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# Qualmark HASS/HASA Guideline

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### Revision History

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## Qualmark HASS/HASA Guideline

### 1. 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.
- 1.2. This instruction also describes the method for performing HASA (Highly Accelerated Stress Audit) Development. With the exception of defining the auditing process and levels, and the resultant changes in throughput requirements, HASA development is nearly identical to HASS development. Unless indicated otherwise, all statements in this instruction that refer to HASS also apply to HASA.

### 2. 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 some mechanical assemblies as well.

### 3. 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)

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- 3.2. HASA (Highly Accelerated Stress Audit) – An environmental stress test that is used in production on a sample of the production units. It is often used in high volume production environments.
- 3.3. 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.
- 3.4. HASS Development - A process used to determine and define the appropriate HASS profile.
- 3.5. HASS Profile - The temperature, vibration levels, SSR control, and number of cycles performed to provide an effective screen using the HASS chamber.
- 3.6. NTF, (No Trouble Found) - A product failure mechanism that has occurred in use but cannot be reproduced on the bench when returned to manufacturer.
- 3.7. 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)
- 3.8. Parametrically Marginal unit – A unit that has been determined to be marginal based on functional testing results.
- 3.9. Product Specific Stresses – Stresses that are applied to the product during the HASS screen in addition to the thermal and vibration stresses provided by the HASS system. For example, applying variations to input voltages or to load levels. These are used to introduce new stresses and stress combinations that can improve the effectiveness of the screen by forcing more and different failure mechanisms to be detected.
- 3.10. Production HASS Test - The process of screening manufactured products using accelerated test techniques.
- 3.11. Seeded Defects - Defects that are intentionally inserted into a test unit to determine the effectiveness of the HASS screen.

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## HASS Development Procedure

HASS Development includes the following processes:

- HALT to determine operating and destruct limits
- Equipment and Functional Testing Requirements
- Fixture Design Qualification
- Fixture Integration Qualification
- Profile Design
- Proof of Screen
- Screen Effectiveness
- Product Life Valuation

### 4. HALT for HASS Development

- 4.1. It is very important that HALT be done on a product before HASS is implemented. HALT provides the basic information on the product's true functional and destruct limits that is used to determine the starting point for the HASS screen levels. Without this accurate starting point, screen development cannot be safely or effectively executed. In addition, if a product has latent design defects that are not detected and corrected in HALT before starting HASS, fallout rates in HASS will be unacceptably high and field returns and warranty expenses will suffer.
- 4.2. For the screen levels determined for HASS to be valid, they must be measured in the same way as the HALT stresses were measured. This means that it is particularly important to carefully document and duplicate sensor placements and measurement methods used in HALT when beginning HASS development. In all cases, the stress values used must be the stress as measured on the product, and not the stress input levels. Typically there are changes, sometimes significant ones, in the product fixturing, orientation or configuration that will change the effect of an input stress. Measuring the actual stress experienced by the product at specific,

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repeatable locations helps ensure that the HASS screen will provide the desired stress levels.

## 5. Equipment Requirements

### 5.1. HASS Chamber Requirements

5.1.1. 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.

5.1.2. 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


5.1.3. 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 50°C/minute)
- Recommended thermal range from -60°C to 120°C

### 5.2. Test Equipment

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


5.2.2. The collection and storage of thermal data is required to provide credible evidence that thermal stresses of the correct levels were applied to the product. This may be achieved by utilizing available thermocouple

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


- 5.2.3. The collection and storage of vibration data is required to provide credible evidence that vibration stresses of the correct levels were 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.
- 5.2.4. 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  $\pm 500$  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.
- 5.2.5. 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  $-60^{\circ}\text{C}$  to  $+120^{\circ}\text{C}$ ). Lighter weight thermocouple wire (22 gauge or less) should be used to minimize the effect of the thermocouple thermal mass on the ramp rate readings.



