International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:7, No:12, 2013

A Study of Environmental Test Sequences for Electrical Units

Jung Ho Yang, Yong Soo Kim

Abstract**—**Electrical units are operated by electrical and electronic components. An environmental test sequence is useful for testing electrical units to reduce reliability issues. This study introduces test sequence guidelines based on relevant principles and considerations for electronic testing according to International Standard IEC-60068-1 and the United States Military Standard MIL-STD-810G. Test sequences were then proposed based on the descriptions for each test. Finally, General Motors (GM) specification GMW3172 was interpreted and compared to IEC-60068-1 and MIL-STD-810G.

Keywords**—**Reliability, Environmental test sequence, Electrical units, IEC 60068-1, MIL-STD-810G.

I. Introduction

ELECTRICAL units are operated by electrical and electronic components on battery power. They include components containing small printed circuit boards (PCBs) comprising various devices, such as resistors and capacitors. Electrical units may also be components in combination with mechanical parts and single- or double-sided PCBs, such as those found in microcomputers. Electrical units found in automobiles and railway vehicles require a very high level of safety and reliability, yet reliability issues leading to recall are common.

Test sequences are applied to electrical units to reduce reliability issues, particularly tests related to environmental conditions. A test sequence can reproduce various failure modes, and combination testing can be used to determine the proper order for individual environmental tests.

In this study, test sequence guidelines based on International Standard IEC-60068-1 and the United States Military Standard MIL-STD-810G were developed. In addition, the General Motors (GM) specification GMW3172 was interpreted, and a test sequence was proposed.

II. Related Studies

Most studies of environmental tests are performed in single or dual environment [1]-[3]. That is, test sequences are not considered except for fields of r automotive electrical units. However, [4] describes guidelines for developing an environmental test sequence. Reference [5] describes each test and provides several example test sequences for different situations. Reference [6] describes test sequences for GM electrical units.

III. Environmental Testing Using Standards

A. IEC 60068-1

A test sequence based on the environmental testing guidelines described in International Standard IEC-60068-1 was developed. The proposed test sequence incorporates the various principles and considerations of IED-60068-1.

The following four principles were applied to the developed test sequence [4]:

1. Information about failure tendencies should be obtained in the early part of the test sequence; i.e., the test sequence should begin with the most severe tests. However, destructive tests that result in the specimen being unsuitable for further testing should be placed at the end of the sequence. This principle is used generally for testing or investigating prototype capabilities.
2. As much information as possible should be obtained prior to specimen damage; i.e., the least severe tests, such as non-destructive tests, should be placed early in the test sequence. This principle is used for testing or investigating prototype capabilities when a limited number of specimens is available.
3. The sequence of tests that provides the most significant information about damage caused by previous tests should be used. This principle is typically used for standardized approval testing of components and equipment.
4. A sequence of tests that simulates the sequence of environmental parameters most likely to occur in practice should be used. This principle is used typically for approval testing of components and equipment and for complete systems when the conditions of use are known.

According to the above principles, the most severe and least severe tests should be carried out during development testing. The tests that provide the most significant information and the tests most likely to occur in practice should be applied during approval testing.

Key test sequence considerations are as follows [4]. A test that includes a rapid change in temperature should come at the start of the sequence, and tests for the robustness of terminations and soldering should be placed early in the sequence of tests. Next, all or a portion of the mechanical tests should be performed to accentuate faults likely to have been caused by

Jung Ho Yang is with the Department of Industrial and Management Engineering, Kyonggi University Graduate School, 154-42, Gwanggyosan-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, South Korea (e-mail: korasjh@kgu.ac.kr).

Yong Soo Kim is an Assistant Professor of the Department of Industrial and Management Engineering, Kyonggi University, 154-42, Gwanggyosan-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, South Korea, (Corresponding author: to provide phone: +82 31-249-9771; fax: +82 31-244-3534; e-mail: kimys@kgu.ac.kr).

rapid temperature changes and to provoke new faults, such as cracks or leaks. Cold and dry-heat phases should be applied early in the climatic test sequence so that the short-term effects of temperature can be revealed. A damp heat cycle phase will introduce moisture into any cracks, the influence of which will be accentuated by the cold phase and, potentially, by a low air pressure phase. In some cases, sealing tests may be used for the rapid detection of cracks or leaks. A damp heat, steady-state test is often applied at the end of the entire sequence of tests, or, when not included in the sequence, on separate specimens to determine the long-term behavior of the component in a humid atmosphere. Tests such as corrosion, drop and topple, and solar radiation are not normally included in the test sequence and should, if they are required, be made on separate samples.

