HALT/ESS Development Process at StorageTek

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Every product Storage Technology develops is evaluated utilizing broad environmental stress conditions. Developing wide operating margins helps ensure the robustness and long term reliability of the product. The processes we use are Highly Accelerated Life Test (HALT) and Highly Accelerated Stress Screens (HASS). Advanced Manufacturing Engineering also utilizes an enhancement on HALT evaluations they call Stress Margin And Robustness Test (SMART) in which involves noise injection and frequency margining under stress conditions for individual circuit boards. In this paper we would like to give a short guideline on the basic process evaluations of HALT and ESS at Storage Technology.

First. there are a few ground rules that need to be followed for production environmental stress screens. It is very important that the screen must not use up significant fatigue life of the product. It can not induce flaws. The screen should not reject product because of intermittent test results. due to applying environmental stresses too close to the operating limits. It should not be a test specification. The screen is developed to stress the product. based on observed stress limits of the product as measured, not pre-determined before design. Most products when built without defects or design flaws will generally have robust margins capable of developing and withstanding an effective screen. Specifying a predetermined environmental stress level to design engineering adds unnecessary costs and becomes a specification. Having a predetermined environmental stress specification would limit the development of a good screen for the assembly, as a good screen must be based on the products capability to withstand the stresses, not a generic specification.

There are many considerations to screening PWAs, card cages, and finished box level systems. Each forms a major category in regards to the test fixtures and screen being applied. Within each category the methods tend to be very similar yet it is very important to understand that every product is unique. No one screen is applicable to all products. Even the same generic types. such as power supplies. may each require entirely different screens.

A good screen requires the product be powered on, operating and significant interfaces monitored. Generally a good thermal screen is run with at least 100°C temperature differential. If the system is unable to operate at the high or low temperature peaks. a screen may need to be run in the non-operating mode. Although there are reasonable thermal limits that some electro-mechanical assemblies cannot be operated at, such as a tape/tape head interface, low margins should be examined very carefully to identify the limiting components. It should be determined that the thermal limits are reasonable and that they are the fundamental limits of the technology.

A screen is not a process that is created and the limits set and left forever. It is a dynamic process that needs to be monitored frequently for its effectiveness and, if necessary, changed to meet product improvements, feedback from failure analysis and field failure information. Variations in operating margins change during the production life of a product. EC changes, component vendor changes, and manufacturing changes can affect the product margins, and consequently, the safe screening parameters dramatically. Over time a product under screen should be re-evaluated under the HALT process to reconfirm the product limits. If the product margins have deteriorated, the stress screen may have to be temporarily lowered to safe limits to avoid injecting flaws into the product. The problems should be fixed and the screen levels returned to normal as soon as possible.

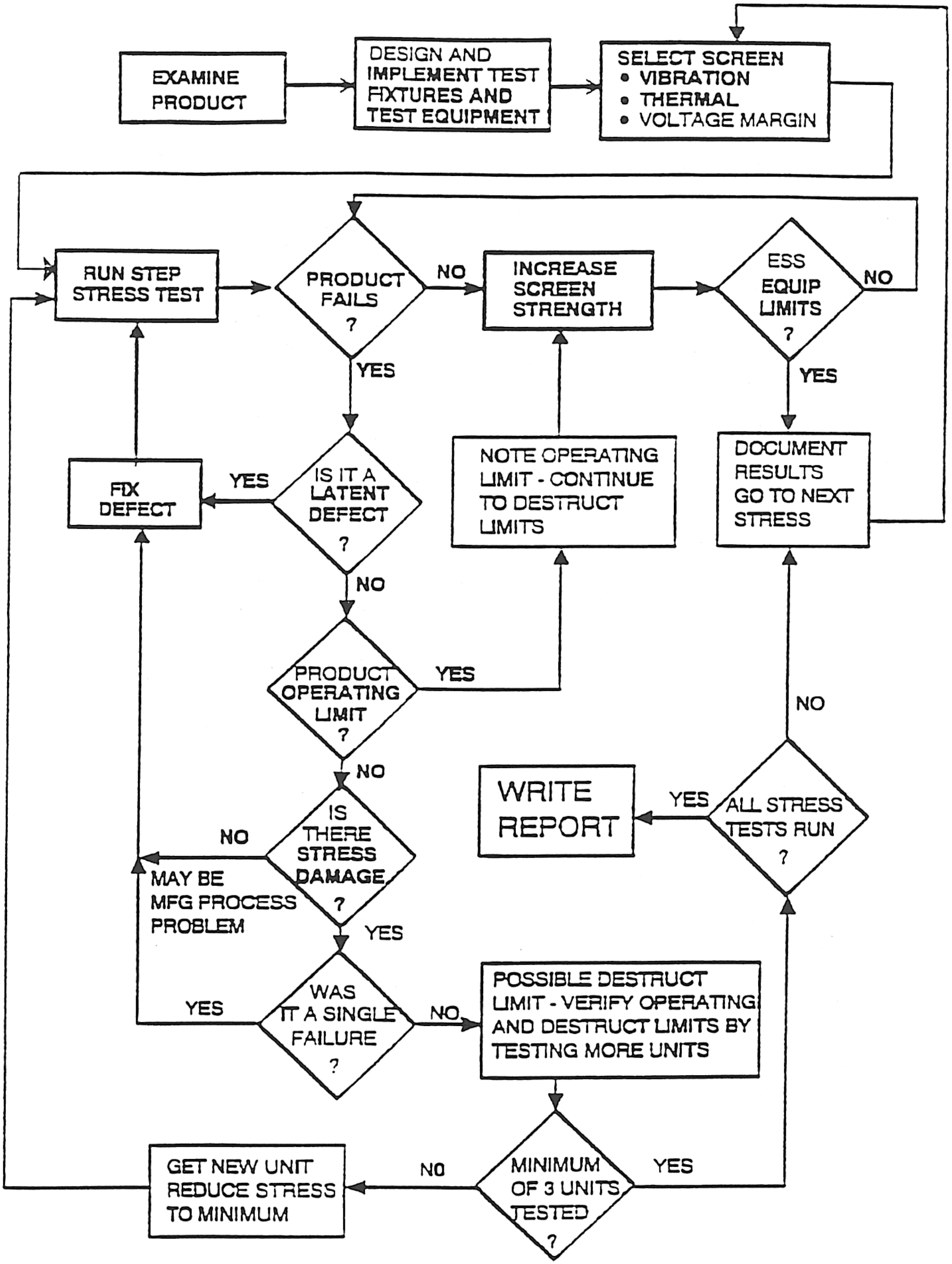
During the HALT process it is very important that each failure be analyzed to root cause. It must be determine that the failure was either a latent defect or caused be excessive screen stress. A determination can be made then whether there is enough margin in the failing system or additional design changes need to be made for product improvement. This is best done with cross functional representatives from design, test and manufacturing engineering areas.