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## 6. Functional Testing and Troubleshooting Requirements

- 6.1. The goal of HASS is to force latent product defects to fail before the product is shipped. If those failures are not detected due to an inadequate functional test, then the HASS effort is wasted and defective products will reach the customer. It is very important that the functional test be as complete and thorough as possible. Functional tests should be able to detect failures that might result from known possible process upsets, or that have been seen already in the field. Because HASS is typically using stresses that are outside of the product's specifications or intended use environments, the failures found can be indications of the tails of failure distributions that have not yet reached a sufficient population or severity to be seen in an ambient environment. Consequently, HASS failures serve as an 'early warning system' of a process or product issue that could become more serious. To get the most value from this early warning, it is very important that failures found in HASS are always taken seriously, with rapid failure analysis and corrective action implementation. In HASA, this even more critical. Immediate, high urgency responses to failures in HASA are always appropriate to minimize field exposure.
- 6.3. Product specific stresses are stresses that are specific to the product tested. If these stresses were used in HALT, then they should also be considered for use 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.
- 6.4. 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.

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## 7. Fixture Design and Qualification


### 7.1. Design and Construction

7.1.1. Proper HASS fixturing must meet several key requirements. These include:

- Applying equal stresses (within a specified variation) to each product
- Applying these stresses consistently every time new product is loaded
- Applying these stresses consistently over time as the fixture ages
- Incorporation of cable management components
- Meeting required human factors considerations
- Maximizing capacity and minimizing load/unload times
- Minimizing any limiting effect of the fixturing on the table vibration characteristics
- Maximizing air flow rate and uniformity of flow through the products


7.1.2. A primary HASS Fixture design goal is meeting the desired uniformity specifications for product-to-product stress variation. Typically, temperature deviations of +/- 5°C or less at the end of a thermal dwell and gRMS vibration deviations of +/-15% or less are specified. These are deviations from the median readings rather than deviations from setpoint or system control values, and are measured on a single reference product that is placed in each location in the fixture. Custom air flow ducting may be needed. The best solution is often a modular fixture design, where several, identical fixtures, each holding a smaller quantity of product, are used simultaneously. In this case, the fixtures should be mounted in locations in the vibration system that have similar vibration characteristics. For example, on a square table, the vibration tends to be symmetric in quadrants of the table, so four fixtures, one in the center of each quadrant, are often used.

7.1.3. Loading and unloading a fixture can affect its transmission characteristics. The fixture must be designed so that these changes are minimized. If necessary, torque values can be specified for the hold-

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down hardware being used, but often it is difficult to use torque wrenches in a manufacturing setting. Pneumatic fixturing that exerts the same clamping force regardless of variations in product size and placement can be a solution. Clamps can also work, although they often include padded clamping surfaces that introduce variability and damping.

- 7.1.4. The vibration tolerance of the fixture itself is important to consider in design. If the fixture characteristics change due to fasteners coming loose, deformation of clamping members, etc, then the screen effectiveness will suffer. All connecting components used in the fixture should be evaluated for vibration tolerance.
- 7.1.5. When many products are tested simultaneously, the number of cables going in and out of the system can become difficult to manage. Also, the integrity of plug connections inside the chamber must be maintained, as connectors tend to wiggle loose during vibration. Finally, minimizing any wear and fretting on connector pins should be considered. A good fixture design will minimize the relative motion between the mating components and so reduce this potential for wear.
- 7.1.6. Human Factors considerations for fixture design include lifting limits, bending and reaching limits, pinch and cut risks, etc.
- 7.1.7. In any production environment, capacity and speed are important. Minimizing cable connections, using simple methods to secure product into the fixture and keeping all of these activities as 'foolproof' as possible will all help meet these needs. It is often feasible to create fixture modules that can be loaded with product outside of the chamber, thus increasing throughput further.
- 7.1.8. The fixture can have a significant effect on the spectral characteristics of the vibration as well as the air flow. These effects should be minimized for the best screen results. Avoid heavy, large, rigid fixture designs that will stiffen large areas of the table. Also, orient product so that the air flows above and below the product without obstruction. High thermal change rates can only be achieved if the product can see high air flow rates. This can be difficult when the chamber is full of product, since the fixturing and product in one quadrant will often disrupt the air flow across the adjacent one. Staggering the product placement slightly, or using custom air flow components can help meet these goals.

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7.1.9. The product may have design characteristics that directly interfere with the goals of HASS. For example, the chassis may be designed to minimize vibration transmission to the interior of the product. The product may be air tight, making fast thermal change rates inside of the product impossible. In these cases, consider doing HASS with covers removed, or perhaps performing HASS at a lower assembly level. For HASS to be successful, it is imperative that the assemblies and subassemblies in the product are stressed sufficiently to meet the HASS screen requirements.

