ENVIRONMENTAL TESTING TYPES AND PROCESSES

Two fundamental forms of environmental testing are simulation and stimulation. The differences, advantages, and applications between these types of environmental tests frequently cause confusion and debate.

Simulation mimics the conditions a product would see in its normal use environment. It is often referred to as "test to pass" because the environmental stresses applied to the product—such as temperature, humidity, and vibration—do not exceed its intended use. Once the product passes the simulation test it's ready for market or consumer use.

Stimulation uses stresses to uncover a product's weaknesses and limits, often stressing a product to the point of failure and beyond. For example, the temperature would gradually increase in an attempt to find the highest temperature at which the product will operate and where damage will occur. Once the product fails, it is determined whether the failure is acceptable or if it needs to be fixed prior to market introduction. Stimulation is also referred to as accelerated testing.

The following are some examples of different types of simulation testing:

Burn-In

Burn-In is a traditional form of testing when large batches of products are tested together at an elevated temperature to aid in the precipitation of premature failures. Elevated temperature conditions are achieved using the heat from products under test or from a heating element.

Burn-In tests are commonly done with the products under test powered, and temperatures may be cycled occasionally, which causes some degree of thermal cycling as the devices heat and cool. The ease with which burn-in is implemented must be weighed against the relatively low screening effectiveness and long test times, which is why many companies are turning to temperature cycling.

Temperature Cycling

As demands increase to reduce testing time and as understanding stimulation grows, companies are transitioning from burn-in to temperature cycling for testing electronics.

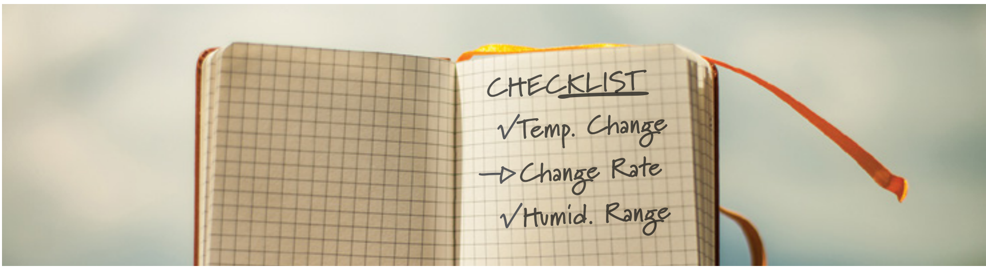
Temperature cycling is the rapid change between predetermined temperature extremes for multiple cycles. While temperature cycling is considered more effective and efficient than burn-in, there are a few complications to overcome. Good airflow, for example, is important because it maximizes heat transfer and ensures the actual product temperature follows the chamber air temperature. It also prevents the formation of hot/cold spots within the workspace of the chamber.

Ramp rate, or the speed in which the chamber can change the air temperature, is also an important consideration. Faster ramp rates are more effective stresses for a given number of cycles; however, if the ramps are too fast they might cause undesired damage. A typical temperature profile transitions between -40°C and 125°C, at 5°C to 15°C per minute. At the temperature extremes, dwell periods (a period of time when the temperature is stable) are used to allow the product temperature to catch up to the air temperature.

Thermal Shock, a form of temperature cycling, exposes a small number of products to severe and extreme temperature changes. This normally is accomplished by moving the products between hot and cold zones of preconditioned air or fluid. Thermal shock can be used for design validation and pre-production validation testing.

Chamber Selection Checklist

- ☐ Desired temperature range and profile
- ☐ Temperature change rate
- ☐ Humidity range requirements
- ☐ Duration and frequency of tests
- ☐ Number of devices to be tested
- ☐ Size of the device(s) under test (DUT)
- ☐ Mass and material of the DUT
- ☐ Power dissipation of the DUT
- ☐ Fixture requirements of the DUT
- ☐ Available lab floor space and utilities
- ☐ Budget and lead time



ESS

Environmental Stress Screening (ESS) identifies weaknesses in manufacturing materials and processes while in production. In an ESS process, every product is subjected to stimulus. The objective of stress screening is to eliminate products that would fail early in use to reduce product infantile mortality rates. A complete exploration of ESS is available as a handbook.

The following is an example of stimulation testing:

HALT & HASS

Highly Accelerated Life Testing (HALT) uses aggressive temperature change rates and multi-axis repetitive shock vibration to reduce required testing time. HALT tests a product to the point of failure to uncover product weaknesses, operating limits, and destruct limits prior to production. HALT is used to detect design defects in order to make design enhancements.

Highly Accelerated Stress Screening (HASS) is a production process used to screen out defective products prior to shipment. HASS uses similar, but less aggressive, stresses to those used in HALT. More details on HALT and HASS are available in a handbook.

Overall, stimulation testing applies stresses to products, bringing them to their breaking points, to improve and ruggedize them. Simulation testing ensures products are reliable and will function as intended. Environmental testing is an important aspect of product design and development. Each product may need different types of testing depending on their intended use environment, design, and materials.

