HASS DEVELOPMENT METHODOLOGY: HOW TO DEVELOP A SCREEN, WHEN TO CHANGE A SCREEN, AND WHEN TO RE-PROVE A SCREEN

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BIOGRAPHY

Mike is an experienced leader in reliability improvement through analysis and testing. He has also led numerous quality system development programs. He has 20 years of reliability and quality experience, the majority in start-up companies. Mike is also an expert in accelerated reliability techniques, including HALT and HASS. He set up and ran an accelerated reliability test lab for 5 years, testing over 300 products for 100 companies in 40 different industries. Mike is founder and managing partner at Ops A La Carte, a Professional Business Operations Company that offers a broad array of expert services in support of new product development and production initiatives. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 100 companies including Cisco, Ciena, Siemens, Intuitive Surgical, Abbott Labs, and Applied Materials. He has consulted in a variety of different industries including telecommunications, networking, medical, semiconductor, semiconductor equipment, consumer electronics, and defense electronics. Mike has authored and published 7 papers on reliability techniques and has presented these around the world including China, Germany, and Canada. He has also developed and currently teaches 8 courses on reliability techniques. Mike has a BS degree in Electrical and Computer Engineering from the University of Colorado at Boulder, and is both a Certified Reliability Engineer and a course instructor through the American Society for Quality (ASQ), IEEE, Effective Training Associates, and Hobbs Engineering. Mike is a member of ASQ, IEEE, SME, ASME, PATCA, and IEEE Consulting Society.

ABSTRACT

HALT and HASS are two very powerful tools that can help manufacturers quickly achieve high reliability both in the design phase and in the manufacturing phase. HALT is used during the design phase to help reduce the number of design-related and process problems. HASS is used during the production phase to help reduce the number of infant mortality failures by discovering problems that may have arisen through an unacceptable (and, in many cases, unknown) change within the manufacturing process. HALT is almost always performed prior to developing a HASS profile because the HASS profile uses the information from HALT when choosing the profile parameters.

Screens for HASS are always developed using a HASS Development process. The goal during HASS Development is to provide the most effective and quickest screen possible. The effectiveness of the screen is measured in its ability to find defects in the product without removing significant life from the product.

This paper describes different methods of developing a screen using the HASS Development methodology. It also gives guidelines on when to change a screen and when it is necessary to re-submit a product through the HASS Development process in order to re-prove a screen.

KEY WORDS

HALT	Acronym for Highly Accelerated Life Test. In HALT, stresses such as six degree-of freedom repeated shock vibration, rapid temperature transitions, voltage margining, frequency margining, and any other stresses that are appropriate are used to find the weak links in the design and fabrication processes of a product. HALT is performed during the design phase.
HASS Development	The process of showing that a screen does not damage good hardware and that the screen is effective in finding all of the defects present in a product.
HASS	Acronym for Highly Accelerated Stress Screen. In HASS, the highest possible stresses are used in order to reduce the time of the screen. The screen must be proven using the HASS Development process prior to using it in manufacturing. HASS is performed on 100% of the units being shipped for the product being screened.
HASA	Acronym for Highly Accelerated Stress Audit. The same screen is used in HASA as in HASS, but rather than screening 100% of the units, a very small statistical sample is screened, and based on the results, root cause and corrective action are pursued.
FMEA	Acronym for Failure Modes and Effects Analysis. This is the process of reviewing each possible mode of failure (for example, a resistor can fail either short, low resistance, high resistance, or completely open), and then determining the effects of each failure on the overall operation of the product. This process can be very useful in determining the vulnerability of the product to each type of failure to decide if the design needs to change (different value, technology, or possibly even redundancy).

INTRODUCTION

During HASS Development, the stress types are chosen (vibration, thermal, electrical stresses, etc.), including magnitudes, sequences, and dwell times using the limits discovered in HALT. For this reason, it is essential to perform a comprehensive and complete HALT prior to development of the screen to find and understand the design margins of the product.

When possible, all the samples used during HASS Development are obtained directly from the manufacturing line, not having gone through HALT or other stressing. Before the HASS Development is begun, a production fixture is designed to test numerous units at the same time (and this is needed in order to meet production requirements).

The production fixture for both temperature and vibration is mapped with a product attached to determine the stress levels at each product location. The chamber control system setpoint levels are adjusted until the desired product response levels are achieved. The samples in the fixture are arranged so that the location with the highest and the lowest vibration response levels are both populated with working samples (non-functioning samples can be placed in the other locations). The reason for this is because the production HASS must be consistent in the types of defects it finds, and therefore, the HASS development must prove this by testing the maximum variation on the table. The same is done with thermal, using locations with both the highest and lowest thermal rates of change.

The byproduct of HASS Development is the screen to be used during HASS.