The stimuli of thermal and vibration are each unique in the resulting response of the product and effects on components. In order to have a better understanding of the effects of each stimuli they should be developed separately and then combined for increased throughput in manufacturing and increased precipitating conditions. The levels of thermal and vibration should be the highest possible without damaging the product. Also screens should utilize the shortest thermal soak time to provide a shorter cycle time for manufacturing. Highly Accelerated Stress Screens (HASS), those that are used at StorageTek, can reduce the overall cycle time by precipitating defects normally found in a long burn-in process. This has been confirmed in many of our ESS processes. The method that is used to verify that good hardware is not damaged by the screen is through the Proof-of-Screen (POS) process. A POS is done by subjecting the a minimum of 3 units to 10 to 20 more cycles of the ESS regime and verifying that the applied stress has not had a significant impact on useful life of the product screened.

The development of an ESS process begins with a Highly Accelerated Life Test (HALT). Almost all of the parameters used in the ESS manufacturing operations are determined from the data derived from the HALT test. HALT testing establishes the upper and lower thermal operating limits, upper vibration operating limits and the destruct limits for thermal and vibration. Additionally, if voltage margin testing is done the upper and lower voltage operating limits can be established. In the early prototype stages the information found in HALT is fed back to engineering to indicate any problems found and to improve the design before the product is put into manufacturing. Many costly design weaknesses have been eliminated from StorageTek products, long before they go into manufacturing, through the HALT process. HALT testing is generally done in the early stages of product development, but it is also useful to evaluate the product periodically throughout its life as the product is subjected to changes in vendor components and engineering changes.

The basic flow chart for the HALT development process is

HALT FLOW


EXAMINE PRODUCT
DESIGN AND IMPLEMENT TEST FIXTURES AND TEST EQUIPMENT
SELECT SCREEN
• VIBRATION
• THERMAL
• VOLTAGE MARGIN
RUN STEP STRESS TEST
PRODUCT FAILS ?
NO
INCREASE SCREEN STRENGTH
ESS EQUIP LIMITS ?
NO
YES
YES
FIX DEFECT
YES
IS IT A LATENT DEFECT ?
NOTE OPERATING LIMIT - CONTINUE TO DESTRUCT LIMITS
DOCUMENT RESULTS GO TO NEXT STRESS
NO
PRODUCT OPERATING LIMIT ?
YES
NO
NO
WRITE REPORT
YES
ALL STRESS TESTS RUN ?
NO
IS THERE STRESS DAMAGE ?
MAY BE MFG PROCESS PROBLEM
YES
YES
WAS IT A SINGLE FAILURE ?
NO
POSSIBLE DESTRUCT LIMIT - VERIFY OPERATING AND DESTRUCT LIMITS BY TESTING MORE UNITS
GET NEW UNIT REDUCE STRESS TO MINIMUM
NO
MINIMUM OF 3 UNITS TESTED ?
YES

shown in Fig. 1 attached. An explanation of the process in detail is described below.

