HASS Guideline

Change Record

Rev	Originator	Description of Change
3/22/04	C. Drake (QualMark Corporation)	Initial release
10/12/07	M. Feero (Qualmark Corporation)	Updated logo

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1.0 Purpose

1.1. This instruction describes the method for performing HASS (Highly Accelerated Stress Screen) Development. It is intended for the use of companies as a guideline to perform the HASS Development process within their facility with qualified personnel and fulfill the requirements as defined in this procedure. The result of adherence to this document is that companies will achieve optimal HASS results and delivery of more robust/rugged products to the marketplace.

2.0 Scope

2.1. The process elements to successfully implement and perform HASS are defined in this document. Adherence to this document will provide management and test personnel the fundamental guidelines to implement and operate a successful HASS test process. This guideline applies to a diversified mix of product segments, including electronic assemblies, electro-mechanical assemblies, and may be applicable to certain mechanical assemblies as well.

3.0 Definitions

3.1. Destruct Limit (DL) – The stress level where one or more of the product's operating characteristics are no longer within specification. The product does not recover when the stress is reduced (i.e. hard failure).

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

3.2. HASS (Highly Accelerated Stress Screen) - A production screen using the same accelerated techniques as HALT, but derated. Its purpose is to monitor the manufacturing process for deviations, by screening production units.

3.3. HASS Development - A process used to determine and define the appropriate HASS profile.

3.4. HASS Profile - The temperature, vibration levels, SSR control, and number of cycles performed to provide an effective screen using the HASS chamber.

3.5. NTF, (No Trouble Found) - A product failure mechanism that has occurred in use but cannot be reproduced on the bench when returned to manufacturer.

3.6. Operational Limit (OL) – The stress level prior to where one or more of the product's operating characteristics are no longer within specification. The product recovers when the stress is reduced (i.e. soft failure).

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

3.7. Parametrically Marginal unit – A unit that has been determined to be marginal based on functional testing results.

3.8. Production HASS Test - The process of screening manufactured products using accelerated test techniques.

3.9. Seeded Defects - Defects that are intentionally inserted into a test unit to determine the effectiveness of the HASS screen. These defects attempt to replicate a manufacturing process going out of control. Typical seeding would include; cold solder joints, or other types of solder defects, excessive mechanical bend radius of component leads or nicking a component lead, or incorrect or improper component insertions.

HASS Development Procedure

HASS Development includes the following processes:

- Equipment and Functional Testing Requirements
- Fixture Design and Qualification
- Profile Design
- Proof of Screen
- Screen Effectiveness
- Product Life Valuation

4.0 Equipment Requirements

4.1. HASS Chamber Requirements

4.1.1. The equipment required to perform HASS testing must be capable of producing thermal and vibration energy stresses as defined below. In addition, it must have the capability to create these stresses in a combined environment; i.e. the chamber must have thermal and vibration capability within one chamber.

4.1.2. Vibration: Chamber technology for HASS is:

- Repetitive shock vibration that is 6 degree of freedom (3 linear and 3 rotational) multi-axis and quasi-random
- Broadband energy exists from 20 Hz up to 5,000 Hz
- 35 Grms minimum vibration table output with no load

4.1.3. Thermal: the goal is to force rapid thermal rates of change 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.

- High rate of change (minimum air temperature average of 45ºC/minute)
- Thermal range from -80ºC to 170ºC

4.2. Test Equipment

4.2.1. Product response data is acquired during the HASS Development process. This data includes thermal, vibration and product functional performance.

4.2.2. 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 HASS test system or the use of a data acquisition instrument capable of multiple channel measurements.

4.2.3. 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 HASS test system or the use of a spectrum analyzer instrument capable of measuring sensors (e.g. accelerometers) and displaying the data.

4.2.4. Accelerometers for the measurement of product response from vibration. These accelerometers should be low mass type (e.g. 4 grams), with frequency response capability of 2 Hz to 10KHz, and a measurement range of ± 500 g's. 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.

