Mixed Flowing Gas Testing Introduction and CALCE MFG Capability

Mixed Flowing Gas (MFG) test is a laboratory test in which the temperature (ºC), relative humidity (%RH), concentration of gaseous pollutants (ppb level), and other critical variables (such as volume exchange rate and airflow rate) are carefully defined, monitored and controlled. The purpose of this test is to simulate corrosion phenomenon due to atmospheric exposure [1].

Test samples that have been exposed to MFG testing have ranged from bare metal surfaces, to electrical connectors, and to complete assemblies. In regards to noble metal plated connector applications, MFG testing has been widely accepted as a qualification test method to evaluate the performance of these connectors.

In the 1980's, researchers at Battelle Labs (Columbus, OH), Telcordia (previously Bellcore), and IBM, carried out tests on the use of MFG to accelerate atmospheric corrosion and its effect on electronic applications. In early 1990's, professional organizations, including American Society for Testing and Material (ASTM), Electronic Industries Association (EIA), International Electrotechnical Commission (IEC), and Telcordia, began to standardize these test methods and published corresponding documents as guidelines. Among them, ASTM provided the most comprehensive list of documents, covering almost every aspect to perform a well-controlled MFG testing. These documents included:

ASTM B827-97—Standard Practice for Conducting Mixed Flowing Gas Environmental Tests
ASTM B845-97—Standard Guide for Mixed Flowing Gas Tests for Electrical Contacts
ASTM B810-01a—Standard Method for Calibration of Atmospheric Corrosion Test Chambers by Change in Mass of Copper Coupons
ASTM B825-97—Standard Test Method for Coulometric Reduction of Surface Films on Metallic Test Samples
ASTM B826-97—Standard Test Method for Monitoring Corrosion Tests by Electrical Resistance Probes
ASTM B808-97—Standard Test Method for Monitoring of Atmospheric Corrosion Chambers by Quartz Crystal Microbalances

The nature of ASTM is to publish voluntary consensus standards for materials, products, systems, and services. Therefore, ASTM standards are more likely a review of existing

MFG practices, rather than a mandatory procedure for individual situations. For industrial applications, Battelle Labs MFG Test Methods [2], EIA-364-TP65A [3], IEC 68-2-60 Part 2 [4], and Telcordia GR-63-CORE section 5.5 Indoor/Outdoor MFG Test Methods [5], are more specific and application-oriented. Each MFG test method is reviewed below.

To make things clear, it is necessary to understand the background or the industrial coverage of the above-mentioned organization. ASTM International, which grows from US industry, is a non-profit organization that provides a global forum for the development and publication of voluntary consensus standards for materials, products, systems, and services [6]. The Electronic Industries Alliance (EIA) is a US national trade organization that includes the full spectrum of U.S. electronic products manufacturers [7]. The International Electrotechnical Commission (IEC), primarily based on European electronic industry, is the international standards and conformity assessment body for all electrical, electronic and related technologies [8].

Battelle Labs MFG Test Methods

The classification and parameters for the Battelle Labs MFG Test Methods are listed in Table 1. The operational environments for electronic equipments in atmosphere are divided into four classes, from least corrosive (Class I) to most corrosive (Class IV). Class I means well-controlled office environment with continuous adjustment. Class II means light industrial environment, such as business offices without effective or continuous environment control. Class III means moderate industrial environment, such as storage areas with poor environment control. Class IV means heavy industrial environment, such as locations adjacent to primary sources of atmospheric pollutant gases.

Since available data for Class I indicate no precedent for environmental effects on reliability, there is no accelerated testing for Class I. The other three classes use a combination of three corrosive gases, NO_2, HS_2, Cl_2, to accelerate corrosion. Most other standards also use a fourth gas SO_2. The reason is that some researchers believe that H_2S

and SO_2 have the synergistic effects on metal corrosion and SO_2 is necessary to stress nickel in corrosive environments [9].

Table 1: MFG Test Methods Developed by Battelle Labs

Class	Temp (ºC)	RH (%)	H_2S (ppb)	Cl_2 (ppb)	NO_2 (ppb)
I	----	----	----	----	----
II	30±2	70±2	10+0/-4	10+0/-2	200±25
III	30±2	75±2	100±10	20±5	200±25
IV	50±2	75±2	200±10	50±5	200±25

Since mixed flowing gas environment is an accelerated testing method, the determination of acceleration factor would be helpful to understand the durability or reliability of "device-under-test". In another words, if samples can survive certain days in the testing chamber, it will be great to approximately estimate how many years it can last without corrosion problem in the field. Until now, there is no consensus over this factor in a typical mixed flowing gas testing process. However, particular to Battelle classified environment, an acceleration factor of 2 days in the chamber for 1 year in the field was mentioned [10].

EIA MFG Test Methods: EIA-364-TP65A

EIA published its own specifications for MFG testing as seen in Table 2. The latest version was approved on Nov 6, 1997. Class II, III and IV parameters come directly from Battelle research. Class IIA and IIIA are adaptation to Class II and III by adding SO_2 along with the other three corrosive gases.

