HALT vs. ALT: WHEN TO USE WHICH TECHNIQUE?

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

BIOGRAPHY

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. The primary set of services currently being offered are in the area of reliability. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 200 companies including Cisco, Ciena, Apple, 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 20 years of reliability, quality, and compliance experience, the majority in start-up companies. He 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 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 and currently the IEEE Reliability Society Santa Clara Valley Chapter Chair.

ABSTRACT

Highly Accelerated Life Testing (HALT) is a great reliability technique to use for finding predominant failure mechanisms in a hardware product. However, in many cases, the predominant failure mechanism is wear-out. When this is the situation, we must be able to predict or characterize this wear-out mechanism to assure that it occurs outside customer expectations and outside the warranty period. The best technique to use for this is Accelerated Life Testing (ALT).

In many cases, it is best to use both because each technique is good at finding different types of failure mechanisms. The proper use of both techniques together will offer a complete picture of the reliability of the product.

KEY WORDS

HALT: Highly Accelerated Life Testing
ALT: Accelerated Life Testing

INTRODUCTION

HALT and ALT are two most of the most effective reliability testing methods but often times people are confused about which to use when. In this paper, we shall examine when to use which technique, and when to use the two techniques together.

HIGHLY ACCELERATED LIFE TESTING (HALT)

HALT is the process of improving the reliability of a product in a very short period of time (usually hours or days) by gradually increasing stresses until the product fails. HALT's are good for finding design weaknesses. HALT's are usually performed on entire systems but can be performed on individual assemblies as well. HALT's do not work well when there is a wear-out mechanism involved.

Highly Accelerated Life Testing (HALT) is performed to uncover latent defects in product design and component selection that would not otherwise be found through conventional qualification methods. The process subjects a test product to progressively higher stress levels, incorporating environmental stresses such as temperature and vibration, electrical stresses such as voltage margining and load variation, along with combinations of each of these stresses, to precipitate inherent defects. Moreover, HALT stresses the product to failure in order to assess design robustness and margin above its intended operation.

An essential component of HALT is root cause analysis and the identification and implementation of corrective action to ensure the product integrity, thus increasing the product's reliability and the robustness of the design. Only by finding and fixing these weak areas of a product can we achieve margin improvement.

Root cause analysis is also perhaps the trickiest part of HALT because often times we identify a potential problem area and then need to determine if this is indicative of what will happen in the field or if this was just a matter of taking a product over its specifications and changing the failure mechanism. Making this determination requires up-front planning and product knowledge, experience, and good root cause analysis skills. Often times we determine that the failure is not relevant because we did change the failure mechanism. This is often a good candidate for Accelerated Life Testing.

ACCELERATED LIFE TESTING (ALT)

ALT is the process of determining the reliability of a product in a relatively short period of time (usually weeks or months) by accelerating the use environment. ALT's are also good for finding dominant failure mechanisms. ALT's are usually performed on individual assemblies rather than full systems. ALT's are also frequently used when there is a wear-out mechanism involved.

In order to set up an ALT, we must know several different parameters, including but not limited to: Length of Test, Number of Samples, Goal of Test, Confidence Desired, Accuracy Desired, Cost, Acceleration Factor, Field Environment, Test Environment, Acceleration Factor Calculation, and Slope of Weibull Distribution or Beta parameter (Beta<1 indicates infant mortality, Beta>1 indicates wear-out).

In order to measure the life of a product with ALT, one key factor we must determine is the Acceleration Factor, and this is sometimes the most difficult to obtain. Two methods we can use are: 1) Existing models (not very accurate without a lot of research) and 2) Determine by experimentation (lots of samples and time).

3.1 Derating Acceleration Factor using Existing Models

Some existing models are: Arrhenius, Coffin-Manson, and Norris-Lanzberg. Using existing models is much quicker and requires fewer samples than the experimentation method, but it is not nearly as accurate. And assigning values to the variables in the model can be tricky. Note that the transition to Lead Free solder will cause all of these to change (and we don't know yet what they will change to).

