



Highly Accelerated Life Testing (HALT) Highly Accelerated Stress Screening and Auditing

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1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard is intended for use as a guideline in performing the Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS)/Highly Accelerated Stress Auditing (HASA) process and using the resulting data in a valid statistical control process to stabilize and improve the product. This standard presents an acceptable and certifiable process for implementing a "common process" across diverse organizations. The goal of defining the requirements of the HALT and HASS/HASA process provides the framework for qualification of a company's HALT and HASS/HASA process through means of an audit. Adherence to this standard will provide the potential for companies to achieve optimal HALT and HASS/HASA effectiveness. HALT testing typically results in more robust and quicker to market products. The HALT process consists of three (3) steps: Physical test, root cause analysis, and corrective action. All three steps are critical, as the physical test alone will make no difference in the robustness of the product. The increased level of robustness achieved during development with HALT will be maintained during production using the HASS/HASA process. The data and information obtained during HASS/HASA is most useful when good statistical process control methods are applied. These methods include control charts to view and react to the data from a "signal to noise" point of view. The other quality control method that should be used is the use of Pareto charts to assist in identification of the root cause of problems and maintain focus on the vital few causes that dominate the source of problems

1.2 Applicability. HALT applies to new technology/designs and can also be used to evaluate product improvements. HASS and HASA are used to detect unexpected and random quality issues during production.

1.3 Remarks. The process elements to successfully implement and perform HALT and HASS/HASA are defined in this standard. This standard identifies technical responsibilities, equipment requirements, testing practice competencies, and statistical quality control methods that will optimize the total process. Adherence to this standard will provide management and test personnel with a common process that represents a collection of "best practices". Procedures are explained in detail; however, the basic nature of the HALT process is one of discovery that requires flexibility of process as it progresses. Consider the HALT related numerical values and procedures as a general guideline. Each product that is destined for the HALT process will dictate its own unique set of test values and stress steps. Accept the ambiguity that is intrinsic to an explorative development test. This standard applies to a diversified mix of product segments, including electronic assemblies and electromechanical assemblies, and may be applicable to certain mechanical assemblies as well.

Note: The use of the acronym HALT has become universally used and accepted by a wide range of industries as a generic reference to a specific type of accelerated testing which uses a combination of very rapid temperature change and all axis broadband vibration.

Several manufacturers now produce HALT like test chambers, and General Motors does not endorse any one brand over any other brand, even though the most commonly used acronym of HALT is used exclusively in this standard.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

AIAG FMEA-4

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- Accelerated Reliability Engineering, Gregg K. Hobbs, John Wiley and Sons, 2000
- Failure Of Materials In Mechanical Design, Second Edition, by Jack A. Collins, John Wiley and Sons, 1993
- Failure Mode and Effects Analysis (FMEA) FMEA-4 available from the Automotive Industry Action Group (AIAG) at Uniform Resource Locator (URL): www.aiag.org

- Industrial Erector Set available from 80/20 Incorporated at URL: www.8020.net
- Product Reliability, Maintainability, and Supportability Handbook, CALCE Electronic Packaging Research Center University of Maryland, CRC Press, 1995
- Quality Control Handbook, Third Edition, Joseph Juran, McGraw-Hill, 1979
- Statistical Methods For Reliability Data, by William Q. Meeker and Luis A. Escobar, John Wiley and Sons, 1998
- Vibration Analysis For Electronic Equipment, Second Edition, Dave S. Steinberg, John Wiley and Sons, 1988

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.3 Failure Analysis Lab. A failure analysis lab (in-house or outside lab) may be required to determine root cause analysis on failures found during HALT.

3.1.4 Technical Manager. The test facility shall have a technical manager who has overall responsibility for the technical operations of the HALT test area.

3.1.5 Cross-Functional Committee Meetings. The test facility should have a committee that meets on a regular basis, i.e., monthly, to define HALT test requirements, review past HALT results and develop test plans for future testing. Records shall be maintained on the decisions of the meetings. These meetings shall occur prior to and subsequent to the product HALT.

3.1.6 Records. The test facility shall maintain records of test events for products tested. These records are stored and shall contain sufficient information to permit repetition of the test, i.e., test report, data, notes, etc. These records are made available for review to determine compliance with this HALT test standard.