ENVIRONMENTAL STRESSES AND THEIR EFFECTS

Creating and designing a product isn't enough. You need to ensure the product will function as it should after shipment and during routine use in the field. Even if you use the product in the same location, think of how a normal use environment would change from season to season. As environmental stresses are applied, the physical and electrical characteristics of products can vary greatly. The environmental stresses appropriate for testing any specific product depend on the product's design and components and the end goal of the test.

Temperature, humidity, and vibration are common environmental stresses applied to products.

Temperature, the most common environmental stress, causes a variety of effects. Changes in electrical constants due to temperature swings can cause unforeseen problems in the product's function. Mechanical issues arising from expansion and contraction can become evident when the coefficient of thermal expansion does not match. Interactions of dissimilar materials, changes in flexibility, and PCB delamination can all occur when temperature stresses are used to uncover problems in the product's design.

Humidity can cause physical changes, such as swelling and embrittlement for some materials, causing the product to malfunction or break. Oxidation (corrosion) and leakage paths between conductors are also exposed with extreme humidity conditions.

Vibration stresses can cause a loss of mechanical strength from fatigue, cracking, displacement, or the impairment of the product's mechanical functions. This is true for both electrodynamic and repetitive shock vibration.

Altitude, corrosion, and sand & dust tests are other environments that can be used to stress products, though, they are less common. Altitude testing is usually combined with temperature-humidity to evaluate airplane components, test items that will ship via air, or items used in high altitude climates. Corrosion tests are performed to determine a material's sensitivity and reactions to salt water spray, for example. Sand and dust tests place a product in a workplace and send puffs of sand and dust into the air to settle on the product to see how it reacts over time.

By diversely and thoroughly stressing products, you can help ensure that your product will operate as intended in its normal use environment. Trying to replicate these stresses without the proper equipment can be a challenging undertaking with poor or disappointing results. Environmental test chambers and vibration shaker systems are essential to consistent and dependable results.

TEST AND MEASUREMENT

Collecting data during an environmental test is extremely important. That data provides relevant information about the product in order to guide product modifications and improvements, or to validate product conformity to existing specifications. Parametric and functional testing are two ways to collect data.

Parametric testing is the detailed analysis of product parameters measured in conjunction with environmental stresses. Data can be analyzed to observe parameters that may shift with changes in environmental conditions. Typically, parametric testing requires more accurate instrumentation than a comparable functional test, as individual functions are compared against more stringent limits. During functional testing, test limits are usually widened to allow for a "go/no go" mindset, where only 'hard' failures are reported. Many companies will perform the more stringent parametric testing prior to the start of long environmental tests, when functional testing is employed to simulate the "lifetime usage" of the product under test. Parametric testing would be performed again at the conclusion of the environmental stresses to analyze any degradation in part/circuit performance.

Functional testing is widely used with environmental testing throughout various stages of product development and production. A functional test is most valuable when monitoring is performed continuously. Two types of failures can be found during functional testing: soft and hard. Soft failures are intermittent and occur when there are changes in product temperature. A soft failure appears at one condition and then disappears at another. If the product is not continuously monitored, it may be incorrectly concluded that all is well. A hard failure is permanent and can be detected by a low performance test system. Some failures can be of very short duration and thus can be easily missed. Eliminating, reducing, or, at least, accelerating any multiplexing helps prevent this problem. Some examples include:

Data gathered from parametric and functional testing provide important information about a product under test. The knowledge gained from these tests guide product modifications and improvements and validate specifications.

Multi-head testing systems permit the testing of several products in an efficient manner. It is challenging, however, to satisfy requirements for stimulus, power distribution, electrical loading, continuous monitoring, communication, interconnect, and fixtures. Add this to the test system reliability requirements for long duration tests, and it is evident why many companies utilize outside test system integrators to implement their systems.

Fixtures are essential to positioning a product in a consistent manner while performing environmental testing. Fixtures can simplify required electrical connections to products that are powered and monitored during a test. Fixtures also provide uniform product spacing in the chamber workspace – allowing for consistent airflow and more repeatable test results. An important thing to consider is whether the product needs to be tested in its intended end use orientation.

Loading. If electrical loads are needed for testing, problems similar to power sourcing can be encountered. Complexities can arise because it is difficult to keep the loads in close proximity to the product. While normally not advisable, it may be possible to place loads—especially passive loads—on the product carriers in close proximity to the products. For both fixed and programmable loads, dissipating the heat from electrical loads can be a substantial engineering challenge, perhaps requiring the use of high velocity air or water cooling.

Powering Products. The selection of power sources for the test system can be somewhat complicated, in a multi-head test system. The initial selection of bulk or individual power sources is typically based on cost. Keep in mind that even though individual power sources cost more, they have several advantages over bulk supplies, such as embedded measurement capabilities, individual activation, and separate sense line connections.

Because the distance between the power sources and the devices under test can be long, voltage drop issues can become a concern. Usually, sense lines are used to reduce this problem; however, in bulk power supply situations, the sense lines can only be placed at the farthest common point—usually bus bars. Also remember to consider the elevated environmental chamber temperatures when temperature de-rating the wires entering the test chamber workspace.