In this study, a test sequence based on the third and fourth principles and the various considerations noted above is proposed as follows: cold, dry heat, rapid change of temperature, impact and vibration, air pressure, damp heat cycle, steady-state, corrosion, and dust and sand tests (see Fig. 1). Rapid change of temperature, impact, and vibration tests may cause mechanical stress, which may make the specimen more sensitive to subsequent tests. Application of the air pressure and damp heat cycle tests will reveal the influence of the preceding thermal and mechanical stress tests. Application of the dust and sand test may aggravate the effects of the preceding thermal and mechanical stress tests.

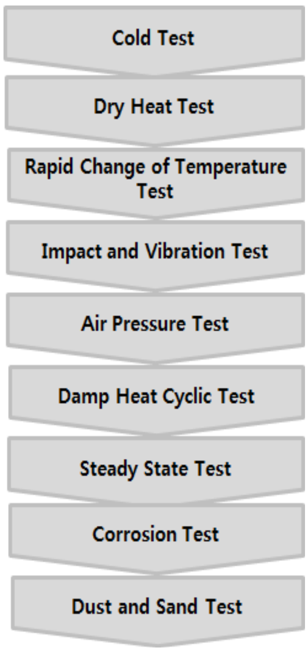

Fig. 1 Test sequence guide line [4]

B. MIL-STD-810G

A description of each test [5] and a test sequence based on MIL-STD-810G is also proposed. Tests associated with environmental testing of electrical units include low pressure (altitude), high temperature, low temperature, temperature shock, solar radiation (sunshine), rain, humidity, fungus, salt fog, sand and dust, and immersion.

The low-pressure (altitude) test is performed early in the test sequence because of both its limited damage potential and its generally early occurrence in the life cycle. However, other tests, such as the high- and low-temperature test, dynamic test, and non-metallic parts test, may contribute significantly to the effects of low pressure on the test item, and thus may need to be conducted prior to the low-pressure test. These tests provide information on failure mechanisms that can occur naturally during transport.

One testing approach to conserve the test item life is to apply those tests that are perceived to be the least damaging, such as the high- and low-temperature test, early in the test sequence. Another approach is to apply tests that maximize the likelihood of disclosing synergetic effects. In this cased, high- and low-temperature testing follows dynamic tests, such as vibration and shock testing.

The temperature shock test employs the test item response characteristics and performance information obtained from the high- and low-temperature tests to better define the test conditions to be used for this procedure.

The solar radiation (sunshine) test applies to all stages. However, high temperatures or actinic effects could affect material strength or dimensions and could thus influence the results of subsequent tests, such as vibration testing.

The effectiveness of determining the integrity of an enclosure is maximized if the rain test is performed after the dynamic tests.

Humidity testing may produce irreversible effects. Therefore, if humidity effects could influence the results of subsequent tests on the same item(s), humidity testing should be performed following those tests. For example, dynamic environments (vibration and shock) may be influenced by the results of humidity testing. Thus, one should consider performing dynamic tests prior to humidity tests. In addition, because of the potentially unrepresentative combination of environmental effects, it is generally inappropriate to conduct humidity testing on test samples that were previously subjected to salt fog, sand and dust, or fungus tests. If necessary, a fungus test should be performed before salt fog, sand and dust, or humidity tests, because a heavy concentration of salt and moisture may influence the germinating fungus growth, and sand and dust can provide nutrients, thus leading to a false indication of the bio-susceptibility of the test item.

If using the same test item sample for more than one climatic test, it is usually recommend that the salt fog test be conducted after the other climatic tests, because salt deposits can influence the results of other tests. As noted above, it is generally inappropriate to conduct salt fog, fungus, and humidity tests on the same test samples, because the accumulation of effects from the three environments may be unrealistic. However, if it is necessary to do so, perform the salt fog test after the fungus and humidity tests.

Sand and dust testing can severely abrade and/or leave a dust coating on the test specimens, which could influence the results of other MIL-STD-810 tests, including humidity, fungus, and salt fog. Therefore, judgment should be used in determining where in the sequence of tests to apply the sand and dust testing. The presence of dust in combination with other environmental parameters can induce corrosion or mold growth, and a warm humid environment can cause corrosion in the presence of chemically aggressive dust.

Two or more approaches can be used for immersion testing. One approach conserves the test item life by first applying the least damaging environments. In this approach, the immersion test is generally carried out prior to most other climatic tests. Another approach is to apply different environmental tests in a sequence that maximizes the likelihood of revealing sequential problems. In this approach, immersion testing should be considered both before and after the structural tests, such as shock and vibration, to aid in determining the test item's resistance to dynamic tests.

When evaluating the cumulative effects of vibration and other environments, a single test item should be exposed to all environmental conditions. Vibration testing generally should generally be performed first. If another environment, such as temperature cycling, is expected to produce damage that would make the item more susceptible to vibration, then tests for that environment should be performed prior to the vibration tests.

