Institute of Environmental Sciences and Technology

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Product Reliability Division
Recommended Practice 003.1

HALT and HASS

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1 SCOPE

1.1 Scope

This Recommended Practice (RP) defines and describes HALT (Highly Accelerated Life Testing) and HASS (Highly Accelerated Stress Screening). This RP contains information on the philosophy behind the testing, generic examples of tests, the differences between standard testing equipment and equipment used for highly accelerated testing, fixturing considerations, alternative approaches, additional environments, and lessons learned, along with other useful information. This style of testing takes a Qualitative approach (looking for the quality of the design and workmanship) rather than a Quantitative approach (being able to use the results to calculate length of life in service). This RP is not meant to take the place of a test specification but to be used in conjunction with a test specification or as general guidance.

2 REFERENCES

The cited editions of the following documents are incorporated into this RP to the extent specified herein. Users are encouraged to investigate the possibility of applying the most recent editions of the references.

MIL-STD-810: Test Method Standard for Environmental Engineering Considerations and Laboratory Tests

Military Standards
Standardization Document Order Desk
700 Robbins Avenue
Bldg #4, Section D
Philadelphia, PA 19111, USA
http://dodssp.daps.dla.mil/

3 TERMS AND DEFINITIONS

acceleration
The rate of change of velocity with respect to time. For vibration testing, acceleration is usually expressed in gravitational units (*g*) but may also be expressed as m/sec^2.

accelerometer
A sensor for converting acceleration into an electrical signal; a transducer featuring instantaneous output proportional to the instantaneous acceleration input.

bathtub curve
A plot of product failures versus time, which has three sections: The first shows decreasing "infant mortality" (early failures); the second, constant random failures; and the third, increasing wear-out failures.

dwell
The length of time during which a test article is subjected to an environment (e.g., thermal or vibration).

electrodynamic (ED) shaker
A type of shaker that uses electrical energy to create dynamic motion. In physics, the technology used is referred to as the "voice coil principle."

environmental stress screening (ESS)
The application of forcing function to a product for the purpose of characterizing the environmental performance of the product.

Failure Modes and Effects Analysis (FMEA)
A methodology conducted during product development to identify and classify potential reliability problems, and to define a course of action to mitigate failures according to priority.

fixture
An intermediate structure used to attach a test unit to a test platform such as a vibration table.

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Fourier transform; discrete Fourier transform (DFT)
The representation of a time-history by a harmonically related series of sines and cosines. The digitally sampled time-history is represented by the DFT.

***g*-level**
The acceleration time-history amplitude of a pyroshock as measured by an accelerometer calibrated in *g*'s. May also be expressed in m/sec^2.

g_{RMS}
The root-mean-square acceleration.

Power Spectral Density (PSD)
The limiting mean-square value per unit bandwidth (i.e., the limit of the mean-square value in a given rectangular bandwidth divided by the bandwidth). These bands are grouped into a plot of power level (in g^2/Hz) vs. frequency (in Hz), over the frequency range of interest. The resulting plot gives an indication of the power at each frequency.

root-mean-square (RMS)
The square root of the time-averaged squares of a series of measurements.

transducer (sensor)
A device that converts shock or vibration into an electrical signal that is proportional to the parameter of the experienced motion or force.
NOTE: The term "transducer" is often used interchangeably with the term "sensor" in industry. The term "sensing element" is used to describe the sensing mechanism inside the transducer or sensor.

4 BACKGROUND AND PURPOSE

HALT (Highly Accelerated Life Testing) and HASS (Highly Accelerated Stress Screening) are two methods for potentially improving reliability and quality of products. The information learned from HALT can show whether the design is acceptable or changes are needed to achieve a more robust design. This information can help a practitioner decide what corrective actions are required.

HASS is a follow-up to HALT and is performed at the end of fabrication to help detect changes in process or components that would adversely affect reliability. Used together, lessons learned from HALT and HASS process can improve quality, reliability, performance, and safety; can reduce cost and warranty issues; and can result in increased satisfaction with the product.

5 HALT

HALT is a process specifically designed to detect design weaknesses in products. HALT was developed from an understanding that reliability is improved by finding and eliminating failure modes. An efficient means for generating failures is required for optimal product development. HALT is a product development approach that can be applied with any reasonable environmental stress. HALT is not a pass/fail test, but rather a discovery process utilizing equipment and exposures for determining the product sensitivity to anticipated, measured, or known field stresses, and a means to develop a product to the practical limit of the employed design technology. The concept is to purposely stress products to understand the mechanisms most likely to cause failure during the product life cycle of transportation, storage, and use. This knowledge can result in design actions that lower the field risk, thus enabling effective business decisions for market success. In HALT, test durations are compressed by increasing stress levels. Failures and their effects found during HALT can then be used to verify a Failure Modes and Effect Analysis (FMEA).

