PRE-HALT ANALYSIS IS ESSENTIAL FOR A SUCCESSFUL HALT

Mike Silverman, C.R.E.
Managing Partner, Ops A La Carte LLC

20151 Guava Court
Saratoga, CA 95070
Ph: (408) 472-3889; Fx: (408) 255-5789
Email: mikes@opsalacarte.com
Website: www.opsalacarte.com

BIOGRAPHY

Mike is an experienced leader in reliability improvement through analysis and testing. He has also led numerous quality system development programs and compliance programs, including Safety and EMC. He has 18 years of reliability, quality, and compliance 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 co-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 50 companies including 3COM, Ciena, Intuitive Surgical, AeroGen, and Brooks-PRI Automation. 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 5 courses on reliability techniques. Mike has a BS degree 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.

ABSTRACT

HALT and HASS are two of the best reliability tools developed to date, and every year engineers are turning to HALT and HASS to help them achieve high reliability. However, in an effort to develop effective reliability programs with HALT and HASS as the cornerstone, many engineers are forgetting some of the basic building block analyses for HALT and HASS – Failure Modes Effects Analyses (FMEAs). Fault Tree Analyses (FTAs). Without first performing these analyses at some level, engineers may be missing important information that can help them avoid chasing non-relevant failures. These analyses can also help identify failure modes that may not be uncovered during HALT but that still should be analyzed to root cause and corrective action taken. Reliability Predictions have their place in a good reliability program because they can be used to predict which components are likely to fail under certain stress conditions, either because these components are much more complex, because the technology is not as well established, or because these components are much more sensitive to high temperature exposure.

KEY WORDS

HALT — Acronym for Highly Accelerated Life Test. In HALT, stresses such as OmniAxial (6 degree-of freedom) random 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 — 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.

FMEA — Acronym for Failure Modes Effects Analysis.

FTA	Acronym for Fault Tree Analysis.
Reliability Prediction	Method by which the reliability of a product is assessed and the estimated failure rate of the product is determined. Reliability predictions are usually expressed in either Mean Time Between Failure (MTBF) or Failure Rates in failures per billion hours (FIT rate).
Effective Screening	Screening that takes into account the amount of stressing being applied (typically using electrical, and vibration stresses, but any stresses that can be used as an accelerant would apply).

INTRODUCTION

In HALT, a product is introduced to a stress (e.g. temperature, vibration, voltage) and then tested. If the product is fully functional at the particular stress, the stress is then increased and the product is tested again. This process continues until the operational limit of the product is discovered, and then the stressing is increased further until the destruct limit of the product is discovered. But what is likely to fail during this process? And, are these failures going to be relevant?

Prior to the start of the test, the sensitivity of each component to temperature stresses and to electrical stresses should be known, and a Reliability Prediction is the perfect tool for quickly determining this. Also, prior to the start of the test, the failure modes and the effects of at least the most critical modes should be known: FMEAs and FTAs are the perfect tools for performing this analysis. One major reason for this analysis is that when failures are discovered during HALT, the criticality of the failure has already been analyzed, making it easier to determine how much time to spend working on the specific failure versus how much time to spend on looking for other failure modes.

Another good reason to perform these analyses prior to HALT is because a HALT is typically performed on between 2-6 products, a large enough sample to find gross design defects, but certainly not a large enough sample to find all failure modes that are likely to plague a product throughout its life because 1) some of these failure modes may not be design related, and 2) some of the failure modes may not be accelerated by using temperature, electrical, and vibration stresses.

RELIABILITY PREDICTION – AN OVERVIEW

Reliability predictions measure the steady state failure rate (failure rate in the constant failure rate portion of the reliability "bathtub" curve for a product) of a product. Reliability predictions serve the following purposes:

1) Assess the effect of product reliability on the maintenance activity and on the quantity of spare units required for acceptable field performance of any particular product.
2) Provide necessary input to system-level reliability models.
3) Provide necessary input to unit and system-level Life Cycle Cost Analyses.
4) Assist in deciding which parts to purchase from a list of competing parts.
5) Set standards for factory reliability tests.
6) Set standards for field performance.