HOW TO DEVELOP A SCREEN

There are four distinct methods for developing screens using the HASS Development process: Method 1 – HASS Development using "seeded" samples; Method 2 – HASS Development with a small sample; Method 3 – HASS Development using a large sample; and Method 4 – HASS Development for sample screening. Methods 1 and 2 are used when the screen must be optimized but the number of units available for the process are low (one to two). The difference between Method 1 and 2 is that in Method 1, "seeded" sample units (samples in which intentional process defects are interjected) are utilized as well as units directly off the production line, whereas in Method 2, "seeded" sample units are not used (usually because they are not available). Instead, the limits are gradually increased until a failure occurs. Method 3 is used when the screen must be optimized and several units can be used for this optimization process. The limits are gradually decreased until the screen runs without failure. Method 4 is used when the screen being developed is to be used on a sample basis and, thus, the profile can afford to be less than optimal.

Method 1

In this method, the HALT limits are reduced for the initial profile and the screen is run 50 times without failure. If failures occur, the screen levels are reduced and the screen is run another 50 times. This is repeated until the screen is run 50 times without failure. Repeating 50 times without failure will give confidence that the final screen is not too strong (that it will not break good hardware). Once this occurs, "seeded" samples are run to ensure that the limits are strong enough. "Seeded" samples are samples in which intentional process defects are interjected, such as cold solder joints and nicked leads. The HASS development process may take up to four days. The advantage of this method is that it usually only requires one set of production units to complete the HASS Development process. However, it will require several "seeded" sample units. Other types of units that can be used are "No Trouble Found" units which can come from the field or from the production floor that have suspected process issues. A disadvantage is that it is often difficult to create a "seeded" sample or to find a unit from the field or from production that is indicative of a process issue that may occur. Also, the "seeded" sample units only represent a portion of the types of process issues and these may not be the most difficult types of defects to find by a screen, thus giving a false sense of security in what percentage of defects the screen will be able to defect.

This method is ideal when units can be successfully "seeded" with defects, or when units from the field or from the production floor can be found with defects indicative of process issues.

Method 2

In this method, the HALT limits are reduced for the initial profile and the screen is run 50 times without failure, as in Method I. If failures occur, the screen levels are reduced and the screen is run another 50 times. This is repeated until the screen is run 50 times without failure. If the initial profile is successful, then the limits are adjusted up and the process is repeated until a failure occurs. This is done to assure that the limits are strong enough. The advantage of this method is that it usually only requires one set of production units. The disadvantage is that the HASS Development process may take more time to complete than Method 1.

This method is ideal when the units are expensive and therefore, the quantity of units available for HASS Development is low and when the reliability of the unit in the field is critical, making it advantageous to optimize the HASS profile.

Method 3

In this method, the HASS Development limits are set just below the HALT destruct limits and the screen is run 50 times. This is repeated until the screen is run 50 times without failure. Note that failures are liable to occur since they occurred near these levels in HALT. The advantage of this method is that it uncovers more failures, so there will be more certainty that the screen is strong enough to find process issues during HASS. One disadvantage is that this method requires as many as 3-4 sets of production units. The second disadvantage is that the HASS Development process may take more time to complete than Methods 1 and 2.

This method is ideal when the units are relatively inexpensive and thus several units can be used for HASS Development and when the reliability of the units in the field is very critical, making it advantageous to optimize the HASS profile.

Method 4

In this method, the HALT limits are reduced for the initial profile and the screen is run 50 times without failure, as in Methods 1 and 2. If failures occur, the screen levels are reduced and the screen is run another 50 times. This is repeated until the screen is run 50 times without failure. However, if the initial profile is successful, the screen is used as is without further modifications. One advantage of this method is that it usually only requires one set of production units. A second advantage is that the HASS Development usually only takes about two days. The disadvantage is that this method does not prove that the screen is strong enough, making it difficult to use the screen to detect small process shifts.

This method is ideal when running Highly Accelerated Stress Audits (HASA) using small statistical samples because HASA is usually only capable of finding gross process issues, and therefore, the screen can err on the low side and still find these issues. In addition, many HASA programs are intended to be low cost programs with very small quantities being sampled, and when this is the case, the HASS Development must be cost effective as well.

WHEN TO CHANGE A SCREEN

In many cases, after HASS Development is run and the screening is begun, the screen may never change over the life of the product. A common mistake is to change a screen if failures begin to occur, even though these failures may be indicative of a process shift. However, screens should still be monitored over the life of the product because there are times when a screen should be changed. Feedback from the production line and from the field are the two key sources of information to determine if a screen needs to be changed. Keeping a log of the screen stress levels is recommended to help with determining process drift.

Feedback from the production line is critical to ensure that failures are analyzed to determine if lot shifts have occurred. These failures should then be compared with the failures found during HASS to determine if the screen is finding the same types of failures (and hopefully more) as does the production bench testing.

Feedback from the field is equally critical because this may indicate that the screen is missing failures (too weak) or is causing latent defects (too strong). Depending on the HASS Development method used, the screen may not be strong enough to find some defects because HASS Development may have stopped short of finding the optimal limits. Conversely, the screen may be too strong and cause latent defects, especially with respect to wearout mechanisms. HALT, HASS Development, and HASS may accelerate a wearout mechanism but stop short of causing a hard failure. If this is the case, then the product may fail faster in the field than if no stress was applied during manufacturing.