There are numerous environmental testing alternatives to HALT, including development, qualification, acceptance, statistical reliability, and reliability growth, each of which has specific goals and methods. HALT is not a substitute for any of the tests listed here. Practitioners must understand each method to select the appropriate test program. It is beyond the scope of this RP to discuss each of these methods.

Reliability Growth Testing (RGT) and HALT are similar, but are conducted differently. RGT applies the defined environmental requirements of the system for extended periods of time or at slightly exaggerated levels, or both. It is the goal of RGT to estimate reliability, design margin, and the infant mortality period of a reliability bathtub curve.

On the other hand, it is the function of HALT to expose potential design weaknesses quickly, and HALT can be applied whether or not the system has defined environments. Defined environments can be used as the starting point for HALT. However, HALT environments are applied at levels that may greatly exceed the defined environments, so correlated statistical failure data cannot be obtained because of the low sample size and potentially high variation observed in times to failure. Damage models may require parameter adjustment for accuracy.

HALT entails a series of exposures (typically five) using various environmental stresses. However, as a philosophy HALT is not limited to only these environments. HALT can expedite the ability to improve the robustness of the product design before the product reaches the production phase. Diligent failure analysis and efficient feedback to the design team result in HALT being a valuable process. To be effective, HALT requires a commitment to the

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process and the recognition that failures are desirable, with design decisions (often actions) required in response. These actions include replacing less robust components, identifying material or interconnect deficiencies, exposing poor processes (though HASS is specifically used to identify these), and improving structures, among other things.

Failures found during HALT should be analyzed to determine the failure mechanism. Hardware and system failures should be evaluated to determine their root cause in light of materials, manufacturing processes, and design. Then informed decisions can be made that are consistent with business risk and technology limitations.

The philosophy is to continue making the product more resistant to environmental and usage stresses, and hence more durable. However, a point of diminishing returns is reached if the product is determined to be sufficiently durable based on expected usage conditions and environmental extremes. The objective is a strong and robust product, but not a product that is overdesigned.

To maximize the efficiency of the HALT process, it is imperative to constantly monitor the unit under test (UUT) and to run functional tests while the unit is being stressed. Electronic monitoring with data acquisition, as well as visual observation by personnel to detect deficiencies that might otherwise be missed, is critical. With each design change, the new configuration should be retested with either a reworked or a new unit. In some cases, changing out one component can result in failure of a different component. It should not be assumed that the replacement of one component will rectify the overall design. Additional testing is required to verify the modified design.

5.1 Product limits during HALT

Many product limits should be factored into the HALT process, including the following:

a) Specifications—The environmental levels under which the product is designed to function correctly.

b) Upper and Lower Operating Limits—The limits at which the product will stop operating correctly. For temperature and humidity there are upper and lower limits. For vibration there is only an upper limit.

- UOL (Upper Operating Limit)
- LOL (Lower Operating Limit)
- VOL (Vibration Operating Limit)

c) Upper and Lower Destruct Limits—The limits at which the product has a complete and unrecoverable failure. Again, for temperature and humidity there are upper and lower limits. For vibration there is only an upper limit.

- UDL (Upper Destruct Limit)
- LDL (Lower Destruct Limit)
- VDL (Vibration Destruct Limit)

Depending on the product and its applicable environments, other limits may also apply. These environments include, for example, humidity, pressure, salt spray, and power cycling. All of these and other environments may be applicable to specific hardware. The extreme limits to be used for the individual tests should be determined before testing commences, taking into consideration hardware availability and time constraints for attaining the desired operating and destruct limits. (The limits may be the same as the HALT chamber/vibration system limits.) Knowing in advance the number of samples available for testing will aid in the decision-making process. It is also important to understand the temperature and vibration limits. Humidity is not always monitored or controlled during HALT, though monitoring humidity when not controlling it can provide valuable additional data for failure analysis. Thus, a humidity limit—high, low, or both—may also be chosen. Choosing predetermined limits (those falling outside of operating and destruct limits) is a matter of engineering judgment.

In deciding whether to make improvements to the test item, any failure found within the range between the product specification and the operating limit is generally considered to be a “must fix,” and any failure between the operating limit and the destruct limit is considered to be a “possible fix.” Keep in mind that an operating limit and a destruct limit may be identical. The first failure may be unrecoverable and virtually destroy the item under test.