4.2.5. Thermocouples for the measurement of product thermal response. Thermocouples used for HASS should have sufficient stability characteristics through the temperature range of the chamber (approximately -100ºC to +200ºC). The diameter of the thermocouple wires should not exceed 22 gauge.

5.0 Functional Testing and Troubleshooting Requirements

5.1. The functional test of the product under test should be of adequacy to determine the performance of each 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 each sample under test.

5.2. Product specific stresses are stresses that are specific to the product tested. They are performed during the HASS profile to enhance additional failure precipitation and detection. These stresses may include power cycling, line voltage margining, line frequency margining, DC supply voltage margining, output loading, and any others that are applicable. These product specific stresses are incorporated into the functional testing and should be performed during the HASS profile.

5.3. As functional limitations or failures are encountered, it may be desirable to perform additional investigation to better understand the failure mode. Investigations, such as these, are inherent to the HASS Development process and should be encouraged when beneficial information can be obtained.

5.4. It is highly desirable that parametric data (gain, noise, common mode rejection, etc.) be gathered on the product throughout HASS Development. Preferably, this data should be gathered through an automated process, i.e., under software control. Parametric data will be valuable as product limitations are encountered to assist in the determination of what their cause may be.

6.0 Fixture Design and Qualification

6.1. Design and Construction

6.1.1. A fixture, or fixtures to support both vibration and thermal requirements, is necessary to perform screening on one or multiple units. The fixture used during HALT should be investigated as it may fulfill the HASS requirements, or as a minimum provide fixture transmissibility information for the new design concept. The product fixture needs to be able to withstand the fatigue damage caused by the repeated stresses that will occur over the fixture's lifetime. The fixture needs to be lightweight, rigid, and have low thermal mass. The design, fabrication, and evaluation of fixturing for thermal and vibration testing shall use the following guidelines:

6.1.2. A special plenum may need to be manufactured, or air ducting modified, which will provide nearly uniform airflow across all products tested.

6.1.3. If possible, modify normally airtight portions of a product's chassis by removing covers to allow airflow to the internal components. This may not be acceptable or practical for many applications.

6.1.4. The ideal fixture will provide a one-to-one transmission of energy from the vibration table to the units measured response.

6.1.5. The fixture must support the required number of units to test (throughput). The fixture design shall attempt to optimize the chamber's table surface area.

6.1.6. The fixture design should accommodate expedient product loading and unloading requirements.

6.1.7. Fixturing should be designed to minimize mass and table dampening. Fixturing will typically be constructed of lightweight aluminum extrusions, sheet metal, and plate, and secured with threaded rod and standard fasteners.

6.1.8. It is desirable to duplicate a product's normal mounting configuration, provided the product can be secured to the vibration table in a way that provides adequate transmissibility of energy to the product.

6.1.9. If a product's chassis is designed to dampen the transmission of vibration energy into the product, then the chassis may be modified, to maximize the transmissibility. This may not be acceptable or practical for many applications as determined by engineering.

6.1.10. Fixturing also needs to allow adequate room for any cable routing, and any required operator intervention or access (though the chamber access port), if necessary, to facilitate the functional test of the unit(s).

6.1.11. An attempt should be made to fixture for an even number of products uniformly distributed across the table, to achieve greater energy uniformity, due to the modal shapes of the vibration table.

6.2. Fixture Qualification

6.2.1. Each product location in the fixture is mapped for thermal uniformity, thermal rate of change, and vibration transmissibility. The intent of mapping is to ensure that each product receive similar stress levels during the HASS test exposure.

6.2.2. Affix a nonfunctional unit to each fixture location, if none are available a functional unit may be used.

6.2.3. Record all torque levels employed for each attachment location.

6.2.4. A thermal pseudo load that would represent similar thermal characteristics as the test unit may be used for occurrences that prohibit direct attachment to the test unit. This may be accomplished by simply utilizing an area on the fixture, or designing a separate load.

