

White Paper

Qualifying for Moisture-Containing Environments

1. Introduction

In general, there are a limited number of tests that are appropriate for accelerating mechanisms triggered by exposure to moisture-containing use environments. They include

- Cyclic temperature/humidity (also known as a dew point test)
- Constant temperature/humidity
- Water spray

2. Cyclic temperature/humidity

The first cyclic humidity test was specified by MIL-STD-810 (see Figure 1). Since, variants of this test have been standardized by a variety of industrial organizations. Examples of three standards, one from the IEC and two from the IPC, are displayed in Table 1.

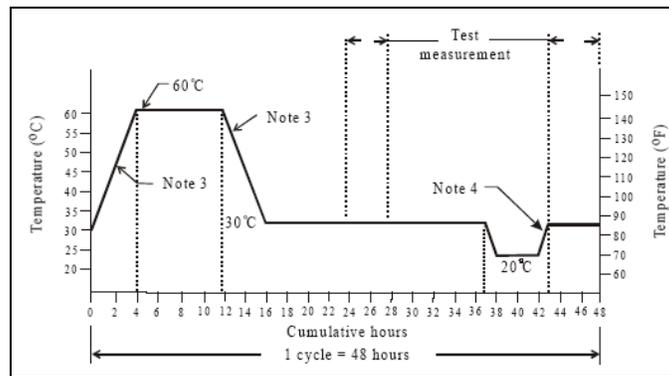


Figure 1: Cyclic humidity testing as per MIL-STD-810 (95%RH, 5 cycles)

Table 1: Industrial standards for humidity cycling

Organization	Standard	Low Temp	Ramp	High Temp	Humidity	#of Cycles
IEC	60068-2-30	12 hrs, 25°C	Not provided	12 hrs, 55°C	90-100% RH	12
IPC, TM-650	2.6.3.1 2.6.3.4	0 hrs, 25°C	1.5 hrs	3 hrs, 65°C	85% RH	20

The purpose of a cyclic THB test is to assess the ability of a product to operate reliably under condensing conditions (dew point). The rationale for more than one cycle is based on observations that repeated applications of temporary condensation events can lead to wearout type behavior ($R > 1$) over time. Initial condensation events “weaken” the circuit by inducing dissolution of conductor material (in this case, copper). The elevated presence of these metals eventually is sufficient to induce electrochemical migration between insulated conductors.

Realizing the intention of the cyclic THB test can provide guidance on the value of this test and the relevant parameters.

2.1 Power Dissipation

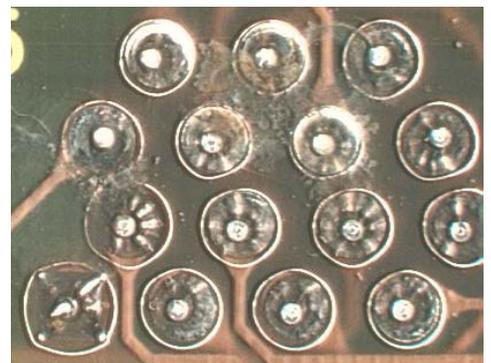
Condensation will occur when the temperature of the product is less than the dew point temperature within the chamber. If the unit is powered, there is a possibility of a temperature rise, depending upon the total power being dissipated. If this temperature rise is high enough, and typically it only needs to be 5°C higher than ambient, the likelihood of condensation on the board plummets. An even higher delta T can induce sufficient heating to inhibit condensation on cabling or on the interior walls of the housing and therefore prevent subsequent dripping.