Similarly, acoustic noise may induce stresses that influence material performance under other environmental conditions, such as temperature, humidity, pressure, electromagnetic fields, etc., and should thus be performed in the early stages of the test sequence.

The placement of the shock test in the sequence will depend upon the general availability of test specimens and on the type of testing, i.e., on whether the goal of the testing is developmental, qualification, endurance, etc. Normally, shock tests should be scheduled early in the test sequence, but after any vibration tests. Shock usually occurs after vibration in practice, and shock testing without vibration is not meaningful.

Two approaches are used for acidic atmosphere testing. One approach conserves the test item life by first applying the least damaging environments. In this approach, the acidic atmosphere test is generally carried out late in the test sequence. Another approach is to apply different environmental tests in a sequence that maximizes the likelihood of revealing synergetic effects. In this approach, acidic atmosphere testing should be carried out after dynamic tests, such as vibration and shock tests. In addition, acidic atmosphere testing should be performed after any humidity or fungus testing, and before any sand and dust testing or other tests that may damage protective coatings.

To conserve the item test life, the icing/freezing rain test should be carried out following rain tests, but prior to salt fog tests, because residual salts may impair ice formation. Icing/freezing rain tests should also be carried out prior to dynamic tests that may loosen components. On the other hand, to maximize the likelihood of revealing synergistic effects, icing/freezing rain tests should be performed after dynamic testing.

Table I summarizes the descriptions of each test and the test sequence. Fig. 2 illustrates several proposed test sequences based on the above suggestions.

TABLE I
DESCRIPTION OF THE TESTS AND TEST SEQUENCE

Before the test	Test	After the test
low and high temperature test, dynamic test, non-metallic parts test	Low Pressure (Altitude)	-
dynamic tests, such as vibration and shock	High Temperature	-
dynamic tests, such as vibration and shock	Low Temperature	-
-	Temperature Shock	-
-	Solar Radiation (Sunshine)	-
-	Rain	-
dynamic tests	Humidity	-
-	Fungus	-
climatic test, fungus and humidity test	Salt Fog	sand and dust testing
-	Sand and Dust	-
structural tests such as shock and vibration	Immersion	climatic test, structural tests such as shock and vibration
-	Vibration	-
-	Acoustic Noise	-
vibration test	Shock	-
dynamic tests, such as vibration and shock, humidity or fungus test	Acidic Atmosphere	sand and dust test or other tests that damage protective coatings
dynamic tests	Icing/Freezing Rain	salt fog test, dynamic tests

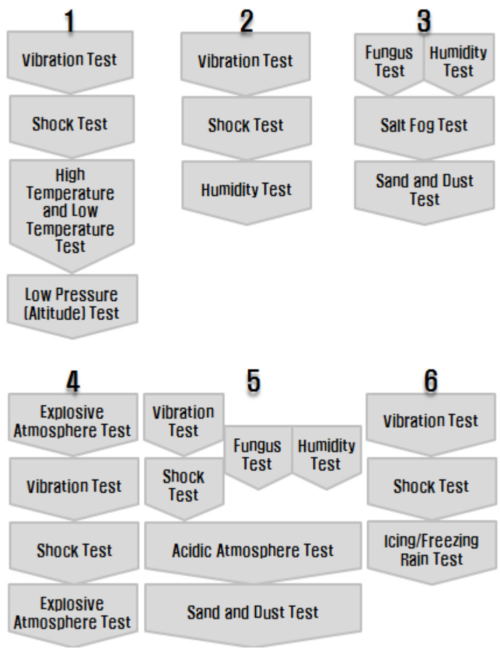

Fig. 2 Test sequence proposition

IV. APPLICATION TO THE GM STANDARD

The 2012 version of GM specification GMW3172 was interpreted and evaluated for comparison to our test sequence proposals based on IEC-60068-1 and MIL-STD-810G. The GM3172 test sequence is divided into development, design validation, and product validation phases, and is composed of four, nine, and ten tests, respectively. The design and product validation phase test sequences for the 2013 version of GM3172 are the same except for the shipping portion. The product validation phase test sequence is shown in Table II [6].

