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 tramways 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 tramway 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 experiments and practical tests, it is yet to be proven that paints, coverings, fabric and otherwise (except possibly asphaltum of one or two inches in thickness), are of much, if any, value. Tests made have only served to emphasize the fact that many of these coverings, such as pitch and burlap wrappings, increase rather than decrease the action of electrolysis.

Certain rather satisfactory results have been obtained by introducing insulating joints in pipe lines at proper intervals. Further developments along this line promise good results, provided experiments prove that the insulating joints can be inserted economically. Some cities have spent quite a little time and money in drainage experiments, their purpose, of course, being to remove as much as possible of the water from the soil and thus reduce the likelihood of electrolytic conduction. So far these experiments have not been productive of very good results, and the opinion seems to be growing that the cost is excessive in comparison with results obtained. To sum up, so far the only method yet developed of securing absolute immunity from electrolysis is to perfectly insulate the return circuit. Several cities, notably Havana (Cuba) and Cincinnati (Ohio), have accomplished this by providing an overhead return wire. Others have their return circuit through insulated underground conduits. At present a committee composed of leading men from engineering societies and kindred associations, organized into what is known as the "American Committee on Electrolysis," are giving the subject of electrolysis mitigation very close study, and it is to be hoped that their findings, when made public, will go far towards settling this rather distressing problem.

Conclusions

From the foregoing statements, and investigations made by the writer in the preparation of this paper, the following conclusions are drawn:—

1. The possibility of electrolysis trouble increases as electric tramways become more numerous and the loading becomes heavier.

2. Stray currents are the principal and most troublesome source of damage. This damage is confined entirely to points where currents leave pipes.

3. Anodic corrosion in underground pipe lines is directly traceable to currents that have leaked from imperfectly insulated return circuits of electric tramways.

4. The really serious damage to supply lines and distribution systems proper is confined in the main to the neighborhood of the power house, except under certain peculiar local conditions, such as unusually wet soil, cinder beds, etc.

5. Service pipes furnish the greater number of failures in a short period of time, and for this reason are generally regarded as the seat of probably 75 per cent. of the total trouble, lead, steel or wrought iron all being readily attacked.

6. The higher electrical resistivity of cast iron and the extra thickness of metal presented greatly reduces the possibility of ultimate destruction in this class of material as compared with ordinary steel or wrought-iron pipes.

7. Self-corrosion, except under extremely trying conditions, is seldom, if ever, sufficiently serious to cause complete failure of cast iron, though it might destroy iron of thinner structure.