Quantitative Evaluation of Corrosive Conditions

By W. F. Bonwitt[1] and I. Eisen

Synopsis

It was found possible to calibrate the effect of natural corrosion and of several artificial accelerated corrosion procedures on a metal by observation of the electrical resistance of a thin foil ribbon of the metal. With copper as the experimental sample, a linear relation was found between the duration of exposure to the corrosive procedure and the increase of resistance of the sample. This linear relation, which held true for natural corrosion and for all of the artificial procedures investigated, made it possible to develop a constant expressed as *percentage increase in resistance per unit time* for the effect of each corrosive procedure. From the data collected this *corrosive effect constant* was computed for each of the corrosive procedures investigated. The constant obtained for each process is significant, of course, only for the particular metal used for the foil. It is believed that further experiments will show whether this method can be applied to other metals and more complex conditions and to the quantitative evaluation of corrosive atmospheres present in various locations.

Various artificial procedures have been used in tests designed to simulate the effects of natural corrosion at an accelerated rate as a means for determining comparatively quickly the probable effects of natural corrosion on a sample under test. There is little basis, however, on which quantitative comparisons can be made between various artificial procedures and natural corrosive processes. The purpose of the work described was to investigate a sensitive means for making such comparisons. In this project the relative severity of a natural corrosive process and of three artificial procedures was determined. The rate of corrosion of metals has previously been measured by the increase of the electrical resistance of the metal. Burns and Campbell,[2] for instance, reported in 1929 on the use of this method for observing the corrosive deterioration of lead by acetic acid vapors. Snelling[3] used the resistance increase of a metallic layer to detect perforation of a paint coating covering the metal, and thus compared the relative qualities of protective coatings exposed to corrosive media. It was also found that a definite relationship seemed to exist between the resistance, diameter, and length of exposure of copper wires to atmospheric corrosion.[4]

However, the authors are not aware of any previous attempt to compare quantitatively the severity of various accelerated corrosion test procedures with each other, and with atmospheric corrosion. Rather, all previous work was concerned with a specific corrosive condition as it would affect a particular metallic sample. Since accelerated test methods are used more and more, a quantitative basis for comparison of different procedures seems essential.

The first step was to select a test sample of such a nature as to provide: (1) sensitivity to a wide range of degrees of corrosive effect, and (2) a significant, accurate, quantitative determination of corrosive effect as a change in a physical characteristic, after short increments of exposure time.

It was found practicable to measure corrosive effect in terms of increase of electrical resistance corresponding to reduction in cross-sectional area caused by corrosion of a corrosion-sensitive conductor. In order to provide maximum surface area with minimum cross-sectional area, the test sample selected was a metal foil ribbon. With such a sample, significant increases of resistance were obtained for small reductions in cross-section.

The corrosion-sensitive test sample used was a strip of copper foil 0.001 in. thick, 1 in. wide, and approximately 55 in. long. This copper foil ribbon was wound back and forth around two parallel rows of pyrex glass rods mounted on a Transite base. For measurement purposes, current was fed into the copper foil through two contacts, one mounted at each end of the Transite base which clamped around the ends of the foil. To prevent corrosion at the contacts, the clamps and the foil ends were solder coated. Potential terminals were provided by two wires soldered across the center of the outermost faces of each end of the foil and fixed to the Transite base.

Procedure

Five test samples as described were prepared. Before assembly each foil was cleaned with carbon tetrachloride. Following assembly the length of foil between measuring points and the area of untinned foil exposed to corrosion were determined. Several resistance measurements were taken over an extended period to establish the initial resistance of each sample.

A standard measuring current of 0.1 amp. was used giving a current density of 100 amp. per sq. in. for the initial cross-sectional area of 0.001 sq. in. This current density was sufficiently low so that the heating effect of the current could be neglected. Measurements of resistance were made at standard conditions with a Leeds & Northrup precision Kelvin bridge.

After stable values for the resistance of the foil strips had been obtained in repeated measurements, the foils were subjected to various corrosive procedures, as described below.

Foil No. 1 was exposed to open air conditions (industrial atmosphere) in New York City. Resistance of this foil was measured at one-week intervals.

Foil No. 2 was subjected to a 24-hr. cyclic accelerated corrosion procedure. Each cycle consisted of 7 hr. exposure, in a test chamber at room temperature, to the mist produced by atomizing a 10 per cent aqueous sodium chloride solution with filtered air, followed by heating in an air oven for 45 min. at 125 C., followed by slow cooling to room temperature in the oven for the remainder of the 24-hr. cycle. This foil was measured at five-cycle intervals.

Foil No. 3 was subjected to a different 24-hr. cyclic accelerated corrosion procedure. Each cycle consisted of 7 hr. exposure, in a test chamber at 38 C., to the spray and mist produced by atomizing a 20 per cent aqueous sodium chloride solution with preheated, saturated air, followed by heating in an air oven for 45 min. at 125 C., followed by slow cooling to room temperature in the oven for the remainder of the 24-hr. cycle. This foil was also measured at five-cycle intervals.

Foil No. 4 was kept in the laboratory at room conditions as a control and was measured at one-week intervals.

Foil No. 5 was exposed continuously

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[1] Burndy Engineering Co., Inc., New York, N. Y.

[2] R. M. Burns and W. W. Campbell, *Trans.* Am. Electrochemical Soc., Vol. 55, p. 271 (1929).

[3] U. S. Patent No. 1,811,765 (1931).

[4] C. Gladson, *Proceedings*, Physical Soc., Vol. 40, p. 207 (1927).