3.2 Equipment.

3.2.1 HALT and HASS/HASA Chamber Requirements. The equipment required to perform HALT testing must be capable of producing thermal and vibration energy stresses as defined in 3.2.1.1 and 3.2.1.2, and to create these stresses in a combined environment, i.e., the chamber must have thermal and vibration capability within one chamber.

3.2.1.1 Vibration. Chamber technology for HALT is a repetitive shock vibration that functions with six degrees of freedom (three linear and three rotational). The vibration is quasi-random in nature and maintains a true Gaussian long tailed distribution of energy.

3.2.1.1.1 Broadband energy exists from 2 Hz to 10 000 Hz.

3.2.1.1.2 Minimum vibration table output of 343 m/s^2 Root Mean Square (RMS) (35G_{RMS}) with no table loading.

3.2.1.2 Thermal. The goal is to force rapid thermal change rates on the product. It is additionally important that the chamber has sufficient air velocity to produce the desired rapid thermal rates of change as measured on the product and to maintain thermal stability.

3.2.1.2.1 High rate of change (the minimum air temperature rate-of-change should be 45 °C/minute).

3.2.1.2.2 Thermal range from -80 °C to +170 °C.

3.2.2 Laboratory Test Equipment. Product response data is acquired during the HALT process. This data includes thermal, vibration, and product functional performance.

3.2.2.1 Collection and Storage of Thermal Data. The collection and storage of thermal data is required to provide credible evidence that thermal stress was applied to the product. This may be achieved by utilizing available thermocouple monitoring channels of the HALT test system or the use of a data acquisition instrument capable of multiple channel measurements.

3.2.2.2 Collection and Storage of Vibration Data. The collection and storage of vibration data is required to provide credible evidence that vibration stress was applied to the product. This may be achieved by utilizing

available accelerometer monitoring channels of the HALT test system or the use of a spectrum analyzer instrument capable of measuring sensors, e.g., accelerometers, and displaying the data.

3.2.2.3 Accelerometers for the Measurement of Product Response from Vibration. These accelerometers should be low mass type, e.g., 4 g, with frequency response capability of 2 Hz to 10 kHz, and a measurement range of $\pm 4900 \text{ m/s}^2$ ($\pm 500\text{G}$). The accelerometers should be small enough to be mounted in the desired location, and light enough that their mass does not significantly impact or alter the vibration dynamic characteristics of the sample tested. Examples of appropriate accelerometers are PCB brand models 352A10 and 352C22 (examples only, similar products may be used).

3.2.2.4 Thermocouples for the Measurement of Product Thermal Response. The use of thermocouple wire is required. Thermocouples used for HALT should have sufficient stability characteristics through the temperature range of the chamber (approximately -100°C to $+200^\circ\text{C}$). The thermocouple wire shall be 0.64 mm diameter (22 American Wire Gauge (AWG)) or less.

3.3 Test Vehicle/Test Piece. This standard applies to new technology production design intent components needing early assessment of potential field related performance issues.

3.4 Test Time. Varies based on test objectives. See 1.3 Remarks.

3.5 Test Required Information. Test required information is to be determined as part of any preparation meetings. See 4.1.

3.6 Personnel/Skills.

3.6.1 HALT Team. The HALT team should include those individuals involved in the design and test of the product. HALT testing typically will require multiple disciplines within the facility to cooperate. These disciplines include design engineering and test engineering expertise on the product to HALT. It is expected that design engineering will assist in the development of the product functional test (including identifying additional stresses which could help to precipitate defects), provide support during the HALT test, and in the failure analysis process, e.g., troubleshooting defects. These individuals need not be present during the entire HALT, but must be available on an as needed basis. Other disciplines to include are reliability engineering, manufacturing engineering, and the personnel who run the HALT system, if they are not part of the aforementioned groups. Each discipline shall take responsibility for their area of expertise as HALT result issues arise.

3.6.2 HASS/HASA Team. The HASS/HASA team is based within a manufacturing environment but may be the same team that was responsible for HALT. This team will finalize the screening profile that is applied, perform 4.3.5.3.5 (Safety of HASS) process, and operate the day-to-day screening operation. This team will also manage the information and data obtained from the screening process and should maintain the Statistical Control Chart (P Chart) and Pareto charts as defined in 4.3.5.5.2.