A common mistake is to not interlock the supply of power with chamber operation. Imagine the predicament if an environmental test chamber cooling fails and the devices under test continue to pump heat into the insulated interior of the test chamber.

Stimulus. Typically, there are "stimulus" signals sent to the product under test. While programmability and accuracy of these signals must be well thought out, it is important to consider synchronization and separate sources for each product. Just as with the application of power and loading, synchronization with the operation of the environmental chamber is useful. Separate parallel sources can prevent the failure of one product from corrupting a signal that is intended to be applied to all products under test.

Monitoring. Product measurement and monitoring need careful consideration. Monitoring the product under test is extremely important because it not only helps determine product problem areas but also can help fine tune the testing process. For example, if a five-day burn-in process has been performed for several months and all witnessed failures have occurred during the first two days of the burn-in, it may make sense to increase throughput by shortening the burn-in period. Continuous monitoring or at least very fast multiplexing is needed to prevent overlooked soft failures. When considering ways to solve the monitoring requirements thought must be given to signal conditioning, synchronization, accuracy, and resolution issues. A typical scheme for detecting failures during a functional test is to set high and low limits on the monitored signal and to record a failure (along with time and environmental conditions) when it occurs. When the failure occurs, remove power to the failed product to prevent a possibly catastrophic meltdown. Note that a somewhat decreased accuracy may be acceptable during functional testing, especially as a trade-off for more monitoring channels.

Software. Some issues that could arise with the system software include: user interface problems, operational features, usability, and the amount of test data to be collected. Software systems typically collect a large amount of data and decide later what is important. This may work in some cases but it can be time consuming for test report generation. Lengthy "life testing" tests can make continuous data recording a formidable problem. A workaround would be to reduce recorded data, especially in functional test systems, and record only hard failures; this, however, would not record soft failures or "passing" information.

Safety. Safety is important when it comes to using an environmental test system. Dangers exist for operators or others who inadvertently touch extremely cold or hot equipment parts. All environmental chambers should be equipped with a separate thermal alarm that signals unintentional temperature excursions. If nitrogen or carbon dioxide is being used, an oxygen monitor is needed. Interlocks should be provided to prevent the environmental chamber doors from being opened during a test and to shutdown test power if a door is opened. And remember to automatically disable product power if the environmental chamber is inactive.

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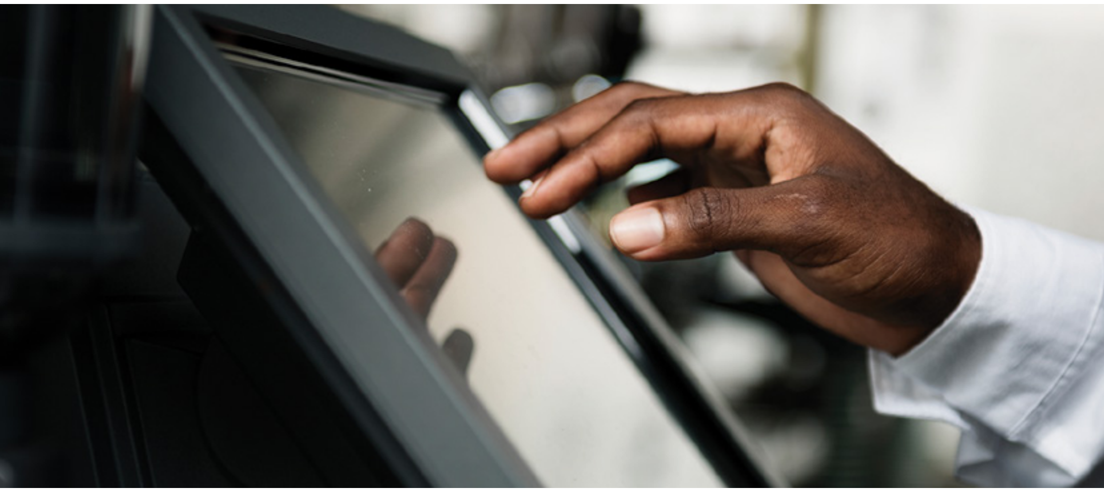
INTEGRATING THE TEST SYSTEM

Integrating a test system with its controller and other data analysis components is not a trivial undertaking. Engineering disciplines — including electrical, mechanical, and software — need to come together for successful integration and implementation. Safety and regulatory standards must be met according to state, federal, international, and industry standards and laws.

The complexity of the test system can easily surpass the complexity of the product being tested. For this reason, documentation of the integration and use of the system should be extensive and accurate in order for future chamber users to be successful.

Integrating and implementing test and measurement with environmental testing can help in multiple ways. For starters, it can streamline testing and data analyzation, which increases time and testing efficiencies. Other benefits include increasing product robustness, improving product reliability and production processes, increasing yields, and reducing warranty and recall expenses.

Test system integration can be difficult, but it is well worth the time and effort. Environmental testing contributes to the success of many types of products, from the design stage to final production. Successful test system integration can contribute to the success of overall company goals, from happy customers and efficient employees to robust, dependable products and increased profit margins. What could test system integration do for you?



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