6.2.5. Thermocouples are placed on each (non-powered) unit, in the same locations on each, and uniformity from unit to unit shall be minimized (rule of thumb: variance $\leq$ 15°C). If thermal variance, from unit to unit is excessive, then the airflow ducting / fixture should be redesigned to meet the criteria. The thermal rate of change variance, from unit to unit, shall also be minimized (rule of thumb: variance $\leq$ 10°C). Engineering expert judgment is used to determine the acceptance of the fixture to these criteria.

6.2.6. The thermocouple measurement data shall be recorded and plotted using a spreadsheet software program, such as Microsoft Excel, to determine rate of change, and to assess temperature uniformity across all units.

6.2.7. Attach accelerometers, during the Fixture Qualification process to characterize the vibration response of the product(s). The attachment locations should replicate those as used during the HALT to determine fixture transmissibility differences from the HALT to HASS fixturing. Attachment of accelerometers is not required during Proof-of-Screen or Production HASS.

6.2.8. Accelerometers are placed on each unit to measure the vibration energy levels. The total vibration variance from unit to unit should be less than 10 Grms, or a maximum of 50% variance between the highest and lowest measured response. If the variance is excessive, then a fixture modification may be required to meet the criteria, and the measurements repeated. Engineering expert judgment is used to determine the acceptance of the fixture to these criteria.

6.2.9. Attachment location torque levels may be increased or decreased from fixture to fixture, within limitations, to counteract vibration response variances.

7.0 Profile Development

7.3. A profile shall be designed, and tested for effectiveness and life valuation (an estimate of product life). This begins by designing the profile around the HALT results, product specific criteria, functional test considerations, the customer's knowledge of their product, and the results obtained during fixture qualification (what are the measured product response variances from HALT to HASS).

7.4. This is not intended to be a rigid process that has an endpoint; rather HASS Development is a living process that may need modification or adjustment over the life of the product. As more is learned about the product over time, including the HASS results, the profile may change and evolve into a better screen.

8.0 Profile Criteria

8.1. The product must first undergo an accepted HALT process as a prerequisite before HASS Development can proceed.

8.2. The HALT results are generally the predominant factor in determining the HASS profile limits. Another factor to consider is any long-term product degradation because of environmental exposures (example - tape read/write head suffers long term degradation effects from a film build-up at elevated temperatures).

8.3. The vibration levels desired are those as measured on the products, typically levels of 10-20 Grms or more are desired.

8.4. Include any product specific stresses, such as power cycling, input voltage variation, load variation, frequency variation, etc. as appropriate.

9.0 Profile Type

9.1. Two approaches to developing the profile can be used, the Standard Profile, or the Precipitation / Detection Profile. This initial profile provides a starting point, hence, both temperature and vibration levels may require modifications to uncover defects without removing significant life from the product(s).

9.2. Standard Profile: This is a more traditional approach to screening, in that repeated cycles (two or more) are typically performed within the OL's of the product.