General Assumptions

As a rule of thumb, the following factors are typically not included or accounted for in a reliability prediction:

- ESD failures will not contribute to the failure rate.
- EMI/RFI problems will not contribute to the failure rate.
- Process issues are not included in this failure rate.

Inputs

In order to perform a prediction, the following pieces of information shall be gathered:

- a bill-of-materials. A soft copy in Excel format is preferable.
- an approved suppliers list for key components on the products.
- information on your manufacturing screening to develop an appropriate learning factor.

Method Used

The majority of reliability predictions performed today are performed using the "Parts Count" approach in which a base failure rate is determined from an industry standard specification (the two most commonly used standards are Telcordia TR-332[1] and Mil-HDBK-217[2]). The base failure rate is then multiplied by specific multiplier factors to obtain the overall failure rate for a specific device.

Multiplier Factors

The following are a list of multiplier factors, along with their corresponding definitions. Information from each of these factors is taken from Telcordia TR-332:

- Temperature Factor (p_T): This factor accounts for the temperature difference from ambient for each component.

- Stress Factor (p_S): This factor accounts for the difference in electrical stress from nominal derating of 50% for each component.

- Quality Factor (p_Q): This factor accounts for the specific quality of each component being purchased, whether the component is being purchased from specifications, whether additional testing is being called out, etc.

- Environmental Factor (p_E): This factor accounts for the environment of use for the product.

- First Year Multiplier Factor (p_{FY}): This factor account for how much screening is performed during manufacturing on each unit.

RELIABILITY PREDICTIONS AND THEIR BENEFITS TO A HALT

For temperature stresses, many component temperatures will be measured during HALT; therefore, a quick analysis is helpful prior to choosing thermocouple locations. This analysis will reveal which component types are more sensitive to temperature from a reliability perspective, and used in conjunction with some basic thermal analysis tools, the temperature gradients of a product can easily be modeled. This analysis, when used properly during the setup of a HALT, can be a very powerful tool in planning out the discovery of the upper thermal operating limit and the upper thermal destruct limit.

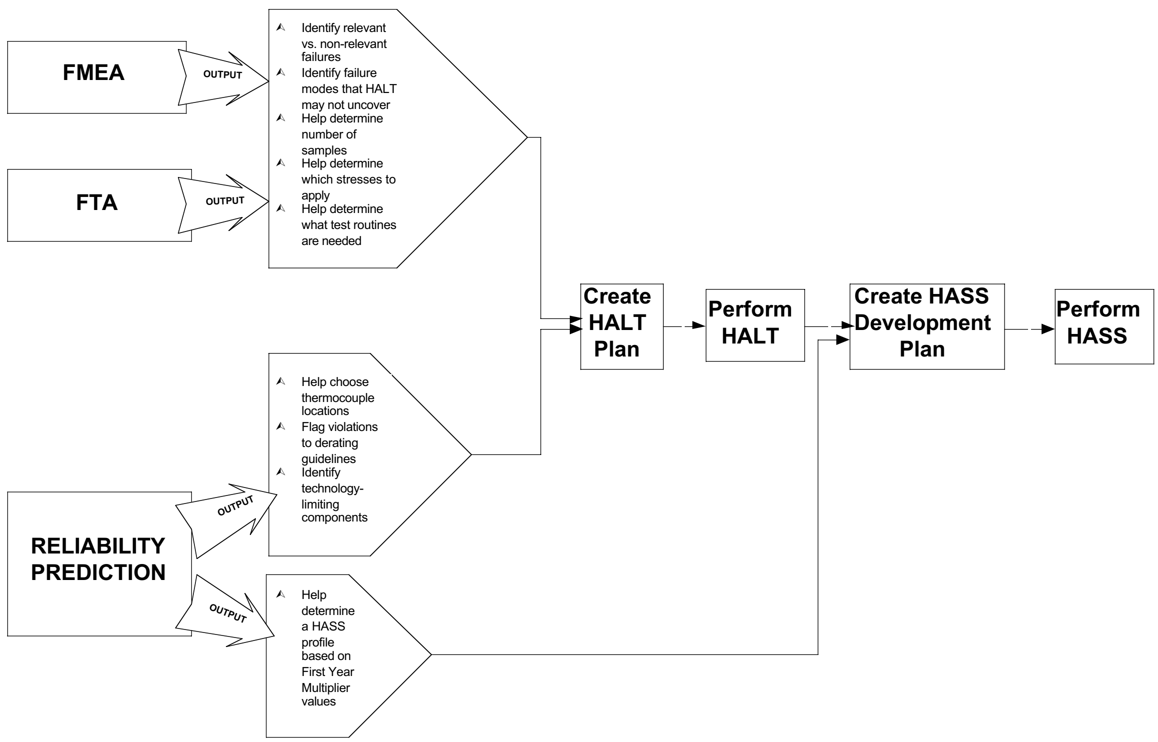
For electrical stresses, design engineers typically follow derating guidelines, but there are times when these guidelines are violated, either by exception or by mistake. Reliability predictions can quickly catch these violations and determine the impact on the reliability of the component and on the product. This is important input when planning a HALT, specifically to determine which electrical stresses to apply as accelerant stresses, and by how much.