## 7.2. Fixture Design and Integration Qualification

Two levels of qualification are recommended before implementing a HASS fixture – Design and Integration Qualification.


- The Design Qualification is done first. Its purpose is to demonstrate the vibration and thermal uniformity and repeatability of the design.
- The Integration Qualification is intended to demonstrate the full functionality of the fixturing in the final production environment.

### 7.2.1. Fixture Design Qualification

7.2.1.1. The Fixture Design Qualification does not need to be done using the final HASS system. If the fixture is being designed and built by a third party, the Design Qualification is typically done by the third party, using non-functional or dummy products.

7.2.1.2. It is important that the fixture be completely loaded with products (not necessarily functional products) during Design Qualification.

7.2.1.3. The key output of the Design Qualification testing is the demonstration of the uniformity of the vibration and thermal stresses across the fixture. The best way to do this is to fully instrument a single reference product with accelerometers and thermocouples in all key locations. Then, mount this reference product into each of the locations in the fixture, taking readings at each location. When the readings are taken, the rest of the fixture should be filled with product, so that the effect on air flow and vibration is accurately simulated. It is better to move the reference product, rather than moving the sensors to different products, to reduce variables in the qualification. All measurements should be taken at the same input stress levels.

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7.2.1.4. During the Design Qualification, it is often necessary to make changes to the fixturing to reach the desired levels of uniformity.

#### 7.2.2. Integration Qualification

7.2.2.1. Integration Qualification is done in the actual production screening environment. Its purpose is to confirm the fixture functionality when all of the additional influences of this final environment are included.

7.2.2.2. For Integration Qualification, the fixture is fully populated with functional units so that any cabling issues can be identified and resolved. The fixture should be loaded and unloaded by personnel who will be using it. The functionality of all test equipment will also be evaluated during this qualification.

7.2.2.3. A part of the Integration Qualification is the repetition of the uniformity evaluation that was done during Design Qualification. The addition of cabling, changes in the system used and even the changes in liquid nitrogen delivery system can affect uniformity, so this second check for uniformity is important.

7.2.2.4. At the end of the Integration Qualification, the fixturing should be ready for production use.


#### 7.2.3. .Fixture Maintenance

7.2.3.1. As with the HASS System, Preventative Maintenance for the fixture is important. A P.M. procedure should be defined that includes verifying thermal and vibration transmission to the product, torque levels on all fasteners, evaluating electrical connectors for wear, etc.

## 8. Profile Development

The goal of the HASS profile is to provide sufficient stresses to force latent defects to become detectable, without inducing new stress related failure modes. This goal is met by starting with stress levels based on the HALT results, properly guardbanded, then doing a Proof of Screen to evaluate the screen effectiveness and safety.

8.1. To create the initial HASS profile, vibration and thermal limits are chosen based on the following guidelines:

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- 8.1.1. 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.
- 8.1.2. The thermal levels are chosen to result in a thermal range that is 80% of the range between the upper and lower operating limits found in HALT. This can be calculated as:

$$X = ((LOL - UOL) * .20) / 2$$

Where X equals the margin temperature subtracted from the upper operating limit and added to the lower operating limit.


Remember to include any product specific stresses, such as power cycling, input voltage variation, load variation, frequency variation, etc. as appropriate.

## 9. Profile Type

There are two basic types of HASS profiles. One is a Detection Profile, where the stress levels are determined as described above, and are within the functional limits for the product. The product is powered and functionally tested throughout the profile. The purpose of the profile is to immediately detect any induced failures. The second is the Precipitation-Detection Profile. In this profile, the product is first stressed beyond its functional limits, without any functional testing, then the stresses are reduced to levels within the functional limits of the product, and the product is functionally tested. The purpose of this two step profile is to first precipitate failures, using higher levels of stresses, then detect the failures while stressing at the lower levels. If a product has a significant delta between the operating and destruct limits found in HALT (For example, greater than 30%) then the Precipitation-Detection profile will be more effective. If, however, the thermal and destruct limits are close to each other, then the Detection Profile alone should be used.

### 9.1. The Detection Profile


- 9.1.1. In the Detection Profile, the temperature is cycles between the upper and lower limits as identified above, while the vibration is applied. The unit is powered and is functionally tested throughout the profile.