> A situation occurred during a laser diode test. HALT exposed a type of laser diode to temperatures of 100°C before failures occurred. From this, 65°C was chosen as the starting point upper temperature for HASS Development (and subsequently for HASS) and the product passed 10 runs of the screen. During screening, very few laser diode failures were discovered. However, about a year later, some of the diodes started failing prematurely and it was speculated that the failures were latent defects caused by the 65°C temperature used during screening. This is a good argument for performing failure analysis on each failure discovered during HALT. The analysis should determine if the failure was due to acceleration (a field failure candidate) or due to overstress (not necessarily a field failure candidate). Another recommendation is to perform failure modes and effects analysis (FMEA) prior to HALT. FMEA will highlight most failure modes for each component, including wearout failure modes. If a wearout failure mode is discovered, the program should be tailored to compensate.

WHEN TO RE-PROVE A SCREEN

A good rule of thumb is to re-prove a screen if the product thermal/vibration response changes. A change in product response is usually either due to a change in the screen or a change in the fixturing. A change in the screen may be anything from a change in the dwell level, dwell time, ramp rate, or even a change in when a stress is applied in relation to the other stress(es). A change in the fixturing may be a change in the number of units being screened, orientation of the units, airflow, and even changes to the environmental equipment itself resulting in changes in the product stress levels.

If an increase in response is expected, re-proving the screen is necessary because of the possibility of damaging good hardware. If a decrease in response is expected, it may also be good to re-prove the screen in order to determine if the screen is still able to find defects. However, if the decrease in response is small, trying to re-prove the screen will likely lead to inconclusive results.

In addition, a screen should be re-proven if a significant change is made to the design of the product, and if it cannot be proven that the design change does not weaken the product in any way. This is especially true if the design change involves a change in technology (i.e. solid state relays to mechanical relays or vise versa). If the change is significant, HALT should be re-run, and then based on the results, the screen levels being re-proven may need to change.

> <u>Examples of When to Re-Prove a Screen</u>
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> In one case, thin foam was used as a protective mechanism between the product and the fixture. However, the foam was found to give inconsistent vibration readings from one set to the next depending on the tightness of the fixture and on the cumulative amount of heat the foam had seen (the heat caused the foam to shrink, thus causing the vibration response to change). A switch was made to thin rubber. By doing this, the vibration response was increased by the fixture change and thus, the recommendation was to re-prove the screen to determine if the screen was now too strong.

In another case, units were tested horizontally two units at a time. However, when moving operations, the screening was moved to a smaller vibration table. There was a need to have the same through-put. Because of lack of space on the table, the mounting of the units was changed from horizontal to vertical. This not only changed the vibration response but the airflow as well. In this instance, the vibration and thermal response were reduced significantly by the fixture change. In this case, the recommendation was to re-prove the screen to determine if the screen was still strong enough to find defects.

In yet another case, a change was made in the size of the hard drive to one with larger capacity in the same size package. In this instance, the vibration and thermal response would stay the same. However, due to the technology change, the recommendation was to re-perform HALT, to establish the limits of the new drive, and if the limits were different that then original drive, then re-perform HASS Development.

CONCLUSIONS

The goal during HASS Development is to provide the most effective and quickest screen possible. The effectiveness of the screen is measured in its ability to find defects in the product (strong enough screen) without removing significant life from the product (not too strong of a screen).

There are four distinct methods for developing a screen using the HASS Development process. Each method is sufficient at proving that a screen is not too strong, but each vary in their ability to prove that the screen is strong enough to find defects. In the first method, seeded samples are used to assure that the screen is strong enough. In the second method, the screen is adjusted upwards until a failure occurs to ensure the screen is strong enough. In the third method, the screen starts out too strong and is then reduced in each successive iteration until the optimal screen is determined. In the fourth method, the screen levels are chosen and, barring any failures during the HASS Development process, the same levels are used.

Once a screen is developed and implemented, the next important step is to know when to change a screen. In many cases, after HASS Development is run and the screening has begun, the screen may never change over the life of the product. A common mistake is to change a screen if failures begin to occur, even though these failures may be indicative of a process shift. However, screens should still be monitored over the life of the product being screened because there are times when a screen should be changed. Feedback from the production line and from the field are the two key sources of information to determine if a screen needs to be changed. If these are finding defects that HASS is not, the screen may need to be changed.

A screen should be re-proven if the response to the product changes, especially if the product response increases. This change is usually due to a change in the screen parameters or a change in the fixturing. A screen should also be re-proven if a significant change is made to the design of the product, especially if it involves a change in the technology, and if it cannot be proven that the design change does not weaken the product in any way.

Mike Silverman is Managing Partner of Ops A La Carte LLC, a Professional Consulting Company founded by him in 1999. Ops A La Carte provides a complete range of Reliability Engineering Services employing both Conventional and Accelerated Reliability (HALT) techniques. Mike has pioneered the concept of "Reliability Integration" using multiple Reliability Tools in conjunction with each other to greatly increase the power of Reliability Programs. Please visit www.opsalacarte.com for copies of this paper and other useful resources.