



Standard Test Method for Monitoring Atmospheric Corrosion Tests by Electrical Resistance Probes¹

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1. Scope

1.1 This test method provides a means for monitoring corrosivity of environmental tests that involve exposure to corrosive gases.

1.2 This test method uses a resistance monitor (RM) probe fabricated from a chosen metal conductor, with one conductor segment uncovered to permit exposure of the chosen metal conductor to the corrosive gas mixture and the second conductor segment covered to protect the metal conductor of this segment from direct attack by the corrosive gas mixture. The covered conductor segment provides a reference for evaluating changes in the uncovered segment. The ratio of the resistance of the exposed segment to that of the covered segment provides a measure of the amount of metal conductor that has reacted with the corrosive gas test environment to form poorly conducting corrosion product, thus providing a measure of test corrosivity.

1.3 Resistance monitoring is applicable to a broad range of test conditions by selection of the appropriate metal conductor and initial metal thickness.

1.4 This method is similar in intent to Test Methods B 808.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

B 808 Test Method for Monitoring of Atmospheric Corrosion Chambers by Quartz Crystal Microbalances²

B 810 Test Method for Calibration of Atmospheric Corrosion Test Chambers by Change in Mass of Copper Coupons²

B 827 Practice for Conducting Mixed Flowing Gas (MFG) Environmental Tests²

G 96 Guide for On-Line Monitoring of Corrosion in Plant Equipment (Electrical and Electrochemical Methods)³

3. Summary of Test Method

3.1 The corrosivity of an atmospheric corrosion test such as a mixed flowing gas (MFG) type test is measured by monitoring the loss in electrical conductivity of a metal element whose surface corrodes to form poorly conducting corrosion product. This corrosion product consumes metal from a conduction path causing an increase in electrical resistance. The resistance of the degraded conduction path is compared with a similar path whose surface is covered to prevent corrosion. This comparison resistance also provides a temperature correction reference. The ratio of the electrical resistance of the path exposed to the corrosive gases to that of the covered path is monitored during the test and compared to an expected ratio-versus-time curve to establish the relationship of the test corrosivity to expected test corrosivity. Alternatively, the ratio-versus-time curve for a given atmosphere can be compared with the behavior of other corrosive atmospheres to evaluate the relative corrosivity of the various atmospheres.

4. Significance and Use

4.1 Corrosivity monitoring of test environments provides a means to monitor an integrated value of test corrosivity which cannot be evaluated from test parameters themselves, such as temperature, humidity, and gas concentration. As such the monitor value can be used for specification purposes such as test validation. Electrical resistance monitoring of conductors exposed to corrosive media is a well-established practice.^{4,5,6,7}

4.2 The resistance method assumes uniform corrosion over the entire surface of the exposed metal conductor segment.

¹ This test method is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

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² *Annual Book of ASTM Standards*, Vol 03.04.

³ *Annual Book of ASTM Standards*, Vol 03.02.

⁴ ASTM G 96, Guide for On-Line Monitoring of Corrosion in Plant Equipment (Electrical and Electrochemical Methods).

Local corrosion such as pitting, crevice, or grain boundary corrosion may provide invalid estimates of test corrosivity. Marked changes in slope of the curve of electrical resistance ratio versus time may indicate undesired processes which can be due to deficiencies in the test atmosphere or in the monitor itself.

4.3 Because of limitations of the diffusion process within the corrosion product formed on the metal conductor segment of the RM probe when passivating corrosion films are formed, resistance monitoring may not be useful for test chamber monitoring purposes for very long test exposures. Chamber monitoring is dependent on detecting changes in the rate of corrosion of the RM as an indicator signal that specified gas concentrations must be reverified. However, low corrosion rates limit the absolute value of the rate of change of corrosion rate with change of test conditions; for parabolic film growth processes, the growth rate decreases with time limiting the sensitivity of the RM at extended test times.