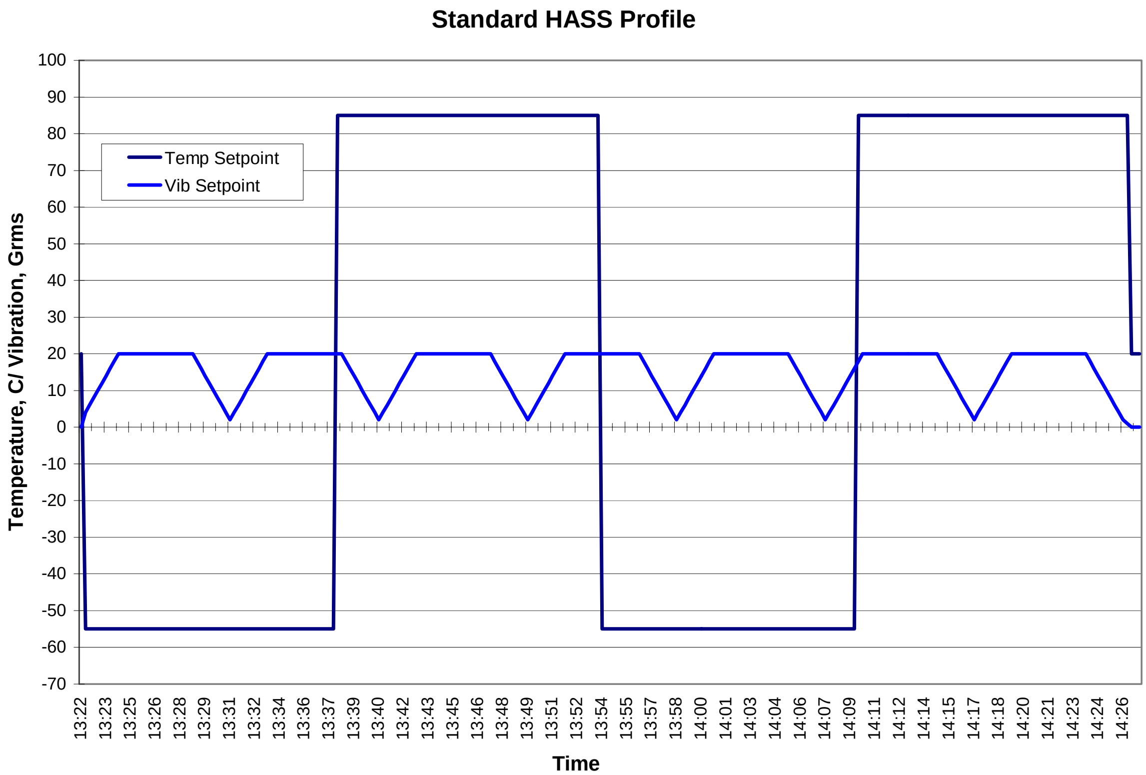
9.3. The typical levels chosen "rule of thumb" are 80% of the cumulative range of the upper and lower thermal operating limits. (Example: for UOL of 100°C and LOL of -50°C equal 150°C range, use 85°C and -35°C). Formula: X = ((LOL - UOL)* .20) / 2. Where X equals the margin temperature subtracted from both the LOL and UOL.

9.4. Vibration setpoint levels should be established to obtain a product response equal to 50% of the DL product response, but within the OL product response, found during HALT, as measured on the product. If the 50% value exceeds the OL, then use approximately 80% of the OL as the setpoint.

9.5. Vibration should be modulated throughout the profile, beginning at 5-10 Grms (or as low as the chamber will easily control without overshoot nor oscillation) and slowly ramped to the maximum level followed by a minimum dwell of 5 minutes. This process is then repeated in reverse, from the maximum level to the minimum level.

9.6. Dwell times at each temperature extreme will be dependent on the product(s) attaining the desired temperature, and dwelling a minimum of 5 minutes. The other variable affecting dwell is the length of the functional test. The full functional test should be completed at each extreme. The vibration modulation ramps should be as slow as possible, based on the aforementioned variables, with a requirement of a 5-minute dwell minimum at the maximum vibration level. Vibration maximum levels should be applied at the temperature extremes and during the temperature ramps, if possible.

Below is an example of a Standard HASS profile using 2 thermal cycles.



9.7. Precipitation / Detection Profile: This profile will involve subjecting the product beyond the OL's for the first cycle (precipitation), and the subsequent cycle(s) within the OL'S (detection). The precipitation cycle seeks to precipitate the dormant or latent defects as quickly as possible. The units are non-functional during the precipitation cycle, but may be powered. The detection cycle(s) seeks to detect the precipitated defects. The product(s) are powered and functionally tested during the detection cycle(s). This profile will typically consist of two cycles, one precipitation, followed by one detection cycle. If there is sufficient margin between the temperature OL and DL, then the Precipitation / Detection Profile should be used. An example of its use is, if thermal safety circuits that cause the unit to shutdown above a benign temperature then this profile may be helpful.

9.8. Precipitation cycle levels are performed between the OL's and DL's. A "rule of thumb" is to select levels equal to half the difference between the OL and DL (example: for UDL of 120°C and UOL of 60°C, use 90°C).