3.6.3 Familiarity with HALT and HASS/HASA References. Familiarity with references such as follows may be useful:

- Accelerated Reliability Engineering, Gregg K. Hobbs, John Wiley and Sons, 2000
- Failure Of Materials In Mechanical Design, Second Edition, by Jack A. Collins, John Wiley and Sons, 1993
- Product Reliability, Maintainability, and Supportability Handbook, CALCE Electronic Packaging Research Center University of Maryland, CRC Press, 1995
- Quality Control Handbook, Third Edition, Joseph Juran, McGraw-Hill, 1979
- Statistical Methods For Reliability Data, by William Q. Meeker and Luis A. Escobar, John Wiley and Sons, 1998
- Vibration Analysis For Electronic Equipment, Second Edition, Dave S. Steinberg, John Wiley and Sons, 1988

4 Procedure

4.1 Preparation. A pre-HALT meeting is required to discuss HALT test specifications, the product functional test requirements, method of fixturing the product to the table, product components and/or locations to monitor with thermocouples and accelerometers.

4.1.1 Test Equipment Setup Requirements. The HALT system and ancillary test equipment setup and operation are performed in accordance with manufacturer's instructions. Verify that all test equipment to be

utilized for the HALT is calibrated and operable. Document the test equipment in the test reporting documentation including equipment description, model number, serial number, and calibration status.

4.1.2 Test Samples. The test samples should be uniquely identified by a serial number or other means of identification.

4.1.2.1 Test Sample Setup Requirements.

4.1.2.1.1 Ensure that a thermocouple (product thermocouple) is properly attached to the test sample to provide the reference for chamber thermal set point adjustment. This is the thermocouple used for HALT control systems that use a closed loop feedback thermal measurement for chamber temperature control. The product thermocouple is attached to a location that provides an accurate approximate average of the temperature of the sample. The product thermocouple should be placed on an exposed surface on the test unit, preferably in an area of relatively low thermal mass. This thermocouple should not be placed on or near a heat generating component, or inside a totally closed portion of a product. A typical location would be on top of a large non-heat generating chip. The thermocouple wires should be attached to the circuit board with polyimide film tape with a silicon adhesive and the thermocouple should be glued to the chip with thermally conductive thread locking adhesive. The thermocouple should be electrically isolated from the active product circuit with an insulating band of polyimide tape. The top of the thermocouple should be covered with a coating of the adhesive to insure that the temperature of the board is measured and not the air passing over the thermocouple. Document the location of this thermocouple to minimize variation when future testing is conducted. Photographic documentation is preferred.

4.1.2.1.2 Secure the test sample(s) to the vibration table using a suitable test fixture that maximizes the transfer of thermal and vibration energy to the sample. The goal is to stimulate products tested to accelerate fatigue damage and uncover product weaknesses. Therefore, optimization of maximum stress to the product is beneficial.

4.1.2.2 Product Size and Weight. Product size and weight should be taken into account when determining feasibility of a particular chamber to properly stress the product.

4.1.2.3 Thermal Transition Rates Thermal transition rates on the sample may be improved by modification of the test sample(s) coverings. This may include the removal of panel/covers or perforation of the cover by drilling holes.

4.1.2.4 Thermocouple Mounting. Product response thermocouples are attached to adequately assess the response of the sample(s) to the thermal environment. Examples include components that may be sensitive to thermal transitions, components designed to respond to temperature, and on a high mass portion of the sample to provide a measure of the dwell time necessary to achieve temperature stabilization.

4.1.2.5 Accelerometer Mounting. The goal for vibration is efficient transmission of table energy to the sample(s). A minimum of one sample response accelerometer is affixed to the test sample. The accelerometer can be attached with either cyanoacrylate adhesive (super glue) or hot melt adhesive. This requirement is performed prior to the vibration step stress portion of the HALT. Document the location of this accelerometer to minimize variation when future testing is conducted. Photographic documentation is preferred.