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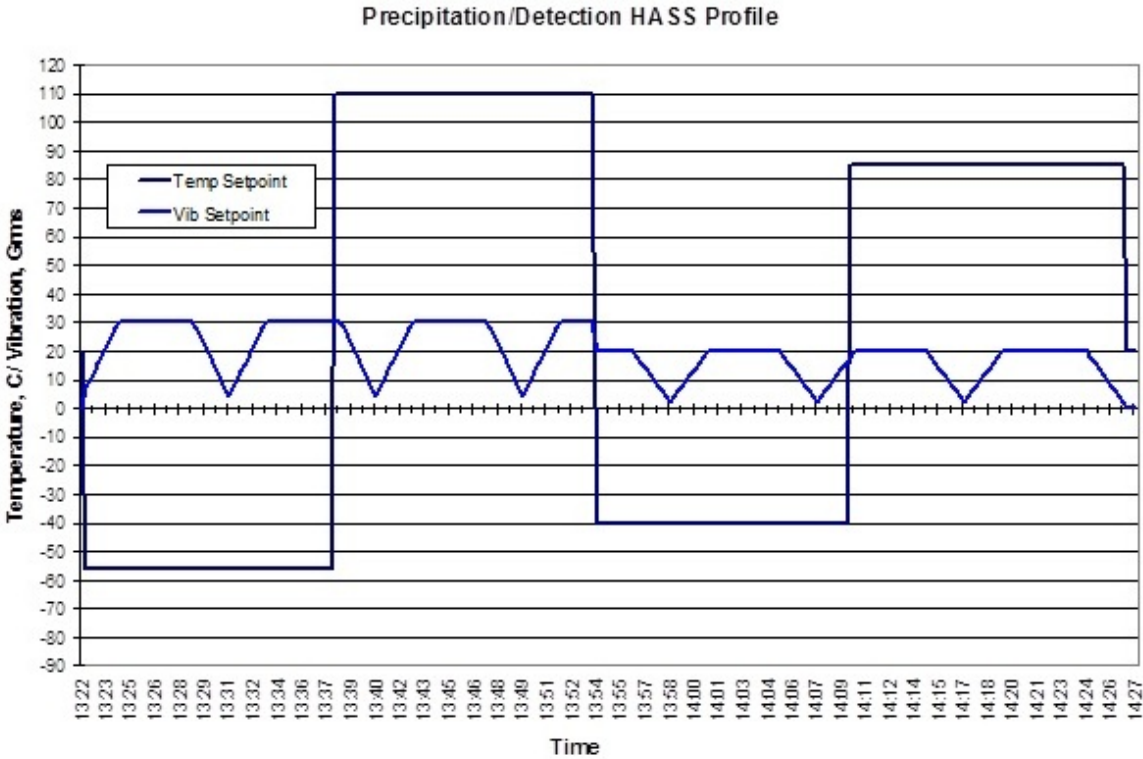
- 9.1.2. The vibration should be modulated throughout the Detection Profile, beginning at 5-10 Grms and ramping to the maximum level followed by a minimum dwell time of 5 minutes. This process is then repeated in reverse, from the maximum level to the minimum level.
- 9.1.3. The temperature cycle is set so that the ramps go as fast as possible. The temperature dwells at the extremes should be at least 5 minutes, longer if necessary to bring the entire product to the temperature setpoint.
- 9.1.4. The Thermal and Vibration profiles are set so that the product sees maximum vibration during the ramps and during a portion of the dwell.
- 9.1.5. It is important that a complete functional test be done during each thermal dwell. If necessary, the length of the dwells should be adjusted accordingly.






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9.4. Vibration levels for the Precipitation Cycle should be 50% of the DL.  
Below is an example of a Precipitation / Detection HASS profile.




**10. 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 (*SOS, Safety Of Screen*)) is to prove that the screen is safe, and will not removed significant life from the screened products.