4.4 Since corrosion rate can be a complex function of test parameters in MFG tests with any given metal primarily responsive to a subset of the gases in the MFG environment, more than one type metal resistance probe is required in order to assist in maintenance of relative gas concentrations. For such test specifications, values of resistance ratios must be referred to ratios obtained under known test conditions as supplied by the test specifier. Information relating to the sensitivity of various metals to various corrodants has been published.^{8,9}

4.5 RM probes can be useful from 1 % of thickness consumed upward to 50 % of thickness consumed by the corrosion film growth. Conductor thicknesses between 25 nm and 0.2 mm are commercially available.¹⁰

5. Interferences

5.1 Resistance monitor probes are generally constructed from thin film metal coatings on dielectric substrates in the form of a serpentine pattern or loop to provide a long conductor path so as to increase the ease of detection of a resistance change. With such configurations, formation of a corrosion product, which grows out from the edges of the conductor paths, can contact adjacent paths; when such contacting corrosion films are formed from conducting corrosion products such as some copper sulfides, abrupt changes in probe resistance can be observed due to shorting of the current path. Such

shorting of the current path can also occur if condensation occurs on the probe, especially in the presence of gases that dissolve in the condensed film to form an electrolyte. Such shorting behavior is seen as an anomalous resistance decrease and indicates that corrosion of the RM is not predictable from its electrical resistance.

5.2 Corrosive gas permeation through the protective covering of the reference conductor can lead to corrosion of the reference conductor, thus reducing the apparent resistance ratio between the exposed conductor and the reference conductor. Excess resistance change of the reference conductor above that expected for any observed temperature change of the RM is an indication of this possible interference. The RM should be examined after the test for discoloration of the reference conductor as a signal of possible corrosion of the reference conductor when such excess resistance change is observed. Presence of corrosion of the reference conductor invalidates the estimate of atmosphere corrosivity based on the observed resistance ratio-versus-time curve.

5.3 Thermal gradients across the RM probe as a result of the presence of local heat sources such as lamps or powered test devices can produce an anomalous resistance ratio change. Such effects can be verified by shutting off the local heat source and remeasuring the resistance ratio.

5.4 Scratches or other localized conductor thickness variations can produce anomalous resistance ratios after reduced corrosion exposures. This behavior can be detected by abrupt increases in apparent rate of corrosion which occur when the thinned region corrodes through to the dielectric substrate. Such abrupt changes indicate the end of useful data from the RM.

5.5 Contaminant films on the surface of the exposed conductor can inhibit corrosion or accelerate corrosion. Care must be taken to assure freedom from fingerprints, spittle, oil, or other surface contamination prior to installation in the test chamber. If a cleaning procedure is used, it should be appropriately evaluated and consistently applied to avoid differing initial conditions on the RM. The exposed metal conductor of the probe should be examined after the test exposure to ensure uniformity of corrosion film growth. Clumps of corrosion product indicate undesirable conditions and potential problems interpreting resistance changes.

5.6 Since in-situ electrical resistance measurements require electrical access to the probe being measured, defects in the electrical access system, for example, cables and sockets, can affect the resistance values being measured. Protection of the electrical access system from the deleterious effects of exposure to corrosive gases is required to ensure a reliable monitoring system.

5.7 Most interferences are detectable when multiple probes are used in a single test by comparison of one probe to another.

6. Apparatus

6.1 The apparatus consists of two elements, a probe that is responsive to the corrosive environment and a means to electrically measure the resistance of the probe.¹⁰

6.1.1 *Resistance Monitor (RM) Probe*, consists of two elements of identical material in thermal contact with each other. One element is capable of interaction with a corrosive

⁵ Allen, R. C. and Trzeciak, M. J., "Measuring Environmental Corrosivity," Institute of Electrical and Electronic Engineers, Components, Hybrids, and Manufacturing Technology Transaction, Vol CHMT-3, 1, March 1980, pp. 67-70.

⁶ Murcko, R., Corrosion-Indicating Device, IBM Technical Disclosure Bulletin, Vol 32, No.10A, March 1990, p. 25.