The lack of condensation effectively eliminates the value of this test. Therefore, in cases where sufficient temperature rise is expected, the operators of this test must ask themselves three questions

1. Is condensation a realistic event in field conditions?
2. Are there other realistic operating conditions with a lower amount of power dissipation and therefore a more realistic possibility of condensation?
3. Could the unit be turned off and then turned on under condensing conditions (i.e., condensation during operation is only for a short time)

2.2 Conformal Coating

There is some value in the cyclic THB test assessing the capability of conformal coating. Conformal coatings are designed to be physical barriers and one of their intentions is to limit the possibility of failure during condensation. Thus, in this regards a cyclic THB test is part of an optimum qualification process. Please note that conformal coating does not provide definitive protection against condensation, as seen in the figure to the right. In this situation, condensation caused during rapid temperature cycling induced electrochemical migration over the conformal coating. This failure mechanism could not specifically be traced to a cleanliness issue, as ion chromatography analysis of the assembly found nominal levels of contaminants.



However, this test is limited by its limited ability to accelerate migration under the conformal coating. This is especially true for the IPC tests, which subject the board to a total exposure time of 60 hours at elevated temperatures. Prior work has shown that approximately 72 to 120 hours of exposure is needed to induce electrochemical migration at the surface. For migration under conformal coating, additional time is necessary to allow for the diffusion of moisture through the conformal coating to the coating/board interface. In addition, the cyclic temperature and humidity behavior could potentially prevent electrochemical migration through the application of stress to the fragile dendrites.

2.3 Continuous Monitoring

Typically, cyclic THB will tend to create failures or operation anomalies on an intermittent basis. As a result, continuous monitoring tends to be critical for this test condition.

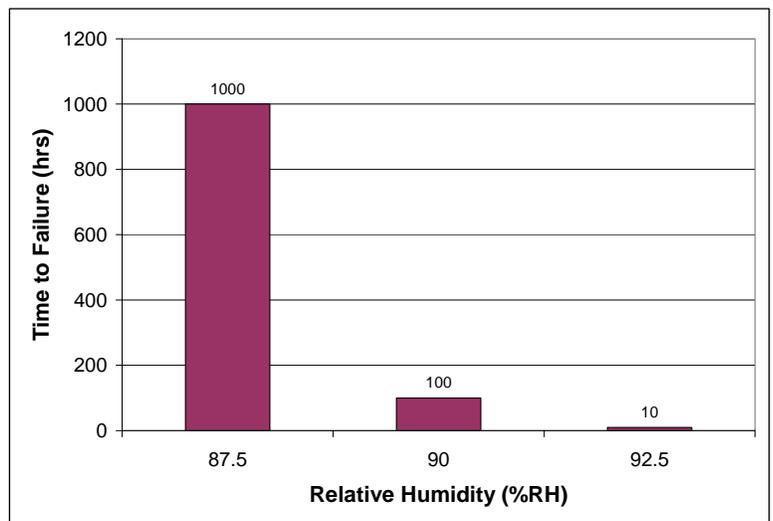
3. Constant temperature/humidity/Bias (THB)

The idea behind constant THB is that the development of dendrites, which can induce product failure, requires a period of time to initiate and propagate. In addition, rapid changes in the environment could potentially damage or destroy the relatively fragile dendrite structures. Constant THB is the more common test method for assessing the potential for failure due to exposure to ambient moisture and is widely used in a variety of industry specifications

Initial specifications primarily focused on 85°C/85%RH testing. However, more recent experimentation has demonstrated that lower temperatures tend to be more appropriate. This is because higher temperatures can actually reduce the propensity for corrosion or introduce a shift in the failure mechanism. At temperatures above 50°C, residues present from no-clean soldering tend to breakdown, creating a more benign condition. In other situations, elevated temperatures can induce plating dissolution, resulting in changes in the migration mechanism.

Studies have also shown that the relative humidity levels are critical, with orders of magnitude changes in time to failure with relatively minor changes in relative humidity (see figure on right).

Since constant humidity is designed to assess reliability in non-condensing environments, there is often a tradeoff between maximizing humidity to induce potential failures while avoiding condensation. This is the primary driver towards 93%RH as the industry standard. Relative humidity is often only controllable to $\pm 2\%$ and 95%RH is often considered the maximum controllable relative humidity before condensation within the chamber becomes highly likely.



