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Standard Guide for Mixed Flowing Gas (MFG) Tests for Electrical Contacts[1]

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~~ε1 NOTE—Footnote 3 was corrected editorially in October 2014.~~
~~ε2 NOTE—Document IEEE P1156.1 in Section 2 was corrected editorially in December 2017.~~

1. Scope

1.1 The techniques described in this guide pertain to mixed flowing gas (MFG) tests containing species that are applied to evaluate devices containing electrical contacts such as slip rings, separable connectors, electromechanical relays or switch contacts. These techniques may be relevant to other devices, but it is the responsibility of the user to determine suitability prior to testing.

1.2 The MFG tests described in this guide are designed to accelerate corrosive degradation processes. These accelerations are designed such that the degradation occurs in a much shorter time period than that expected for such processes in the intended application environment of the device being tested. Application environments can vary continuously from benign to aggressively corrosive. Connectors and contacts within closed electronic cabinets may be affected by an environment of different severity than the environment on the outside of such cabinets. In general, indoor environments are different than outdoor environments. The MFG tests described herein, being discrete embodiments of specific corrosive conditions, cannot be representative of all possible application environments. It is the responsibility of the test specifier to assure the pertinence of a given test condition to the specifier's application condition.

1.3 The MFG tests described herein are not designed to duplicate the actual intended application environment of the device under test. An extended bibliography that provides information which is useful to test specifiers to assist them in selecting appropriate test methods is included in this guide. The bibliography covers the scope from application condition characterization, single and multiple gas effects, and material and product effects to key application and test variables as well as discussions of atmospheric corrosion processes.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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 Safety Data Sheet (SDS) for this product/material as provided by the manufacturer, to establish appropriate safety, health, and environmental practices, and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B542 Terminology Relating to Electrical Contacts and Their Use
B808 Test Method for Monitoring of Atmospheric Corrosion Chambers by Quartz Crystal Microbalances
B810 Test Method for Calibration of Atmospheric Corrosion Test Chambers by Change in Mass of Copper Coupons
B825 Test Method for Coulometric Reduction of Surface Films on Metallic Test Samples (Withdrawn 2018)[3]
B826 Test Method for Monitoring Atmospheric Corrosion Tests by Electrical Resistance Probes
B827 Practice for Conducting Mixed Flowing Gas (MFG) Environmental Tests

[1] This guide 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

2.2 *Other Documents:*

EIA-364B-TP65 Mixed Industrial Gas Test Procedure[4]

IEC Standard 68-2–42 Basic Environmental Testing Procedures, Test K_c Sulphur Dioxide Test for Contacts and Connections[5]

IEC Standard 68-2–43 Basic Environmental Testing Procedures, Test K_d Hydrogen Sulfide Test for Contacts and Connections[5]

IEC Technical Trend Document 68-2–60 TTD Environmental Testing, Corrosion Tests in Artificial Atmosphere at Very Low Concentration of Polluting Gas(es)[5]

IEC 68-2–60 (second edition) Environmental Testing—Part 2: Tests—test Ke: Flowing mixed gas corrosion test, 1995

IEEE P1156.1 Environmental Specifications for Computer Modules (Draft 4 Approved June 17, 1993.)[6]

3. Terminology

3.1 Terms relevant to this guide are defined in Terminology B542 except as noted in the following section.

3.2 *Other term:*

3.2.1 *mixed flowing gas test, n*—a laboratory test conducted in air that flows through a test chamber in which the temperature, relative humidity, concentrations of gaseous pollutants, and other critical variables are carefully defined, monitored and controlled.

4. Significance and Use

4.1 Preservation of a conducting surface on electrical contact is vital to the continued functioning of such contacts. Contamination of the surface with insulating layers formed by corrosion processes is one potential hazard. Laboratory testing of contacts in MFG tests is used to assess the effectiveness of design features and materials.

4.2 MFG tests are used in development studies of processes and materials for contacts. For example, coupon specimens may be exposed to MFG tests to evaluate new contact materials, layers of new coating materials on a supporting substrate, reduced coating thicknesses, or protective surface treatments.

4.3 MFG tests are also employed to test the durability of a finished product with respect to atmospheric corrosion. For example, finished connectors may be exposed to a MFG test and their performances compared against each other or against a set of fixed requirements. Relays or switch contacts may be exposed in the operated and non-operated conditions to compare performance.