⁷ Sproles, E. S., "Electrical Resistance of Wires Used as a Corrosion Rate Monitor," *Corrosion of Electronic and Magnetic Materials, ASTM STP 1148*, P. J. Peterson, Ed., American Society for Testing and Materials, 1992, pp. 11-20.

⁸ Rice, D., et al., "Atmospheric Corrosion of Copper and Silver," *Journal of Electrochemical Society*, Vol 128, No. 2, February 1981, pp. 275-284.

⁹ Rice, D., et al., "Indoor Corrosion of Metals," *Journal of Electrochemical Society*, Vol 127, No. 4, April 1980, pp. 891-901.

¹⁰ Resistance monitor system manufactured by Rohrback Cosasco Systems, Inc., 11841 E. Smith Ave., Santa Fe Springs, CA 90670, United States, have been found to be satisfactory for corrosivity monitoring of airborne corrosion agents; see Model CK-3 Corrosometer.

gas environment and is the detector of test chamber corrosivity. The second element is protected from interaction with the corrosive gases from the chamber by means of an impervious overcoat such as epoxy or other polymer and serves as a reference. The electrical properties of the elements are chosen with regard to the expected amount of corrosion to be detected. Mildly corrosive environments would be monitored by means of thinner conductors than would be employed in strongly corrosive environments so as to be more sensitive to the decreased amount of corrosion expected.

6.1.2 Resistance monitor probes are measured with standard electrical resistance measurement equipment or with suitable commercial systems.¹⁰ A Kelvin bridge or a potentiometer shall be used when measuring resistance less than 10 Ω. A Wheatstone bridge may be used with resistances greater than 10 Ω. The resistance shall be measured with an accuracy of 0.1 %. The measuring current shall be so small that the resistance being measured changes by less than 0.1 % due to temperature rise.

6.2 It is highly desirable that a means for continuous monitoring of the probe be available so that a record is maintained during times when the test facility is unattended.

7. Calibration

7.1 Calibrate electrical resistance measuring apparatus in accordance with the manufacturer’s instructions once every six months or more frequently if drift indicates that the requirements of 0.1 % accuracy cannot be met with semiannual calibration.

8. Procedure

8.1 Store probes in a glass desiccator after fabrication, free from exposure to plastic materials that emit volatile plasticizers or other organic vapors. Handle and store commercial probes¹⁰ in accordance with the manufacturer’s instructions. Take care to ensure that the exposed metal conductor of the probe remains free of contaminants prior to use in the test chamber for corrosivity monitoring. Some commercial probes¹⁰ have been supplied with a removable protective film covering the conductor that is to be exposed to the corrosive gases. Users are cautioned that such film have been reported to leave a residue that affects the initial sensitivity to a corrosive environment. If such a film is present, remove this film just before installation of the RM probe in the gaseous corrosion test chamber or other location where corrosivity is to be monitored.

8.2 Install probes in the corrosive gas stream within the test chamber between 4 and 6 cm from the test samples being evaluated in the test chamber. The RM probes and the test samples shall all be in a single plane that is perpendicular to the gas flow direction. Probes shall not be behind any gas flow obstruction such as a test sample or test sample support rack, nor shall they obstruct the gas flow to any test sample. The plane of the metal conductor of the RM probe shall be parallel to the gas flow with the exposed metal conductor closest to the source of the gas flow and the protected reference metal conductor downstream from the exposed metal conductor. The

long axis of the probe shall be perpendicular to the gas flow direction. The RM probe may be mounted with the plane of the conductor vertical or horizontal for the case of horizontal gas flow; for vertical gas flow, the plane of the conductor shall be vertical. In some cases, it may be desired that the conductor be facing downward to avoid settling of particulate material on the face of the conductor. See Fig. 1.

8.3 Installation of the probes shall be consistent with installation of the test samples in accordance with Practice B 827. Alternatively, if it is desired to use resistance probes as a complement to weight gain for corrosion chamber calibration, probe placement shall be consistent with Test Method B 810.