3.2 Derating Acceleration Factor by Experimentation

If there do not exist good acceleration models specific to your product and environment, these will need to be derived. When determining the acceleration factor through experimentation, we divide samples into 3 Stress Levels: High Stress, Medium Stress, and Low Stress. We then set up the test to assure that the same failure mechanism occurs at each level. This is a more accurate method but it requires more time and more samples.

Generally the procedure is to estimate the failure rate at low and high stress values using best available information and assumptions. These values are primarily used for sample size calculations as the intent is to conduct the experiment and experience sufficient failures to permit the data analysis to work well (generally at least five). For the set-point values, the intent is to select a high stress that quickly accelerates the units to failure (shorter test time) and excites the same failure mechanisms as at use conditions. The low stress set-point is selected as close to use conditions and high enough to provide at least five failures during the expected testing time. Then we select a third set-point in between the two to permit a robust statistical fitting of accelerated data to provide the ability to extrapolate to use conditions. This test is called a 4:2:1 allocation scheme 1 because we allocate 4/7th, 2/7th, and 1/7th of the test units to the low, middle, and high stresses, respectively. Then we calculate the acceleration factor.

When the Acceleration Factor cannot be determined, often times we are left with only being able to accelerate the duty cycle. For instance, we can increase how often a button is pushed or how often a device is used. However, by increasing the duty cycle, we must make sure that we do not change any other parameters inadvertently – we sometimes find that if we increase the duty cycle too much, we also increase the internal temperature of the device, not allowing it time to cool between cycles.

Some examples of good candidate products for ALT are cell phones, fans, hard drives, automotive electronics, robots, and infusion pumps.

COMPARING HALT TO ALT

In HALT, we don't concern ourselves with determining the life of the product because we are more interested in making the product as reliable as we can, and measuring the amount of reliability is not as important. However, with mechanical items that wear over time, it is very important to know the life of the product as accurately as possible.

One key advantage of HALT over ALT is its speed in finding defects that will affect the field population. A typical HALT takes 2 to 4 days to complete and our success rate in finding defects that will ultimately turn into field issues is very high.

One key advantage of ALT over HALT is that we often do not need any environmental equipment. Benchtop testing is usually adequate, and in many cases, this can be performed at the customer's facilities. An additional benefit is that the product's life is determined as well, where that's not typically the case for HALT.

Figure 1 shows a comparison between the two methods.

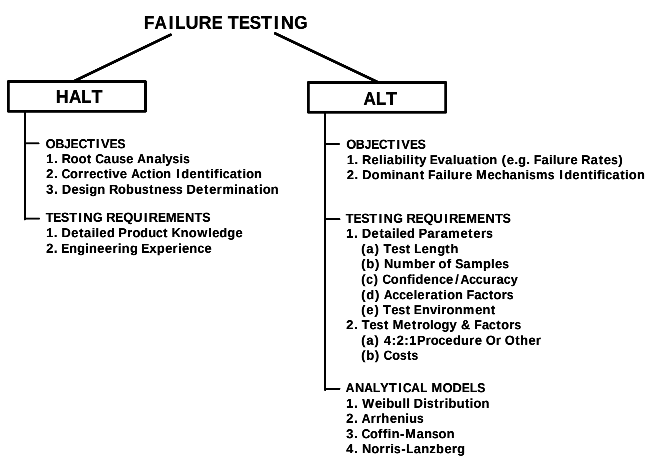

Figure 1 – Comparison Between HALT and ALT

USING HALT AND ALT TOGETHER

Often times we will run a product through HALT and then run the subassemblies through ALT that had predominant wear-out mechanisms and thus were not good candidates for HALT.

In Figure 2, we performed HALT at the unit level. For most of the assemblies, this was the appropriate level for finding issues, but for the fan assembly, we did not run the stresses long enough to excite the dominant failure mechanisms. Therefore, we followed up the HALT with an ALT on the fan assembly by itself, and from the ALT, we were able to find the dominant failure mechanisms.