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## 10.1. Screen Effectiveness

- 10.1.1. The screen's effectiveness is measured by its ability to precipitate latent defects. To demonstrate this effectiveness, it is necessary to screen products that would be expected to fail in the HASS screen due to latent defects. Units classified as No Trouble Found (NTF) are good for this purpose (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. . If necessary, known good units can be "seeded" with defects. These defects should be representative of the manufacturing process going out of control. These defects attempt to replicate defects that could occur if there was a problem in the manufacturing or sourcing processes, i.e. poor solder process, damaged or incorrect component insertion, etc. The defects should not be detectable by the production testing that is normally done. They should include marginal but acceptable performance defects, component value errors and any other valid defects that would demonstrate the effectiveness of the screen.
- 10.1.2. All fixture locations should be populated. If there are not enough units with latent defects available to fill the fixture, then known good products should be used in the remaining fixture locations.
- 10.1.3. The products shall be subjected to the initial HASS screen. 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, and there is a perceived risk that the failed unit may be damaged further if the screen is continued, possibly masking the original failure, then the test should be paused and the failing unit removed for RCA and replaced with another unit. Then, the testing should resume where it left off.
- 10.1.4. 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

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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, and so is less desirable.

## 10.2. Safety of Screen

10.2.1. This process shall demonstrate that the HASS screen profile is safe, and will not remove appreciable life from a product.. In this portion of the screen, the fixture should be loaded with fully tested and known good units. The profile shall be repeated a minimum of 20 times, without failure occurrences. This shows that production units exposed to only one pass of the profile, will still have 95%, minimum, of the useful life remaining, or 5%, maximum, of life removed. For example, if the HASS profile were 2 cycles, then these units would be subjected to 40 cycles. For greater confidence, it is recommended that of the screen profile be repeated 30 to 50 times.


10.2.2. 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.

10.2.3. After passing through these multiple screen cycles without failing, more rigorous evaluations of the products can be done. For example, the products can be subjected to accelerated life tests, or put through the Design Qualification Testing that was done during product development. 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.

10.2.4. 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. 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

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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.

## 12. Failure Analysis in HASS

- 12.1. Because the failures found in HASS are almost always found at stress levels far outside of the normal use environment, there can be a tendency to discount the validity of the failures, particularly in the face of production schedules and limited engineering resources. It is very important that this is not allowed to happen. A clearly defined closed loop failure analysis and corrective action process should be implemented on every failure found in HASS.

## 13. Variations on HASS

- 13.1. As with HALT implementation, the implementation of HASS often does not follow a specific, repeatable and unchanged process. Careful thought must be given to each product's characteristics, limitations and sensitivities, and the final HASS procedure that is implemented could be very different from what has been described in this document. The important part is to ensure that the core points of HASS – controlled overstressing of a product, based on known limitations found in HALT, and proved to be safe and effective in Proof of Screen – are adhered to. Following are some common variations to consider.
- 13.2. HASS on subassemblies: In many cases, the final product is not an ideal HASS candidate. Key components may be isolated from thermal and vibration stresses by the outside case. The shape of the product may not lend itself to consistent fixturing. Plastics or other soft, flexible materials that are part of the outside case may deform or experience cosmetic damage under HASS stresses. In these cases, it can be much more valuable to HASS the major subassemblies rather than the final, full-up assembly. This decision must be made by carefully considering the advantages and disadvantages of each process, including test coverage, complexity of test equipment, complexity of fixturing, cost and throughput.
- 13.3. Sometimes it is difficult, or even impossible, to find products that would be expected to fail during the HASS Screen Effectiveness Evaluation. In this case, a screen can be safely implemented by starting with screen levels that are somewhat higher than normal, then doing an aggressive Safety Evaluation (50 cycles or more) to ensure that the screen levels are safe.

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Then, implement the screen in production and monitor the failures closely for first several weeks. If failures are occurring in the first few cycles of the screen, and failure analysis shows that the failures are not due to overstress, then the screen can be considered to be effective. However, if valid failures are consistently occurring near the end of the screen, or failure analysis shows that the failures are due to overstress, then the screen should be adjusted.

#### **14. Use of HASS in contract manufacturing**

- 14.1. When a product is manufactured by a contract manufacturer, there can be communications delays and discontinuities between the designers of the product and the manufacturer. The impact of production issues or component changes may not be fully understood until field failures reach an unacceptable level. If the product is being manufactured off-shore, these problems are compounded. If HASS is used, it can provide a 'safety net' because it will detect potential problems early, and, if the designers are kept aware of HASS failures and failure analysis results, it will allow corrective action to be done quickly and efficiently. A properly implemented HASS process can dramatically reduce the risk of loss of control that is inherent in remote manufacturing.