flowing, which makes the possibility of electrolysis in the case of cast iron approximately one-twelfth what it would be for the other two kinds of pipe mentioned. It should also be borne in mind that in practice cast-iron pipe has a metal thickness about four times that of wrought iron or steel, which proportionately delays the ultimate total destruction in the case of this class of pipe.

If pipe is of steel or wrought iron, results of electrolysis are seen in pits, these finally extending through the plate. Where the current leaves such pipe the metal is converted into iron oxide, which is frequently noticeable in surrounding soil. If the pipe be of cast iron, the oxides formed often are still held in position by the graphite, and the external appearance of the pipe remains unaffected. When the pipe has been entirely eaten through the mass is about the hardness of pencil lead and collapses under an ordinary hammer stroke, yet a pipe in this condition, if the soil is rather tightly packed about it, may remain without leaking for a considerable period. It is frequently necessary to make a direct physical examination of a pipe and subject it to a hammer test to determine if it has been attacked by electrolysis. So far, we have dealt only with trouble in the mains and distribution system proper. However, while less serious, probably the greater percentage of damage actually occurs in the service pipes, because these frequently pass under the car lines close to the rails, and the pipes being relatively thin, are quickly pierced. Investigation made in about fifty cities brought out the fact that, roughly, seventy-five per cent. of the trouble experienced occurred in the service pipes, lead, wrought iron or steel all being readily affected. Besides the damage to the service pipes themselves, stray electric currents flowing on these may occasionally reach the steel structure of buildings, causing electrolysis to attack the steel, but seldom to any serious extent. Under certain unusual conditions, current flowing on these service pipes may be sufficient to raise them to a temperature approximating red-heat, and in this way cause fires. In some cases of gas pipes, explosions have been brought about. However, such occurrences are undoubtedly very rare at the present time, and there seems no good reason to anticipate any increase in this hazard.

Electrolysis from Local Action.
(Self-Corrosion.)

In the preceding section it has been the intention to deal only with the effects of electrolysis due to stray currents, or what is usually spoken of as "anodic corrosion." That is action when the pipe serves as the anode, corrosion taking place only where current flows from the pipe to other conductors. Now, in addition to this form of electrolysis, we have what is termed "self-corrosion." That is, electrolysis by local galvanic action. This is termed "self-corrosion," for the reason that the current originates on the metal itself, and is due in the case of pipe to the impurities of the metal or the presence of carbon or coke in the surrounding earth, or both. Salts and acids in moist soil increase this action. Small pieces of coke or carbon in wet soil in contact with the pipe, even if no physical differences between adjacent parts of the metal exists, will bring about local action because a difference of potential will exist between the carbon and the iron, which will cause a current to flow from the pipe to the carbon. The potential difference existing under such conditions is approximately one-half a volt—causing a sufficient flow of current to bring about rapid deterioration. An instance of this kind came to the writer's attention where a large coated steel pipe passing through a cinder bed failed completely in a short time, the metal structure of the pipe becoming a mere honey-comb of rust. Self-corrosion is undoubtedly accelerated where anodic corrosion exists, galvanic action following as a secondary reaction. The primary action due to the stray currents produces iron oxide which is precipitated on the pipe exterior. This oxide acts just as a piece of coke in the case previously cited, bringing about a current flow due to the potential difference existing. The general effect of self-corrosion on iron pipes differs very little, if any, from the effects of corrosion by stray currents, the pipe being pitted and gradually eaten away, oxides form and behavior of these are the same. It is often very difficult to distinguish between the two actions. This has led to some disputes in an attempt to place the responsibility for electrolysis troubles, it being the practice in many cities to force the electric railways to pay for all the damage caused by electrolysis.

However, it should be stated that, in the case of cast iron at least, except where this is laid in excessively damp cinder beds or like materials, the local action is very seldom, if ever, sufficiently severe to cause the entire destruction of the pipe within the period of years usually ascribed to the life or usefulness of the ordinary pipe line. In other words, since practically all of the mains and distribution systems in the great majority of our cities consist of cast iron, there is not much trouble to be expected, except under unusual local conditions, from electrolysis other than that caused by stray currents that have leaked from electric railway systems. Owing to the present growth of the interurban lines, even many small towns and cities that have no street railway systems of their own, are no longer free of possible trouble from electrolysis. Hence this is a subject that demands attention from both towns and cities.

Mitigation of Electrolysis.

While it is not the writer's purpose, nor is it possible in the limited time and space assigned, to cover in detail the broad subject of electrolysis mitigation, this paper would be incomplete without a brief discussion of this and a mention in general of a few of the methods—good and bad—that have been tried to date. First of all, a more careful attention to proper bonding of rails would materially lessen the trouble by reducing in this way the leakage of current from the rails. Such a practice has been employed in European countries, particularly England and Germany. Many patented devices or so-called "mitigation systems" have been brought out and in some instances these have seemed to work out very satisfactorily. In other cases results have not been so good. Local conditions differ so widely that a system which might answer in one city would do very little good in another. The writer considers these systems still in the experimental stage. In this country many cities have attempted to lessen the evil by bonding at frequent intervals the pipe to the rails, employing some good conductor like copper wire in this operation. In most cases this method has been attended with only indifferent success and in the writer's opinion is more likely to prove a detriment than a help, because it is liable to increase rather than decrease the current leaving the pipe at points not in the neighborhood of the power house as the bonding would have a tendency to cause a larger current flow than would otherwise be the case.

From time to time in recent years a great many paints, dips, tar and fabric coatings and various so-called "insulating coverings" have been on the market and claims made of their worth, but so far, after extensive