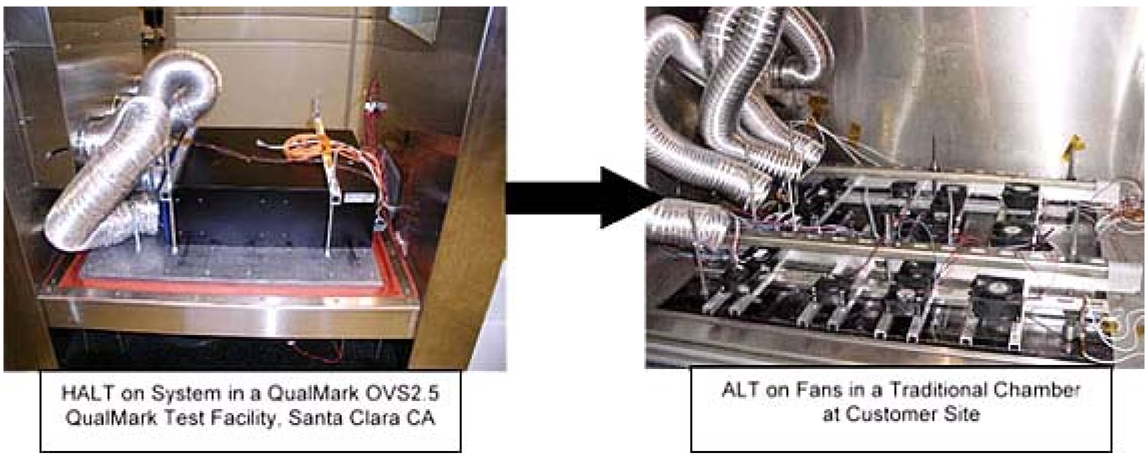

Figure 2 – Fan Assembly run through ALT after Unit Level HALT

At other times, we may develop the ALT based on the HALT limits, using the same stresses but lowering the stress levels so that the acceleration factors are at measurable levels.

In Figure 3, we performed HALT on a power supply assembly, discovered the margins of the product, made several design changes as a result, and then performed a Verification HALT to show improvements in the design margins. Then, we followed up the HALT process with an ALT on the power supply to measure the life of the product.

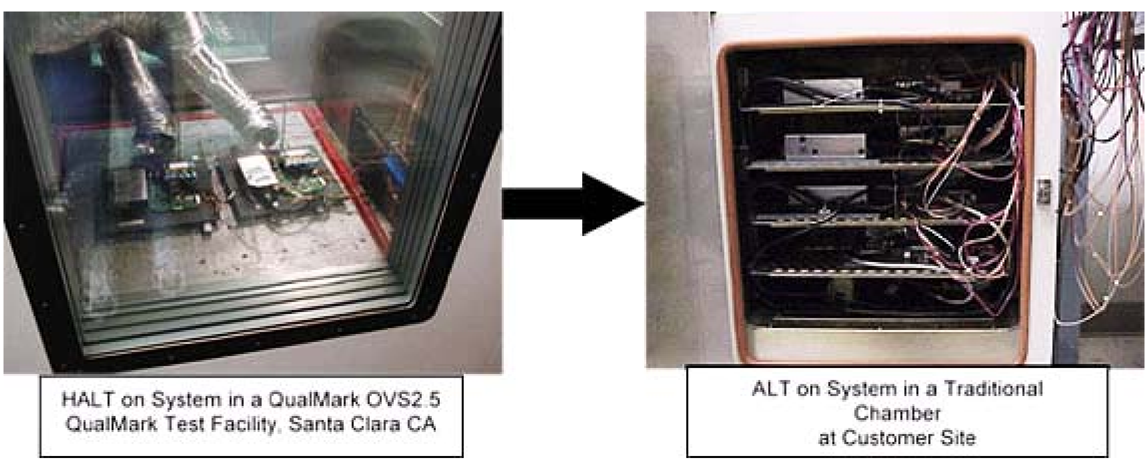

Figure 3 – Power Supply Assembly run through HALT and then ALT

CONCLUSION

In conclusion, both HALT and ALT are excellent techniques to use as long as you know which to apply when in the process.

REFERENCES

1. Meeker, William Q., and Hahn, Gerald J. "How to Plan an Accelerated Life Test", American Society for Quality Control, Statistics Division, The ASQC Basic References in Quality Control: Statistical Techniques, Volume 10, page 14, 1985. John A. Cornell, Ph.D. and Samuel S. Shapiro, Ph.D., Editors.

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.