5.2 Hardware suitable for HALT

The HALT process can reduce the test time required to identify failures representing design weaknesses. HALT is most commonly applied to electronics or electromechanical products that provide almost immediate feedback upon failure. However, the method has also been found to be valuable for mechanical devices and material samples. Failure in these types of test units typically is not seen until the UUT is removed from the test chamber, so it is more difficult to determine at exactly what level of stress the failure occurred. If used as a wear process, HALT can nonetheless be very effective in identifying failure modes. In all cases, failure analysis uses visual (with optical microscopy) and analytic failure analysis tools (such

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as radiography, scanning electron microscopes, and Fourier Transform Infrared spectroscopy) to examine the unit after test.

When testing electronics, failure detection is critical. It is important to power-up units (either full time or intermittently) and monitor the units continuously. Intermittent failures are likely to occur during testing. These failures would not be detected in a bench test before or after application of the environmental stresses.

At least one sample per environmental stress should be used. Multiple samples should be used if possible, because different UUTs can potentially display different failure modes. If only one sample is available for all tests, extra care must be taken during both testing and failure analysis. When testing with one sample per environment, it is essential that the unit being tested represents the blueprint of the design and that it has not been overbuilt for the purpose of the test. The impact of manufacturing and materials variations can be ignored when using a single sample but should be taken into consideration for multiple samples. The number of samples used for HALT is governed by UUT cost and availability, as well as availability of test equipment, trained personnel, time, overall test cost, and related factors. Figure 1 illustrates criteria for determining the number of samples to be tested.

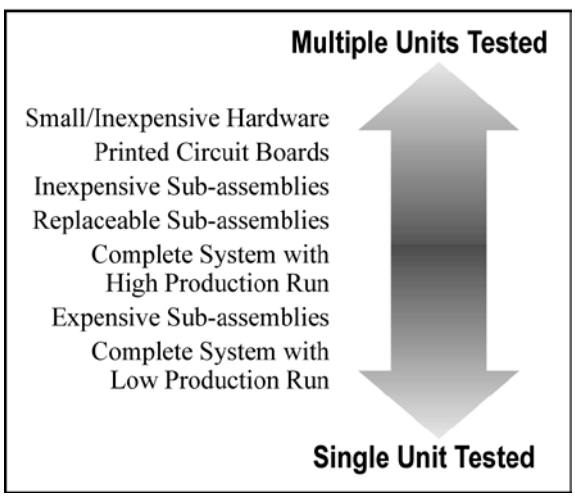

Figure 1—Example for determining how many samples to test.

5.3 Uses of HALT

The following cases represent typical uses of HALT:

- Pre-production (typically the design phase)—to help fully understand and improve the product limits at a stage when it is easier and less expensive to make necessary design changes.
- In the case of an unusually high number of field failures/returns—to help determine the root cause(s) of the stresses and mechanisms relating to the high-risk failure modes. Failures can be replicated in the lab, the data analyzed, and product improvements implemented.
- A comparative HALT (sometimes termed a "Re-HALT")—performed when a material, materials source, or process changes in an existing design. This may also be performed when field failures are higher than expected.

5.4 Common HALT testing procedures

HALT can be applied as a method of investigation for many stress types. The standard series of HALT tests consists of:

1. Cold step stress
2. Hot step stress
3. Vibration step stress
4. Rapid thermal cycling
5. Combined vibration and thermal cycling

It is important to conduct each one of these tests because some products fail only with temperature exposure, others only with vibration exposure, and some only with the combination of temperature and vibration. Other stresses may be applicable, depending on the configuration and operating environment of the hardware. Further information is provided in section 11.

The hardware to be tested may have a cover that encloses its internal components. The cover should be removed for all thermal and thermal/vibration combined tests to permit rapid thermal transitions of the internal components. Air ducts may also be used to direct conditioned air towards the UUT if it is necessary for faster temperature change rates or more uniform temperature change. If covers cannot be removed they may be aerated for more rapid thermal changes of the internal components.

Testing commences with single environments applied individually to the UUT to provide a baseline for the response of the product to each environmental stress. It is not recommended to start with a combined environment because failure analysis and the identification of the critical environment will be more difficult. After the response to the individual environment has been characterized and the product strengthened as necessary, combined tests can be conducted.

Again, for all tests, functional testing and monitoring should be performed continuously during thermal step stress testing, as long as the UUT is operating.

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