Table 2: MFG Test Methods Developed by EIA

Class	Temp (ºC)	RH (%)	H_2S (ppb)	Cl_2 (ppb)	NO_2 (ppb)	SO_2 (ppb)
I	----	----	----	----	----	----
II	30±2	70±2	10±5	10±3	200±50	----
IIA	30±1	70±2	10±5	10±3	200±50	100±20
III	30±2	75±2	100±20	20±5	200±50	----
IIIA	30±1	70±2	100±20	20±5	200±50	200±50
IV	40±2	75±2	200±20	30±5	200±50	----

IEC MFG Test Methods: IEC 68-2-60 Part 2

The latest version of IEC 68-2-60 Part 2 about MFG testing was published in Dec 1995. Table 3 shows the parameters for MFG testing by IEC 68-2-60. Test method 1 can be used as a pore corrosion test on gold coatings. Test method 1 is for testing of contacts with gold-plated surfaces to be used in mild environments. Methods 2 and 4 are appropriate for electronic products to be used in moderate corrosive environments. Such environments may be found in telecommunication centers, most office environments and some industrial instrument rooms. Test method 3 is appropriate for more corrosive environments. Such environments may be found in some industrial locations.

Table 3: MFG Test Methods Developed by IEC

Method	Temp (ºC)	RH (%)	H_2S (ppb)	Cl_2 (ppb)	NO_2 (ppb)	SO_2 (ppb)
1	25±1	75±3	100±20	----	----	500±100
2	30±1	70±3	10±5	10±5	200±50	----
3	30±1	75±3	100±20	20±5	200±50	----
4	25±1	75±3	10±5	10±5	200±20	200±20

Telcordia MFG Test Methods: Telcordia GR-63-CORE Section 5.5

Telcordia, previously known as Bellcore, is a center for technological expertise and innovation that provides the driving force for standardization within the tele-communication industry. Based on this nature, the MFG test methods developed by Telcordia focus on electronic equipment in Telecommunication applications. Since these kinds of equipments may operate inside or outside the room, two MFG test methods are available from Telcordia, which are known as indoor and outdoor. The parameters for these two methods are listed in Table 4.

Table 4: MFG Test Methods Developed by Telcordia

Method	Temp (ºC)	RH (%)	H_2S (ppb)	Cl_2 (ppb)	NO_2 (ppb)	SO_2 (ppb)
Indoor	30±1	70±2	10±1.5	10±1.5	200±30	100±15
Outdoor	30±1	70±2	100±15	20±3	200±30	200±30

IBM MFG Test Methods: G1(T)

IBM has worked on accelerated corrosive gas testing extensively since the late 1960's. They divided the working conditions for electrical equipments into three classes, which are G1 (business office), G2 (industrial) and G3 (harsh industrial). In order to simulate the accelerated corrosive effect of equipment in G1 environment, IBM designed and verified the G1 (T) MFG test environment, where they used four corrosive gases. Unlike other test methods, IBM's recommended gas concentrations are very different from that of Battelle (see Table 5) [11]. As far as we know, the IBM MFG test method does not gain much popularity in the industry. In the last 10 years, almost no paper is available concerning or citing the application of IBM G1(T) method.

Table 5 G1(T) MFG Test Method Developed by IBM

Temp (ºC)	RH (%)	H_2S (ppb)	Cl_2 (ppb)	NO_2 (ppb)	SO_2 (ppb)
30±0.5	70±2	40±5%	3±15%	610±5%	350±5%

CALCE MFG Chamber Capability

Table 6 lists the capability of the MFG chamber located in CALCE research center at the University of Maryland. It is capable of 3 or 4 corrosive-gas-testing. The CALCE center provides quality services to electronic applications that require qualification test by MFG chamber. Figure 1 shows the photo of this Mixed Flowing Gas testing system.

Figure 1: MFG Chamber Located in CALCE Center at the University of Maryland

Table 6: CALCE MFG Chamber Capability

Temp. Range (ºC)	RH (%)	Corrosive Gas Concentrations (ppb)				Interior Dimensions (inches)
		NO_x	SO_2	H_2S	Cl_2	
25~50	20~95	10~1000	10~1000	10~1000	10~1000	29X30X38

References:

[1] American Society for Testing and Material, ASTM Designation B845-97: Standard Guide for Mixed Flowing Gas (MFG) Tests for Electrical Contacts, 1997.

[2] Abbott, W.H., "The development and performance characteristics of flowing mixed gas test environments," IEEE Transactions on Components, Hybrids, and Manufacturing Technology, vol.1l, no.1, pp.22-35, Mar 1988.

[3] International Electro-technical Commission, IEC Standard 68-2-60 (second edition) Environmental Testing-Part 2: Tests-Flowing mixed gas corrosion test, 1995.

[4] Electronic Industries Association, EIA Standard TP-65A: Mixed Flowing Gas, Jan. 1998.

[5] Telcordia GR-63-CORE Issue 2, Section 5.5, "Airborne Contaminants Test Methods", Nov. 2000.

[6] www.astm.org

[7] www.eia.org

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[9] Gore, R.R., Witska, R., Kirby, J.R., and Chao, J.L., "Corrosive Gas Environmental Testing for Electrical Contacts", IEEE Transactions on Components, Packaging, and Manufacturing Technology, vol.13, Issue 1, pp.27-32, March 1990.

[10] Williams, D.W.; "The Effect of Test Environment on the Creep of Base Metal Surface Films over Precious Metal Inlays"; IEEE Transactions on Components, Hybrids and Manufacturing Technology; vol.11, no.1, pp.36-42, Mar. 1988.

[11] Chao, J.G., Gore, R.R., "Evaluation of a mixed flowing gas test," 1991 Proceedings of the Thirty Seventh IEEE Holm Conference on Electrical Contacts, pp.216-228, Piscataway, NJ: IEEE, 1991.