TABLE II
PRODUCT VALIDATION TEST SEQUENCE [3]

Leg0	Leg1	Leg2
Initial Inspection	5-Point Functional/Parametric Check	
	Low Temperature Wakeup	
	□High Temperature Degradation □Mechanical Shock-Pothole □Mechanical Shock-Closure Slam	Thermal Shock Air-To-Air →Power Temperature
Test set-up Verifications	Vibration With Thermal Cycling	Humid Heat Cyclic/ Humid Heat Constant/ Salt Mist
	seal or Leakage Check	seal or Leakage Check
	5-Point Functional/Parametric Check + dimensional Check	
	Visual Inspection and Dissection-DRBTR	
	Leg1 Complete	Leg2 Complete

Leg3	Leg4	Leg5
5-Point Functional/Parametric Check	5-Point Functional/Parametric Check	5-Point Functional/Parametric Check
Low Temperature Wakeup	Low Temperature Wakeup	Low Temperature Wakeup
Dust	seal	Salt Spray
Water		seal or Leakage Check
5-Point Functional/Parametric Check + dimensional Check		
Visual Inspection and Dissection-DRBTR		
Leg3 Complete	Leg4 Complete	Leg5 Complete

Leg6	Leg7
5-Point Functional/Parametric Check	
Low Temperature Wakeup	
Electrical Tests □Jump Start □Reverse Polarity □Over Voltage □State Change Waveform Characterization □Ground Path Inductance Sensitivity □Power Supply Interruptions □Battery Voltage Dropout □Insulation Resistance	□Frost □Temperature Measurement □Connector Installation Abuse-Side Forces □Connector Installation Abuse-Foot Loads □Crush For Housing-Elbow Load □Crush For Housing-Foot Load □Sugar Water Function Impairment □Water Freeze □Thermal Shock/Water Splash □Mechanical Shock-Collision
	5-Point Functional/ Parametric Check
	Free Fall
5-Point Functional/Parametric Check + dimensional Check	
Visual Inspection and Dissection-DRBTR	
Leg6 Complete	Leg7 Complete

Leg8	Leg9	Leg10
Fretting Corrosion	GMW3191 Connector Tests	□Shipping Vibration □Inspection for Structural Damage of Expose Surfaces □5-Point Functional/Parametric Check
		Visual Inspection and Dissection-DRBTR
		Leg10 Complete

The 2012 version of GM3172 is characterized as follows. The placement of electrical stress testing is not critical, because cumulative effects from electrical stress do not exist. High-temperature testing should be performed after low-temperature testing. Air-to-air testing should be performed prior to power temperature testing, which is considered harsher. To reproduce the erosion and proliferation described in MIL-STD-810G, water testing should be performed after dust testing [4]. Sealing is suggested for several tests, which indicates that GM considers immersion testing important. High-and low-temperature testing should be performed prior to shock and vibration testing the first set of tests to effectively reveal cumulative impacts. Overall, this test sequence is consistent with IEC-60068-1 [4] but not with MIL-STD-810G [5]. In addition, the fretting corrosion test, which requires 28 days, should be performed independently according to GM3172 to eliminate the possibility that performing other tests prior to the corrosion test will increase the corrosion severity.

V. Conclusion

Faults occurring in the field in electrical units have been difficult to predict and prevent, and new concepts for reliability testing are desired. Therefore, a composite reliability test sequence based on International Standard IED-60068-1 and the United States Military Standard MIL-STD-810G was proposed to enable better prediction of field failures. The GMW3172 standard was interpreted and compared to IEC-60068-1 and MIL-STD-810G. Tests providing the most significant effects and tests mimicking model conditions most likely to occur in practice were identified from the test sequence guidelines on the basis of the principles applied to approval testing. In addition, descriptions for each test were provided and suitable test sequences were proposed [4], [5]. In future studies, Ford Motor Company and Volkswagen specifications will be interpreted and analyzed for similarities and differences compared to the GM specification evaluated in this study [7], [8]. Using this process, additional new test sequences can be proposed.

References

[1] A. Piccolo, "Thermal performance of an electrochromic smart window tested in an environmental test", *Energy and Building*, vol.42, no.9, pp.1409-1417, 2010.

[2] K.-N. Song, S.-D. Hong, H.-Y. Lee, and H.-Y. Park, "Macroscopic structural behavior on the small-scale PHE prototype under high-temperature test condition", *Procedia Engineering*, vol.10, pp.48-56, 2011.

[3] A. Salahouelhadj, M. Martiny, S. Mercier, L. Bodin, D. Manteigas, and B. Stephan, "Reliability of thermally stressed rigid-flex printed circuit boards for high density interconnect applications", *Microelectronics Reliability*, Accepted for publication, 2013.

[4] IEC 60068-1, "Environmental testing – Part 1: General and guidance," 1988.

[5] MIL-STD-810G, "Environmental engineering considerations and laboratory tests," Oct. 2008.

[6] GMW3172, "General specification for electrical/electronic components – Environmental/durability," Nov. 2012.

[7] WDS EA-D11, "Environmental Requirements - (Non-EMC) Vehicle Electrical and Electronic Systems," May. 1999.

[8] VW 80000, "Electric and Electronic Components in Motor Vehicles up to 3.5 t - General Component Requirements, Test Conditions and Tests," Jan. 2010.