4.4 MFG tests are useful for determining the effectiveness of connector housings and shrouds as barriers to ingress of atmospheric corrodants to the contact surfaces. These tests can also be used to assess the screening of the metal-to-metal contact areas of mated connectors.

4.5 MFG tests are employed as qualification tests to determine connector failure rates in application environments for which correlation between test and application has previously been established.

4.6 This guide provides test conditions which are to be applied in conjunction with Practice B827 which defines the required test operation and certification procedures, tolerances, and reporting requirements. Where the test specifier requires certifications or tolerances different than those provided in Practice B827, the required certifications or tolerances shall be part of the test specification. Differences from the specifications in Practice B827 shall be reported in the test report provided by the test operator to the test specifier. Specification of one of the test conditions defined in this document in the form of a statement such as, "Parts shall be tested in accordance with ASTM B845 Method Z.", implicitly requires test condition, Z, applied according to Practice B827.

5. Procedure

5.1 Decide upon a test plan appropriate for the contacts being evaluated. Consider test parameters such as preconditioning, performance measurement and other evaluation techniques, and experimental controls.

5.2 Select a MFG test and exposure length appropriate for the parts being evaluated. Table 1 lists a number of such tests that have been documented in the technical literature. The next section provides brief discussions of the origins and intended purpose of each of the methods.

6. Abstracts of Methods

6.1 *Method A*—Method A was originally developed as a highly accelerated test to stress equipment that might be exposed to environments with high levels of air pollution from combustion of high sulfur coal (**1**).[7] The method is included in this list for completeness. It is generally not considered realistic for evaluation of electronic equipment for the vast majority of applications. Typical exposure time is 4, 10 or 21 days, depending upon the specification for the product under test.

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[4] Available from IHS, 15 Inverness Way East, Englewood, CO 80112, http://www.global.ihs.com.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, http://www.ieee.org.

[7] The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Test Conditions of Mixed Flowing Gas Tests

ASTM Method	H_2S ppb[A]	SO_2 ppb[A]	Cl_2 ppb[A]	NO_2 ppb	Temp. °C	RH %	Air Changes (# /h)	Air Velocity (m/h)	Duration (days)	Source	Ref.	Notes
~~ASTM Method~~	~~H_2S ppb[A]~~	~~SO_2 ppb[A]~~	~~Cl_2 ppb[A]~~	~~NO_2 ppb~~	~~Temp. °C~~	~~RH %~~	~~Air Changes (# /h)~~	~~Air Velocity (m/h)~~	~~Duration (days)~~	~~Source~~	~~Ref.~~	~~Notes~~
A		25,000 ±5000			25 ± 2[B]	75 ±5		20-60	4, 10, 21	K_c	(1)	C
B	12,500 ±2500				25 ± 2[B]	75 ±5	3-5	20-60	4, 10, 21	K_d	(2)	
C		500 ±100			25 ± 1[B]	75 ±3	3-5	60	4, 10, 21	K_e Method A	(3,4)	
D	100 ±20				25 ± 1[B]	75 ± 3	3-5	60	4, 10, 21	K_e Method B	(3,4)	
E	100 ±20	500 ±100			25 ± 1[B]	75 ±3	3-10	60	4, 10, 21	K_e IEC 68-2-60 Test Method 1	(3,4)	
G	10 +0/−4		10 +0/−2	200 ±25	30 ±2	70 ±2	3-8			Battelle Class II	(5,6,7) (8)	D
H	100 ±10		20 ±5	200 ±25	30 ±2	75 ±2	3-8			Battelle Class III	(5,6,7) (8)	E,F
K	200 ±10		50 ±5	200 ±25	50 ±2	75 ±2	3-8			Battelle Class IV	(5,8)	
L	40 ±5 %	350 ±5 %	3 ±15 %	610 ±5 %	30 ±0.5	70 ±2		1832		G1(T)	(9)	
M	10 ± 5	200 ± 20	10 ± 5	200 ± 20	25 ± 1[B]	75 ± 3	3-10		10, 21	K_e IEC 68-2-60	(3,4,10) (11)	
N	10 +0/−4	200 ± 25	10 + 0/−2	200 ± 25	30 ± 2	70 ± 2	per ASTM B827	per ASTM B827	5-30	Telecom central office	(12,13)	
O	10 ± 5	100 ± 20	10 ± 3	200 ± 50	30 ± 1	70 ± 2	per ASTM B827	per ASTM B827	10, 20	Telecom central office	(6,7)	
P	100 ± 20	200 ± 50	20 ± 5	200 ± 50	30 ± 1	70 ± 2	per ASTM B827	per ASTM B827	20	Telecom uncontrolled environment	(6,7)	

Notes:

[A] Gas concentrations in ppb refer to parts per billion (1 in 10^9) volume per volume (vol/vol) in air.

