Corrosion Not Caused by Electrolysis.—While electrolysis is undoubtedly responsible for much destruction of underground piping and other underground metallic structures, the author has frequently been asked to examine cases where the destruction had clearly not been produced by electrolysis from stray currents, but by altogether different causes. It must be remembered that corrosion of a metal from electrolysis can only occur where current leaves the metal to pass to an electrolyte, such as damp soil. Service pipes have sometimes been found destroyed inside of cellar walls where they were not in cantact with an electrolyte; the corrosion here is purely of a chemical nature, and not in any way chargeable to stray current electrolysis. Brass or copper pipes and fittings and brass condenser tubes in contact with salt water also corrode quite generally, but this is

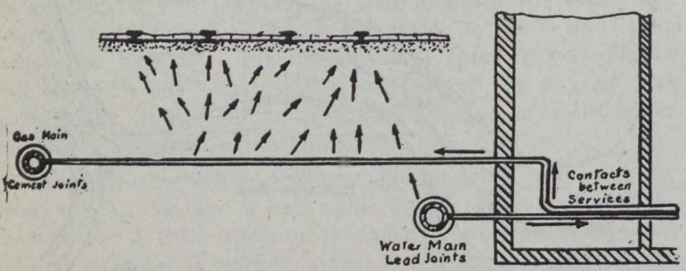

Fig. 12.—Showing Stray Currents Entering and Leaving Building Through Service Pipes and Causing Fire Hazard and also Destroying Gas Service Pipe by Electrolysis.

caused by electrochemical action of the salt or contaminated water upon the metal, and not by electrolysis from stray currents.

Remedial Measures.—The only one complete remedy for electrolysis is the use of a completely insulated return circuit. Such railways may be provided with double overhead trolley wires, as used (for example) in Cincinnati and Havana, Cuba; or with an insulated outgoing and return conductor in underground conduits, as used (for example) on the surface lines on Manhattan Island and in Washington, D.C.; or with separate insulated third and fourth rails for the outgoing and return current, as is used on the Metropolitan District Railway in London. With these systems the running tracks are not used as a part of the electric circuit, and as both positive and negative sides of the circuit are insulated no stray currents are produced.

Where a road operates on private right-of-way the rails can often be practically insulated from ground and the escape of current from the tracks prevented. For surface roads this can be practically accomplished by placing the rails on wooden ties above ground, using broken stone for ballast and keeping the rails out of contact with ground. In the case of railway lines operating on elevated structures the rails can be fastened to wooden ties and kept out of contact with the structure. These rails, supplemented where necessary with negative feeder cables, also insulated from the structure, can then be used for the return conductor. In this way the return circuit is quite thoroughly insulated from the elevated structure and from ground, and stray currents are entirely prevented.

A number of remedial measures intended to reduce stray currents from electric railways using the grounded rails for a return conductor have been tried. These methods may be divided into two classes, the first class aiming to remove the current harmlessly from pipes by metallic connections or bonds between the pipes and the railway return circuit, the second aiming to minimize stray currents through ground.

Since stray currents cause damage only where they leave pipes to flow to the surrounding soil, attempts are frequently made to prevent destruction from electrolysis by connecting or bonding the pipes or other structures by means of metallic conductors to the rails or to the negative return circuit, so as to remove the electric current by metallic conduction and thus prevent corrosion from electrolysis. As the lead sheaths of underground cables form continuous and uniform metallic conductors, it is, therefore, possible to protect such cable sheaths against electrolysis by bonding or connecting them to the railway return circuit. This practice is, however, exceedingly objectionable because by such bonding the trolley rails are paralleled by a low resistance grounded conductor which greatly increases the tendency for current to flow through ground from the tracks. The second objection is that such bonding makes the cable sheaths negative to all other underground structures, such as water and gas pipes, thereby setting up a tendency for current to flow from such pipes to the cable sheaths. This effect is illustrated in Fig. 13. In this a case is shown, frequently found in practice, where the pipe is everywhere negative to the trolley rails, except in a very restricted area in the immediate vicinity of rail feeder connections, but is everywhere positive to the underground cable sheaths. The pipe is consequently everywhere in danger from stray current flowing from the pipe to these cable sheaths. In one city, in fact, where there was an underground cable system with its lead sheathing bonded to the railway return circuit, it was found that the underground pipes were everywhere negative in potential to the trolley rails, and were, therefore, considered immune from electrolysis. An investigation showed, however, that these pipes were at all points highly positive to the underground cable sheaths and were in fact in considerable danger from electrolysis. It has been frequently found that, where gas or water service pipes cross bonded cable sheaths, currents are caused to flow from the service pipes to the cable sheaths, and produce gradual destruction of the service pipes. A case of this kind was illustrated in Fig. 11. In the case of one city 19 service pipes were destroyed in the course of one year directly where these pipes cross telephone ducts containing cables whose sheaths were bonded to the railway re-

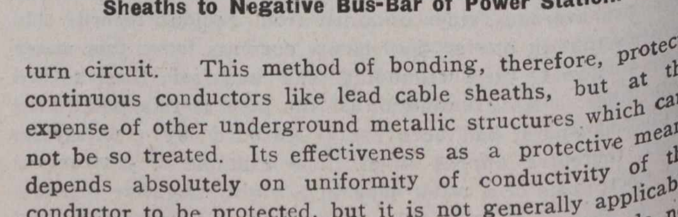

Fig. 13.—Showing Path of Stray Railway Currents and Showing Effect of Bonding Underground Lead Cable Sheaths to Negative Bus-Bar of Power Station.

turn circuit. This method of bonding, therefore, protects continuous conductors like lead cable sheaths, but at the expense of other underground metallic structures which cannot be so treated. Its effectiveness as a protective means depends absolutely on uniformity of conductivity of the conductor to be protected, but it is not generally applicable to underground piping systems, because the latter do not form continuous electrical conductors, but are more or less discontinuous networks. While lead calked joints usually have a relatively low resistance, it frequently happens that they develop such high resistances as to make them practically insulating joints, due undoubtedly to the formation of oxide coatings. Cement joints and cement pipes have such