Failures of Steel Pipe-lines.—A number of very costly failures, due to corrosion, are on record in regard to mild steel pipe-lines. The use of this material for water conduits was adopted some 25 years ago, and, so far as durability is concerned, may almost be said to be still in the experimental stage. But, apart from the probability of early deterioration, mild steel mains have many advantages from a structural engineering point of view, such as greatly reduced weight, as compared with cast iron, for a given carrying capacity, greater reliability under heavy pressures, and generally increased adaptability to meet the conditions of route of any particular pipe-line.

38-in. Main, Rochester, New York.—The steel pipe-line in connection with the Rochester water undertaking, New York, already referred to above, is 38-in. in diameter and 26 miles long, and, within 6 years of being brought into use in the year 1894, rust-hole leakage, due to external corrosion, took place.

Causes of Failure.—The cause of this failure was attributed to "electrolysis," and occurred in parts of the main laid in wet soils. Corrosion is found to be much retarded in dry, sandy or well-drained soils. Subsoil water in contact with steel in such cases is found to produce electromotive force from electro-chemical action, and the electrolytic damage is proportional to the time during which the current acts.

The three leading conditions which brought about serious corrosion in the Rochester main were: The wet soils through which the main was laid, ineffective protective coatings, and want of uniformity in the composition of the steel.

Even in the best and most uniform qualities of steel there exist contiguous areas of different electrical potential, and if the steel tubes lie in contact with an ionized solution, like soil water, corrosion will occur by electrolysis, as in this case.

Failure of 30-in. Main in Australia.—Another case of serious corrosion occurred during recent years in connection with a large and costly steel main 350 miles long by 30 in. diameter, in Australia—the corrosion being first observed about 3 years after completion. The official reports in such cases form an instructive study to those interested in such matters.

Relative Durability of Cast Iron, Wrought Iron, and Mild Steel.—The relative durability of cast iron, wrought iron, and mild steel is a matter of considerable commercial importance. In the case of cast iron, it would appear, in some instances, that no practical limit can be put upon this material when used under suitable conditions. The cast iron flanged pipes supplying water to the great fountains at Versailles were laid in 1685, or 229 years ago, and are stated to be still in use. Evidence is also available of cast iron bridges having been in use over a century and a quarter without visible deterioration from corrosion. Some wrought iron bridges are said to have shown over 60 years' service, but as regards mild steel bridges the life is usually much less, some such structures having become unsafe from corrosion after 25 years' use. In the author's experience, when mild steel bridges arrive at about this age, much annual attention is necessary to cope with deterioration due to corrosion.

Influence of Electrolytic Activity, Strain, etc.—In the decay of metals by corrosion, electrolytic activity is a much more serious factor than was formerly thought, and its action is of a subtle and elusive nature and difficult to stop. Many intricate complications arise, e.g., iron subjected to strain or uneven treatment, generally speaking, corrodes more rapidly than that treated uniformly. A difference of electrical potential exists between strained and unstrained pieces of similar metal, also between tempered and untempered portions. Galvanic activity can therefore be induced by immersing metals under these conditions in electrolytic solutions, and corrosion of the anodic metal results.

In some experiments strained portions of metal were found to be cathodic to the unstrained, and the latter specimen was therefore attacked the more vigorously.

No Rules Generally Applicable.—No general rules appear to be universally applicable, but the important point for engineers to bear in mind is that a difference of electrical potential does exist, and that strain of any kind will induce such change of potential, resulting, when immersed in an electrolytic solution, in corrosion due to galvanic activity. Beforehand, it is difficult to say whether the strained or the unstrained portion will act as the cathode, and so be preserved at the expense of the other, as the difference of potential is small and dependent on the actual local conditions of the case in point.

Differences of Potential.—Differences of potential between two metals placed in the same electrolyte under different conditions do not always remain constant. The potential difference may change in degree, and in some cases even the polarity may undergo reversal. The metal which is at the higher potential corrodes and constitutes the "anode," whilst the cathodic metal will remain unaffected.

Reversals of Polarity.—In cases where reversals of polarity occur, owing to the initial difference in potential being slight, both metals will corrode proportional to the time each has served as the anode.

Potential Difference.—Potential difference depends upon the chemical nature of the electrolyte, on its degree of concentration, temperature, rate of motion and other factors.

Means of Retarding Corrosion.—Corrosion due to galvanic activity can be retarded by securing greater uniformity of composition in the metal, a minimum of segregation as occurring in steel, uniformity of physical condition in the metal, and protection from moisture, which will act as an electrolyte.

Theories of Corrosion.—Although the foregoing observations on the corrosion of metals are intended to bear primarily upon the practical side of the question, a brief reference to the principal theories of corrosion which have been suggested to explain the cause of this great waste and decay which takes place may be of interest in the present connection.

Many theories have been proposed, but two only merit serious consideration, viz.: the acid and the electrolytic theories respectively.

Acid Theory.—According to the acid theory, oxygen, *pure* water and iron may remain in contact indefinitely without producing rust, the presence of a trace, at least, of some acid being essential to the oxidation of the metal. Carbonic acid, being naturally prevalent in air and water, is generally understood to be the primary cause of attack in ordinary cases of rusting.

Electrolytic Theory.—The electrolytic theory, on the contrary, depends upon the solubility of iron in pure water, and maintains that the presence of even traces of an acid is not necessary to its oxidation, but that water