[B] The test temperature of 25°C may require refrigeration in order to assure compliance with specified temperature and humidity variation limits.

[C] Carbon dioxide, 4500 parts per million (vol/vol) maximum.

[D] References (6 and 7) show NO_2 level as 100 ppb and temperature as 25°C while reference (5) shows the values in the table above; difference in corrosion of copper is minor between the two sets of conditions per private communication dated April 26, 1991, W. H. Abbott to E. Sproles.

[E] Relative humidity of 75 % (as shown in References (6 and 7)) is the recommended test condition for Class III per private communication dated April 26, 1991, W. H. Abbott to E. Sproles.

[F] Test conditions are defined in purchase contract.

6.2 *Method B*—Method B was originally developed as a European standard, and has largely been replaced by methods with lower levels of sulfur bearing gases (**2**). The method is included in this list for completeness. It is generally not considered realistic for evaluation of electronic equipment for the vast majority of applications. Typical exposure time is 4, 10 or 21 days, depending upon the specification for the product under test.

6.3 *Method C*—Method C was developed in Europe as an alternative to Method A in response to requests for a less aggressive test that would simulate exposures in less aggressive environments (**3,4**). Method C may simulate the majority of usage environments better than Method A. Typical exposure time is 4, 10 or 21 days depending upon the specification for the product under test.

6.4 *Method D*—Method D was developed in Europe as an alternative to Method B for the same reasons cited in the above discussion of Method C (**3,4**). Typical exposure time is 4, 10 or 21 days, depending upon the specification for the product under test.

6.5 *Method E*—Method E was developed in Europe as a first step toward a test containing more than one pollutant gas (**3,4**). Typical exposure time is 4, 10 or 21 days depending upon the specification for the product under test.

6.6 *Method G, H, and K—General Information*—These methods are often called the Battelle Class II, III, and IV Tests[8] respectively, since they were developed by the Battelle Columbus Laboratories after an extensive study of electronic equipment operating conditions (**5**). The test conditions were the result of correlation studies between corrosion products and mechanisms, and test and application conditions, in order to obtain a valid estimate of the corrosion response in the expected electronic service

[8] It was found that the lack of electrical corrosion failure mechanisms in Class I environments made it unnecessary to develop a Class 1 MFG Test.

environments. From this study, it was concluded that most operating or application environments for electrical connectors and electronic components can be categorized by a limited number of Severity Classes, which can be simulated, and their effects accelerated, by adjusting the critical parameters of the MFG test.

6.6.1 The descriptions in reference (**5**) of operating environment Classes I through IV are as follows: Class I is characterized by formation of oxides on copper coupons and no visible attack on porous gold plated, nickel underplated, copper coupons (Au/Ni/Cu) Class II is characterized by pore corrosion of Au/Ni/Cu coupons and formation of oxides and complex copper hydroxy chlorides on copper coupons. Class III is characterized by pore and tarnish creepage corrosion of Au/Ni/Cu coupons and the formation of oxides, sulfides and other unknown corrosion products on copper coupons. Class IV is characterized by tarnish creepage on Au/Ni/Cu coupons and copper coupon corrosion products similar to Class III except that sulfide presence greatly exceeds oxide presence whereas for Class III, the oxide presence is equivalent to the sulfide presence (**5**).

6.6.1.1 *Method G*—Method G accelerates the effects of Battelle Class II environments. These correspond to conditions that are often found in business offices or control rooms that are associated with light industrial areas or where environmental controls are not operating effectively and continuously (**5,14**). Light tarnish creepage corrosion has been reported to be found in Class II gas tests. Typical industry practice has been to expose test hardware (such as connectors) to this test for 1 to 3 weeks.[9]

6.6.1.2 *Method H*—Method H accelerates the effects of Battelle Class III environments. These correspond to many industrial and related locations (including many storage areas) where moderate amounts of pollutants are present in poorly controlled environments. These might be found nearer to primary sources of atmospheric pollutant gases or in industrial environments where there are a multiplicity of sources for pollutant gases within a region such that all businesses in such regions are susceptible. Potential failure mechanisms in this test include severe pore corrosion and corrosion product migration from the pores or from the base-metal edges adjoining the gold finish. Heavy film growth on base metals and accelerated attack on other susceptible materials are also possible (**5**). Typical industry practice has been to expose test hardware (such as connectors) to this test for 10 or 20 days.[10]