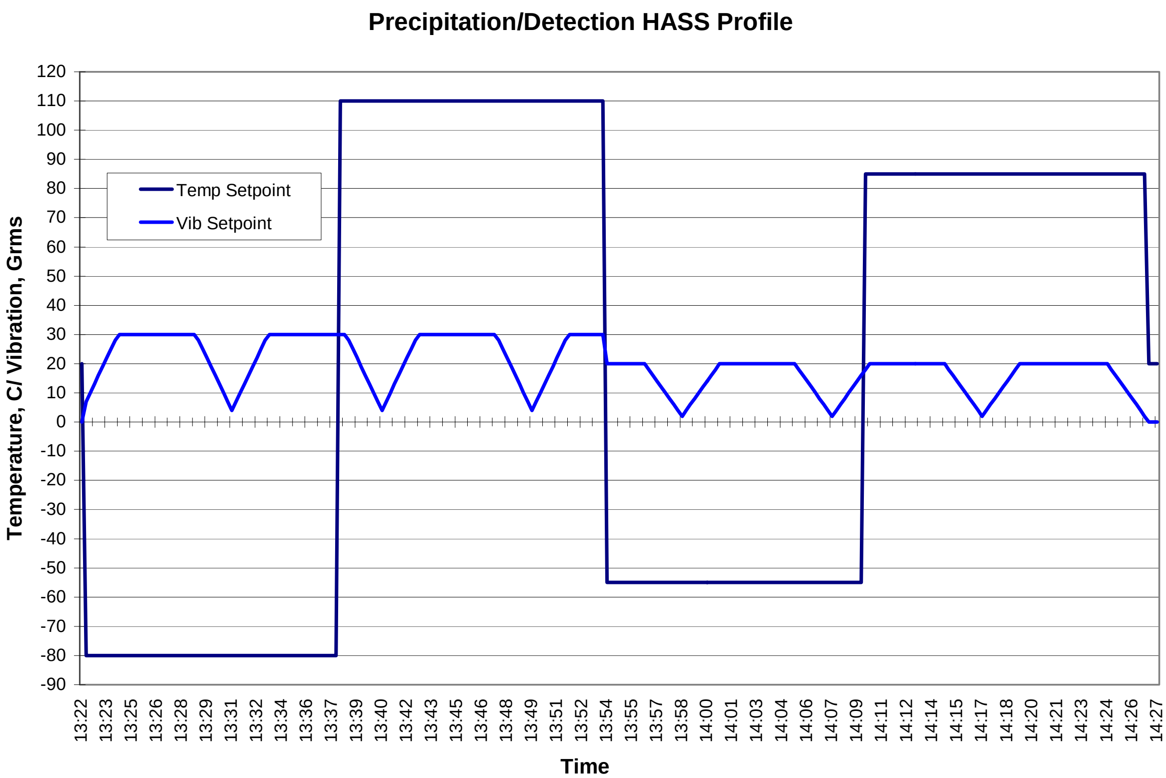
9.9. Detection cycle levels are performed within the OL's. A "rule of thumb" is to select levels 5°C to10°C within the OL's (example: for UOL of 60°C and LOL of -20°C, use 55°C and -15°C).

9.10. Vibration levels for the precipitation cycle should be 50% of the DL, and levels for the detection screen should be 80% of the OL, as measured on the product. (Example: for DL of 40 Grms and OL of 20 Grms, use 20 Grms for the precipitation cycle and 16 Grms for the detection cycle).

9.11. Vibration should be modulated throughout the precipitation and detection cycles, beginning at 5 to 10 Grms (or as low as the chamber will easily control without overshoot nor oscillation) and slowly ramping to the maximum level. This process is then repeated in reverse, from the maximum level to minimum. The vibration maximum level will be higher for precipitation, as defined above.

9.12. Dwell times at each temperature extreme will be dependent on the product(s) attaining the desired temperature, and dwelling a minimum of 5 minutes. The other variable to the dwell is the length of the functional test. The full functional test should be completed at each extreme. The vibration modulation ramps should be as slow as possible, based on the aforementioned variables, with a requirement of a 5-minute dwell minimum at the maximum vibration level.

Below is an example of a Precipitation / Detection HASS profile.