Reliability predictions can also reveal technology-limiting components – components that are much more sensitive to external stresses due to the technology being used (e.g. opto-electronics are very sensitive to high temperature).

One added benefit to performing the reliability prediction is that after HALT is complete, the effects of the first year multiplier factor on the reliability prediction will play a big part in helping to determine the HASS profile because the first year multiplier factor is derived from the amount of "effective" screening being performed, and HASS is probably the most effective type of screening developed to date.

Figure 1 shows the first input to the HALT process is the information from the reliability prediction, specifically the sensitivity of each device to temperature and to electrical stresses.

FIGURE 1: FLOW CHART FOR PREPARING FOR HALT



FMEA – AN OVERVIEW

FMEA is a technique for systematically identifying, analyzing, and documenting the possible failure modes that exist for a product and the effects of such failures on the product's performance. The term failure mode is used to refer to the possible ways in which a product can fail.[3] FMEA is an important technique for a reliability assurance program. The analysis is begun in the conception, planning and definition phases of a project, and then performed more fully during the design and development phases. The purpose of a FMEA is as follows:

1) Evaluate the effects and the sequences of events caused by each identified item failure mode, from whatever cause, at various levels of a product's functional hierarchy;
2) Classification of identified failure modes according to their detectability, diagnosability, testability, item replaceability, compensating and operating provisions (repair, maintenance and logistics, etc.) and any other relevant characteristics;
3) Estimation of the significance and probability of failure.

Although several derivatives of FMEAs have been developed, there are two basic types: DESIGN and PROCESS.

Design FMEA

Design FMEAs help to verify that a product has been properly designed to meet all of the customer's requirements and that it can be manufactured at a target rate, cost and yield.

Design FMEAs capture the relationship between customer requirements, how a product can fail to meet the requirements, the effects of the failures, problems with the design that cause the failures and how the design will be validated to prove it will not fail.

Subsets of Design FMEAs are User Task Analysis (UTA) FMEAs and Software Design FMEAs. In UTA FMEAs, the goal is to uncover all failure modes relating to the user interface. In Software Design FMEAs, the goal is to uncover all failure modes relating to errors in software code or logic.

Process FMEA

Process FMEAs assess the adequacy of a process in producing a product that the design FMEA has validated. Process FMEAs also identify the process and product controls that must be implemented to ensure that the product can be produced within specifications.

Process FMEAs capture the relationship between each process step, the unacceptable process outputs that can be created at each step, the effects of the unacceptable process outputs, causes of the unacceptable outputs and how the unacceptable outputs will be either prevented or detected in the event they occur.

Top-Down vs. Bottom-Up FMEAs

The two most common methods for performing Design or Process FMEAs are the Top-Down Method and the Bottom-Up Method. In the Top-Down Method, system and subsystem functions are first determined, and then failure modes are identified for these functions. In the Bottom-Up Method, each part or step is listed, and then failure modes are identified for each of these parts or steps. The Top-Down Method is best used when the product is very complex or when the main goal of the FMEA is to identify the most critical failures first. If the product is not as complex, or if the main goal is to identify all failure modes, the Bottom-Up Method is best.

FTA – AN OVERVIEW

FTA is one of the most widely used and versatile methods of deductive analysis. FTA is concerned with the identification and analysis of conditions and factors which cause or contribute to the occurrence of a defined undesirable event, usually one which significantly affects product performance, economics, safety or other required characteristics.[4] Many times, FTAs are used in conjunction with FMEAs to further analyze the most critical failures.