The first step is to examine the product and determine the best way to restrain the product during the vibration stress stage of the process. If possible it is best to duplicate it's normal mounting configuration. This allows the product experience the vibration stresses in the same manner it would during its life in its final usage. This is especially important if the housing has inherent resonant modes. To achieve adequate thermal change rates special fixtures may be needed to provide the required air flow across the unit under test (UUT). To create maximum thermal stress. the ambient air within the product must follow the chamber air temperature. This air flow may need to be directed utilizing air ducts and/or small card cage cooling fans. The rate of thermal change on the product is especially important for the production ESS. It has been documented that the higher the thermal rate of change the more effective a screen is for many defect types. Thermal rates as high as 60°C degC/min have been used to precipitate defects without inducing flaws.

After determining the best method to hold down and thermally stimulate the product. the next step is to identify the areas to be characterized. The vibration levels need to be monitored at several locations including the housing and areas that would be more prone to large resonances. such as the center of a circuit board with transformers on it. or a section of card cage that has the least bracket support. It is very important that these locations for measurement be documented so that as the product goes through EC changes and manufacturing process changes during its life. beginning reference points will be available for comparison to verify whether the vibration margins are improving or deteriorating. It is important that the UUT be evaluated periodically throughout its life to ensure that the product changes have not put its operating margins so close to the screen levels as to induce flaws or cause intermittent results. Make sure that you have all the unique test equipment and test procedures in place with adequate diagnostic capability.

Before the HALT test begins it is important to verify that the fixtures adequately hold down the product during vibration. that the air flow temperature inside the product follows the chamber temperature. and verify the test equipment functions as desired and that no intermittent connections occur when the product is under vibration or during thermal ramping. Verify that the product functions normally with no stresses applied.

Next, decide on either thermal or vibration and then run a stepped stress test. Generally, for vibration. the starting point is either 2 grms (gravity root mean squared) or 4 grms (depending on the sensitivity of the equipment to be tested) for ten minutes and increased in steps of 2 grms for ten minutes each until the UUT fails or the test equipment vibration limit is reached. For thermal stimuli. start at ambient temperature (20°C) and increase in 10°C steps holding each temperature long enough for the internal temperature of the UUT to stabilize. The same test should be performed for the low temperature limits until the product fails or a -100°C is reached. For the application StorageTek products are used in. stressing to a -100°C can be considered adequate to find and verify any product weaknesses or inadequate thermal margins.

During the step stress test every failure must be analyzed to the root cause. This may require involvement of failure analysis organization. design engineering, or the supplier quality assurance group. If during the step stress test a failure is determined to be a latent defect then it should be repaired and the step stress test continued. If a product fails due to the operating limit then root cause needs to be determined to understand if the limit is representative of the design limits or was it a device tolerance problem. If it is a device tolerance problem. it should be fixed and then continue the step stress test. If the true operating limit is reached it should be determined that sufficient product margin exists and is the limit high enough as required to produce an adequate production screen. More importantly the question that should be asked is. are low margins indications of a less than robust design ? It is very important that design engineering consider changes to increase the operating margins. If it is determined that a reasonable limit is reached. where the product can be stressed enough to precipitate defects. then no changes need to be made and the step stress test for other stimuli should be run to determine the other stimuli limits. Once the operating and destruct limits are determined a manufacturing screen can then be developed.

The ESS process for a product is based uniquely on the limits found in the HALT process. A good rule of thumb to start with is the temperature extremes should be about 20% less than the operating limit. The vibration levels used in the manufacturing ESS should be about 50% of the destruct limit of vibration. Once the profile is determined a Proof-of-Screen (POS) should be run on a minimum of three samples. A POS consist of running the ESS profile on the same units ten to twenty times to verify that the screen does not induce flaws or take out significant fatigue life. Ideally, a life test should be run at ambient conditions and any indications of degraded performance examined carefully. If a product fails during the POS because of stress damage and not a latent defect then reduce the screen levels by 10% to 20% and rerun the POS. It is our experience that vibration will cause the most significant impact on fatigue life. It may be determined that much less than the 50% reduction of vibration from the destruct level provides enough stress to precipitate and detect flaws. It may be most effective to use two separate vibration steps, such as a high precipitating vibration level and a lower detection level. The defects that are precipitated and the defects that get through the screen undetected need to be understood for an optimal screen.

This is the process for ESS development at StorageTek. We have had many success stories that have saved millions of dollars. Screening has been very successful in quickly indicating manufacturing process problems and vendor component problems before becoming field failures in our products. It is our desire that our vendors use the ESS process to develop robust designs and robust processes and to continue to monitor the quality and reliability of their product with these techniques. We will work with any of our vendors to share our knowledge on this process and help them on the path of phenomenal reliability growth.