10.0 Proof-of-Screen

Proof-of-Screen is a two step process. The first step (*Screen Effectiveness*) is to determine how effective the screen is in detecting manufacturing flaws. This is done by precipitating and detecting latent defects. The second step (*Life Valuation*) is to prove that the screen has not removed significant life from the screened products. If a failure is not precipitated during the screen effectiveness process, because units with latent defects were not available, then expert engineering judgement shall be used to determine screen effectiveness.

10.1. Screen Effectiveness

10.1.1. The screen's effectiveness is measured by its ability to precipitate latent defects. Symptoms of manufacturing assembly related issues associated with the manufacturer's or vendor's process going out of control can include component weaknesses, PCB flaws, circuit timing problems, mechanical tolerance problems, solder defects, and others.

10.1.2. For this process, units classified as No Trouble Found (NTF) should be used (ideally, production floor NTF's should be used versus field return NTF's). Other candidate units would be those that are determined to be marginal from parametric functionality testing. Any production units, which meet these criteria, are excellent candidates to determine whether the screen will detect inherent failures. All of these units, if there are inherent failures that can only be detected by stressing, should fail during the HASS profile. If NTF units are not available, then production units should be "seeded" with defects. These defects should be representative of the manufacturing process going out of control, i.e. poor solder process, damaged or incorrect component insertion, etc.

10.1.3. All fixture locations should be populated with NTF, seeded, parametrically marginal, or functional units if none of the other types are available.

10.1.4. The initial profile shall be performed and the results analyzed. If any failures occur on the screened unit(s), these failures shall have a root cause analysis (RCA) performed to determine if the failure(s) were the result of overstress or wear-out, or due to a manufacturing process flaw. If a failure occurs, at any point during the profile execution, the profile should be stopped, and RCA performed.

10.1.5. The RCA results will determine whether the profile levels are correct, or require modification. If the failure(s) were the result of overstress or wear-out, the profile levels shall be reduced, and the profile re-executed using previously non-tested unit(s). On the other hand, if the defects are not detected, the screen severity is increased and the process repeated. The severity shall be increased by either expanding the profile levels, or increasing the number of cycles performed. The levels will typically be increased in 10°C increments, but the increment value can be higher or lower, depending on product variables. Increasing the cycle count extends the total Production HASS duration. Therefore should be done only when the level severity can not be increased.

10.2. Product Life Valuation

10.2.1. This process shall estimate the degree of appreciable life remaining in the product(s) after exposure to the HASS screening profile. The profile shall be repeated a minimum of 10 times, without failure occurrences. This shows that production units exposed to only one pass of the profile, will still have 90%, minimum, of the useful life remaining, or 10%, maximum, of life removed. For example, if the HASS profile were 2 cycles, then these units would be subjected to 20 cycles, or one order of magnitude greater than the HASS requirement without failure. For greater confidence, it is recommended that these repeats be in the order of 30 to 50 times.

10.2.2. Production level unit(s) shall be used for this process, with all fixture locations populated.

10.2.3. If any failures occur on the screened unit(s), these failures shall have a root cause analysis (RCA) performed to determine if the failure(s) were the result of overstress or wear-out, or due to a manufacturing process flaw. If a failure occurs, at any point during the profile execution, the profile should be stopped, and RCA performed.

10.2.4. This unit(s) may be subjected to the normal qualification process for your products, if done as part of the product development cycle, or other accelerated life tests, upon completion of this Life Valuation. The purpose of this would be to give even greater confidence that the products have not been degraded significantly and that minimal life has been removed.

10.2.5. The RCA results will determine whether the profile levels are correct, or require modification. If the failure(s) were the result of overstress or wear-out, the profile levels shall be reduced, and the profile re-executed using previously non-tested unit(s).

11.0 HASS Profile Evolution

11.1. It is essential that the screen profile be audited on a continual basis throughout the life of the product. This ensures that the screen remains effective, and that subtle changes in the product are not causing the screen levels to move into the damage area. If failures are occurring in use, then screen severity levels may need to be increased if the failure are process related, or the screen severity may need to be reduced if the failures are due to overstress or wear-out.