NOTE 1—Probes can be used for only one test. It is optional to use more than one probe sequentially during a test to capture the most sensitive period when the corrosion film is thinnest before a thicker, more slowly responding, corrosion film has formed.

8.4 Check the probe and the internal calibration of the instrument for proper functioning, as recommended in the manufacturer’s instructions.

8.5 Connect the instrument to the probe, record the measured resistances of the probe elements, and check the element resistances against expected values. Alternatively, check commercial equipment that provides a scale reading of corrosivity instead of resistance values for expected behavior of the scale reading in accordance with the manufacturer’s instructions. In the event of discrepancies, check all parts of the apparatus and correct installation until desired values are obtained.

8.6 Proceed with test operation in accordance with Practice B 827 or in accordance with other specified test procedures, recording RM values as required by Practice B 827 or as specified by the test specifier or test requester.

8.7 Monitor RM probe electrical resistances for values within expected range. Calculate and record the ratio of the resistance of the exposed metal conductor to that of the covered metal conductor and compare with specified values of the ratio for the test time at which measurements were made. Take corrective action of adjusting test parameters when RM probe ratio values move outside expected range in order to bring RM probe ratio values within the required range, if corrosivity control by RM probe is required by the test specification.

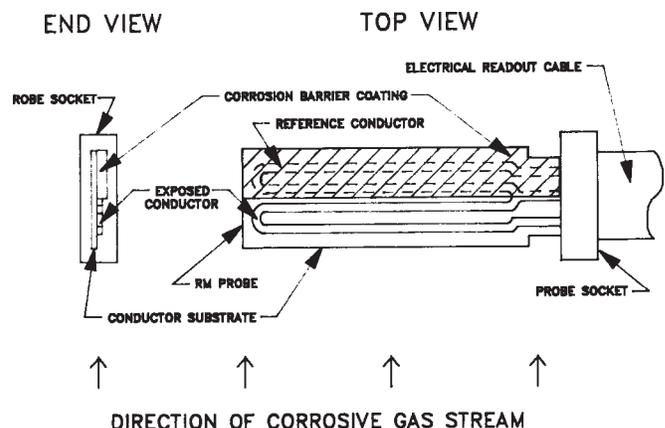


FIG. 1 Installation of RM Probe in Corrosive Gas Stream

9. Report

9.1 Prepare a test report including the following information:

- date test started;
- test operator;
- test conditions, that is, gas concentrations, temperature, humidity, air velocity, and so forth;
- location of RM(s) within chamber;
- specimen preparation procedure, including, if applicable, any cleaning procedure used;
- resistance ratio as a function of time; and
- nominal metal loss as a function of time.

10. Precision and Bias

10.1 The precision of this test method is a function of the construction of the probe used for resistance monitoring, including metal conductor thickness uniformity. Multiple evaluations of a given probe system are required to establish expected precision. Since the parameters of a given system are selected by the test operator or specified by the test requester, the required precision must be a part of the test specification. Precision of this test method will be measured with a single thickness of a selected metal in a specific corrosive gas atmosphere when Practice B 827 is available to define the corrosive gas test practice.

10.2 Since there is not accepted reference material for determining the bias for the procedure in Test Method B 826 for measuring the corrosivity of all corrosive gas atmospheres by electrical resistance probes, bias has not been determined. The bias of this test method arises from the selection of metal for the conductor that is to be corroded and from the selection of corrosive gases for the test exposure. Copper has been used extensively for corrosivity monitoring of selected corrosive atmospheres, but copper is not suitable for all atmospheres and sufficient data is not available to establish the bias of copper as a function of atmosphere. Sufficient data is also lacking to establish the bias of other metals with respect to copper for a given atmosphere. If required, the bias must be quantified prior to use of a given metal as a test specifier. Published literature provides some guidance as to metal selection for monitoring various atmospheres.^{8,9}

11. Keywords

11.1 atmospheric corrosion monitor; atmospheric corrosion testing; corrosivity monitor; electrical resistance probe; environmental test; mixed flowing gas test; resistance monitor probe

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