The primary differences in the industrial specification tends to be in duration of exposure, with surface insulation resistance (SIR) tests extending approximately 4 to 7 days and electrochemical migration tests extending approximately 500 hours (21 days).

- IEC 60068-2-3 40C / 93%RH, up to 56 days (typically 500 hours)
- IEC 61189-5 40C / 93%RH, 72 hrs
- IPC TM-650, 2.6.3.5 35C / 88%RH, 96 hrs
- IPC TM-650, 2.6.14.1 40C / 93%RH or 65C / 88%RH or 85C / 85%RH, 500 hrs
- IPC 476A 65C / 85%RH, 500 hrs
- GR-78-CORE 35C / 85%RH, 96 hrs
- GR-78-CORE 65C / 85%RH, 500 hrs
- ISO 9455-17 40C / 93%RH, 168 hrs

For product with no conformal coating, DfR typically recommends a 40C/93%RH exposure for 3 to 5 days. An additional 2 to 3 days are required for diffusion through the conformal coating. Therefore, the recommended test parameters are

- Number of Samples: 3
- Orientation: Vertical or Horizontal
- Procedure:
 - Place samples in chamber
 - Set to 40C/93%RH
 - Power product on
 - Monitor functionality over 5 to 8 days of exposure
- Best practice: continuously monitor functionality
- At minimum: Check functionality twice a day

It is important to note that cyclic humidity and static humidity testing could be combined into one test, in a similar manner as the MIL-STD-810 test displayed in Figure 1.

4. Water Spray

Water spray testing is relatively rare for the majority of companies in the electronic marketplace. Most existing test specifications are derived from the original military specification, MIL-STD-810, Section 506.4. It primarily consists of three rain-related test procedures

- Procedure I (Rain and Blowing Rain)
- Procedure II (Watertightness)
- Procedure III (Drip)

Procedure I is applicable for material which will be deployed outdoors and which will be unprotected from rain or blowing rain. Procedure II is not intended to simulate natural rainfall but will provide a high degree of confidence in the watertightness of material. Procedure III is appropriate when material is normally protected from rain but may be exposed to falling water from condensation or leakage from upper surfaces. The test conditions and required equipment are specified in detail in the MIL spec. Exposure times range from 15 to 40 minutes, with operation either during or after exposure.

4.1 Water Spray Test

- Number of Samples: 1 to 3
- Orientation: Vertical
- Procedure:
 - Open outer door
 - Spray with tap water for 3-5 minutes¹
- Power product on; operate for approximately 5 minutes; power off; power back on and check functionality

The water spray test subjects the unit to a similar, but potentially more extreme environment as the cyclic humidity test. This is because both tests are designed to assess the robustness of the product to the presence of physical water on the electronics. The water spray provides a greater amount of water, but its coverage may not be as extensive.

¹ This step is designed to replicate water exposure due to sprinklers or driving rain. The high pressure of the hose should be sufficient to replicate a similar amount of water during a downpour in a much shorter period of time. If the company is not attempting to qualify for military applications, a shorter period than that specified in MIL-STD-810 is appropriate.

5. Conclusion

Moisture sensitivity testing is a critical step in a best practice approach to ensuring product reliability. This is especially true given the intermittent nature of electrochemical migration-based failures, which can be a root-cause of no trouble founds (NTFs), and the primary focus in the electronics industry on temperature cycling. What is especially surprising is how manufacturers of indoor products typically underestimate relative humidity levels (enclosures with minimal airflow can see %RH values rise to 85 or greater, even in controlled environments) and manufacturers of outdoor products typically overestimate the risk of condensation (most products are turn on/leave on and dissipate sufficient power to prevent surface temperatures from ever falling below dew point).

In either case, it is important to understand the purpose of each test. This allows for optimization of the parameters and maximum return on investment in qualification procedures.

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