negative terminal, is shown. The running tracks consist of rail lengths about 30 feet long, and these are mechanically fastened together by fishplates which consist of steel plates bridging across the rail ends and bolted to both rails. Such fishplates, while mechanically fastening the rail lengths together, do not form good electrically conducting connections between the successive rail lengths. For this reason, copper wires or straps, called rail bonds, are generally used to bridge across the abutting ends of the rail lengths for the purpose of affording a good electrically conducting path between successive rail lengths. The two rails of a single-track road, or the four rails of a double-track road, are also generally connected together at frequent intervals by cross bonds so that the 2 or the 4 rails may be available for the return of current. Instead of using copper rail bonds, the rail ends are sometimes welded together, or soft steel plates are welded across each side of the abutting rail ends, thus forming both a strong mechanical and a good electrically conducting connection between the successive rail lengths. A well bonded railway track should have a conductivity not less than 80 per cent. of the equivalent conductivity of continuous rails. To give some idea of the relative conductivity of steel rails, it may be stated that a single rail, weighing 90 pounds per yard, which is a size commonly used where the traffic is heavy, has about the same conductivity as a copper wire 1 inch in diameter. Thus the 2 rails of a single-track line, or the 4 rails of a double-track line, laid with 90-pound rails and well bonded, afford a good conducting path for electric current.

In the simplest form of single-trolley railway, already shown in Fig. 1, 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 on the level of the surface of the street, as is common in cities, then the rails will be exposed for a considerable area to contact with soil. If the tracks are laid on a concrete base a considerable area of the rails will similarly be in contact with the concrete. Since both damp soil and damp concrete are under ordinary conditions conductors of electricity, part of the current returning through the rails will shunt from the rails through the surrounding soil, as is illustrated diagrammatically in Fig. 2. It will be seen that, with the usual connection of positive terminal of the generator to the trolley wire and the negative terminal to the rails near the power station, the current will leave the rails for ground at points distant from the power station, and return to the rails in the neighborhood of the power station, in its path back to the negative terminal of the generator. Since every electric circuit must be completely closed, all current escaping through ground must again leave ground to return to the dynamo so as to complete the electric circuit. When underground metallic structures, such as gas or water pipes, lie in ground in the path of these stray currents, and where these pipes have electrically conducting joints, such as lead-calked joints or screw coupling joints, current will flow from ground to such pipes and flow largely on such pipes in a direction towards the power station. In the neighborhood of the power station this current will leave the pipes to return to the negative terminal of the generator, as shown in Fig. 2.

In the negative terminal of the generator or negative bus-bar is connected to the rails, at points some distant from the power station by means of insulated negative return feeders, then, at such connection points, the rails will be rendered negative in potential to ground, and currents will tend to flow from underground pipes through ground to return to the rails in the neighborhood of these connections. Stray railway currents on pipes will, therefore, tend to leave these pipes to return to the rails in all regions where these rails are connected to return feeders.

It must be noted that, while ordinary soil is a conductor of electricity, compared with metals its electrical resistance is enormously high; for instance, the resistance between the opposite faces of a foot cube of ordinary soil may measure anywhere from 10 to 1,000 ohms, depending upon the amount