6.6.1.3 *Method K*—Method K accelerates the effects of Battelle Class IV environments. These represent the most severe electronic equipment operating environments, such as might be found at or adjacent to primary sources of atmospheric pollutant gases or where the combined effects of multiple pollutant gases and high humidity combine to rapidly destroy the integrity of precious metal finishes and produce thick corrosion films on some base metal surfaces (**4**). Testing to Class IV environments is not generally recommended because material selection alone is seldom sufficient to protect the reliability of electrical contact surfaces. See Section 4 for information on attenuation of pollutant effects. Exposure time in this test is best determined by study of the specific application environment.[11]

6.7 *Method L*—Method L refers to the GIT test conditions which have been used by IBM to qualify connectors and electrical components for operation in the IBM business office applications environment as part of a comprehensive corrosion evaluation strategy (**9**).[12] The GIT test conditions were selected to provide correlation of both corrosion product and mechanism between test and application conditions to obtain a valid estimate of the corrosion response in the expected environment. The selection of test conditions was based on X-ray diffraction studies of copper coupons exposed to both application (field) sites and test conditions.

6.8 *Method M*—Method M has been developed by the International Electrotechnical Commission (IEC) SC 50B and consists of the Method G (Battelle Class II) three gas mixture plus sulfur dioxide. It is based upon investigations conducted, over several years, by the Siemens Corporation of Munich, Germany, in public buildings belonging to the German Federal Railways and Post Office Department (**10,11**). Tolerances on gas composition have been added since the draft versions of the IEC document were published. Verification of test performance using mass gain of copper coupons is recommended because allowed tolerances on chlorine and hydrogen sulfide content of the test atmosphere permit a large range in relative gas composition. The IEC standard recommends a mass gain on copper of 1.2 to 2.4 mg/dm^2 ~~day.~~ · day.

6.9 *Method N*—The values for pollutant gases are identical to the IEC standard in Method M above with the provision for testing at 30°C rather than at 25°C as in the proposed IEC standard (**12**). These test conditions have been used in some qualification testing of connectors for telecommunications products and included in an industry round robin. Present industry practice is use of Methods O and P in place of Method N.

6.10 *Method O*—This method is used to evaluate connectors for use in telephone central offices and similar environments (**12**). Typical practice is exposure 10 days in the unconnected state, followed by 10 days in the connected state. Users normally place requirements for verification of test severity based on mass gain of copper coupons in accordance with Test Method B810. One widely used recommendation for mass gain is 15 ± 3 µg/cm^2 · day.

6.11 *Method P*—This method is used to evaluate connectors for use in telephone equipment exposed to uncontrolled environments such as outdoor sheltered, semi-sealed enclosure (**12**). Typical practice is exposure 10 days in the unconnected state,

[9] EIA 364 TP-65 designates these test conditions as 'Environmental Class II' (**8**).

[10] EIA 364 TP-65 designates these test conditions as 'Environmental Class III' (**8**).

[11] EIA 364 TP-65 designates these test conditions as 'Environmental Class IV' (**8**).

[12] Current IBM test conditions may differ from Method L and may be obtained by consulting the IBM Corporation Standards Project Authority for Environmental Gaseous Corrosion Testing (SPA 129.20) (**15**).

followed by 10 days in the connected state. Users normally place requirements on test severity based on mass gain of copper coupons in accordance with Test Method B810. One widely used recommendation for mass gain is 45 ± 9 $\mu g/cm^2$ · day.

6.12 *Method X*—The interested parties, for example, purchaser and supplier, may require a test different than any already defined. In such cases, the parties must agree upon values for all relevant parameters including those listed in Table 1.

7. Report

7.1 Reporting requirements are as per Practice B827 unless otherwise stated by agreement between test specifier and test vendor or operator.

8. Keywords

8.1 accelerated test; air velocity; atmospheric corrosion; chlorine; connector; corrosion; corrosive gas testing; electrical contacts; environmental; humidity; hydrogen sulfide; mixed flowing gas; nitrogen dioxide; pollutant; reliability; sulfur; sulfur dioxide; tarnish; temperature; testing

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