4.1.3 Functional Testing Requirements. The functional test of the sample under test should be adequate to determine the performance of the sample and the occurrence of multiple types of failure modes. The test must exercise the major functions of the product with a feedback measurement of performance of these functions. The goal of the functional test is to achieve 100% test coverage, or as complete test coverage as is possible, of the sample under test.

4.1.3.1 Product Specific Stresses. These stresses are specific to the product tested and are performed during each step stress to enhance additional failure precipitation and detection. These stresses should include power cycling, and may include intentionally varying the line voltage, line frequency, Direct Current (DC) supply voltage, on-board oscillator frequency, output loading, and any others that are applicable. These product specific stresses are incorporated into the functional testing and should be performed at each level of stress throughout the HALT process.

4.1.3.2 Test Sample Documentation. The functional testing of the sample under test must be documented. The documentation shall provide definition of the amount of test coverage, in percentage, and include a detailed description of the test performed, identifying how and what is tested on the product. Documentation shall also provide evidence of how the functional test objectives as defined in the pre-HALT meeting were achieved.

4.1.3.3 Pre-HALT Test Integrity/Sample Baseline. Before beginning the HALT process, the test sample(s) is subjected to one or more cycles of functional testing to verify the integrity of the test setup and obtain baseline performance information for the test samples, if applicable.

4.1.3.4 Sample Degradation. At each level of applied stress, functional testing is performed on the sample to evaluate the operation of the sample. Documentation shall detail the occurrences of sample degradation and the conditions at which they occurred, including the operating and destruct limits of the sample and any other important comments.

4.2 Conditions. Varies based on test objectives. See 1.3 Remarks. See 3.2.1.1 Vibration.

4.2.1 Environmental Conditions. Varies based on test objectives. See 1.3 Remarks. See 3.2.1.2 Thermal.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions. The process outlined in 4.3.1 through 4.3.6 included the following:

- HALT with corrective action to make the product robust.
- HASS/HASA, a process to maintain that robustness throughout the production life cycle.
- Use of Control Charts and Pareto Charts to form a decision making process for continuous improvement as well as reaction to perceived problems during screening.
- Re-HALT to act as a maintenance process to insure that expected design margins are maintained over long periods of screening activity.

4.3.1 HALT Test Procedure. The methods or activities that are performed during the actual process of performing a HALT on a product in a test facility are given in 4.3.1.1 thru 4.3.1.4.

4.3.1.1 Thermal Step Stress Test. See Figure 1.

4.3.1.1.1 Thermal Step Stress shall begin at ambient temperature (defined as +20 °C to +30 °C). The maximum "high" temperature should be identified prior to test based on the phase change limitations of the materials involved. Plastic cases should be removed to allow electronics to reach higher temperatures. The test should never allow for the phase change of materials. The legitimacy of the temperature test will depend on not creating intentionally foolish failures. The step increments usually occur in 10 °C steps, but may be increased to 20 °C steps when appropriate.

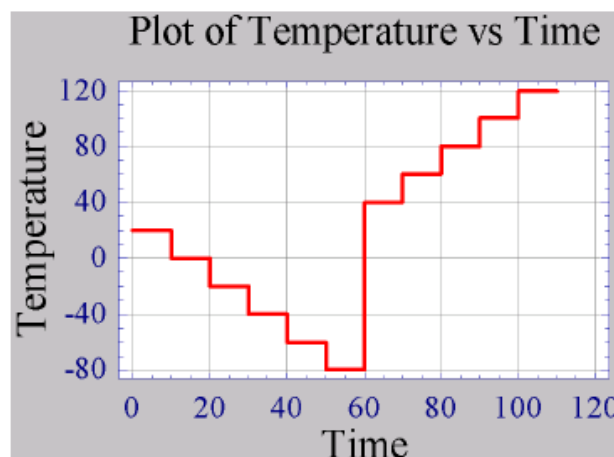


Figure 1: Thermal Stress Step: Temperature Profile

4.3.1.1.2 The temperature dwell time must be long enough to ensure complete stabilization and saturation of the device and its components. This dwell time is usually between five minutes and fifteen minutes following stabilization of the sample at the set point temperature as determined by the sample thermocouple response. Thermal mass of components will direct the engineering judgment of using a minimum or maximum dwell period. Complete functional testing immediately follows the dwell period, and may also be performed throughout the step.