An FTA is an organized graphical representation of the conditions or other factors causing or contributing to the occurrence of a defined undesirable event, referred to as a “top event”. The representation is in a form which can be understood, analyzed and, as necessary, rearranged to facilitate the identification of:

1) factors affecting the reliability and performance characteristics of a product (e.g. component fault modes, operator mistakes, environmental conditions, software faults);
2) conflicting requirements or specifications which may affect reliability performance;
3) common events affecting more than one functional component, which could cancel the benefits of specific redundancies.

The objectives of an FTA are:

1) the identification of the causes or combinations of causes leading to the top event;
2) the determination of whether a particular product reliability measure meets a stated requirement;
3) the demonstration that assumptions made in other analyses, regarding the independence of systems and non-relevance of failures, are not violated;

4) the determination of the factor(s) which most seriously affect a particular reliability measure and the changes required to improve that measure;
5) the identification of common events or common cause failures.

The FTA is particularly suited to the analysis of complex products comprising several functionally related or dependent subsystems with different performance objectives. The FTA is also very useful in analyzing particular system effects identified in the FMEA, especially the most critical ones. In many cases, FMEAs are performed on entire systems and then FTAs are performed only on each of the most critical system effects identified from the FMEA.

FMEAS AND FTAS AND THEIR BENEFITS TO HALT

A FMEA will identify all failure modes, including the ones that will be found in HALT, and an FTA performed on the most critical failure modes will help identify the full impact of these failures on the overall reliability of the product. In addition, FMEAs and FTAs will find many failure modes that HALT may not find and will give the relative criticality of each. When used in planning a HALT, tests can be designed to concentrate on looking for and diagnosing these critical failures. A FMEA will also point out many failure modes that don't require much attention.

In many cases, an FTA may analyze failures that are critical but that HALT cannot find, either because 1) the failure *is not* design-related and the sample size is not large enough to uncover this type of random error, or 2) the failure *is* design-related but is affected more by length of test time and less by temperature, vibration, and electrical stresses, or 3) the test routines either do not exercise or cannot detect this failure mode.

FMEAs and FTAs can also help determine the number of samples to allocate for the test because based on a FMEA, the number of critical (and non-critical) failures likely to be uncovered during HALT, can be estimated.

One of the first steps in planning out a HALT is to determine which stresses to apply and what test routines and monitoring techniques to use. The next step is to determine the number of units. The FMEA can help with both. In determining which stresses to apply, the FMEA will identify the major modes of failure and the sensitivity to each over different stresses. Then, based on the number of failure modes identified, an estimation can be made as to how many failure modes will be uncovered during HALT, thereby helping to determine the number of samples needed for the test.

As shown in Figure 1, inputs from FMEAs and FTAs are essential in the planning process of a HALT.

SUMMARY

HALT is a very effective tool at finding design issues with products. However, it is essential to use reliability analysis tools prior to performing HALT in order to reap the most benefit from the test. Reliability Predictions, FMEAs, and FTAs are a few examples of excellent analysis tools to use. Each one can offer invaluable input when planning a HALT. Reliability Predictions can help in planning a HALT in the following ways: 1) help in choosing thermocouple locations; 2) point out violations to derating guidelines; 3) identify technology-limiting components; and 4) help to determine the HASS profile. FMEAs and FTAs can help in planning a HALT in the following ways: 1) help to assure engineers are identifying important information that can help them avoid chasing non-relevant failures and to assure that failures modes not uncovered in HALT are still analyzed and root-cause analysis/corrective action taken if necessary; 2) help determine the number of samples to allocate for the test, and 3) help determine which stresses to apply and what test routines and monitoring techniques to use.

REFERENCES

1) Telcordia TR-332, "Reliability Prediction Procedure For Electronic Equipment", Issue 6
2) Mil-HDBK-217, "Reliability Prediction of Electronic Equipment" Version F, Notice 2
3) Sematech Technology Transfer #92031014A-Gen, "Guidelines for Equipment Reliability", May, 1992
4) IEC 1025, "Fault Tree Analysis", 1st Edition