HALT/HASS - The Next Generation of Environmental Testing

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Introduction

For decades, product quality has been determined through environmental testing such as vibration tests, thermal cycling, mechanical shock, thermal shock, and more. More recently, there has been a significant trend in the marketplace to improve product quality even further. This paper will discuss why Highly-Accelerated Life Testing (HALT) and Highly-Accelerated Stress Screening (HASS) are starting to supplant traditional vibration and thermal testing to meet these new quality targets.

The need for Increased Product Quality

One of the most pervasive trends across a wide range of consumer, industrial, and military markets is the need for increased product quality. In consumer markets, a high rate of product failure can result in the manufacturer's loss of credibility with an attendant loss of sales, from which it can take years to recover. In industrial markets, a high failure rate can result in expensive field service calls, or--potentially worse--significant downtime. In military markets, product failures can result in the loss of lives.

Although the need for quality is increasing, certain developments are making it more difficult to maintain existing quality levels. The most challenging development has been the increased use of manufacturing sub-contractors. The "manufacturer" whose name goes on a product, is likely to be relying on an outside resource--a sub-contractor--over which the manufacturer does not have direct control. This subcontractor is relying on a number of vendors, further weakening the control that the manufacturer has on product quality. Should a product fail, the customer will blame the manufacturer. Since the manufacturer's name is on the product, they are the ones responsible for its quality level.

Another challenge to maintaining quality is a continually decreasing number of engineers with comprehensive QA/QC backgrounds at these manufacturing companies. Many of the highly-experienced QA/QC engineers are retiring or being replaced by younger engineers who are far less experienced.

Before we examine the solutions to these challenges, it is helpful to explore the traditional methods which have been used to test product quality.

TRADITIONAL VIBRATION AND TEMPERATURE TESTING, AND ITS LIMITATIONS

Traditional vibration and temperature testing has played an important role in the genesis of today's reliable and sophisticated electronic and electro-mechanical products. The core philosophy of this testing method is to define a set of specifications, usually minimum or maximum temperatures and/or vibration levels, and to conduct the tests by changing only one variable at a time. Vibration testing is performed one axis at a time. If the device is still functional after being tested according to the test specs, it is considered to have "passed."

A "passing" result is a positive outcome. However, thinking about this further, it becomes clear that a "pass" result does not help identify the weakest link in the product. In other words, the traditional test cannot help the engineer make the product any more robust. Furthermore, with the "one-at-a-time" change in environmental variables, and the one-dimension vibration testing, the test specs are not similar to real-world operating environments. As a result, this kind of testing does not provide an accurate indication of how the product might perform in the field.

This critical look at traditional environmental testing is not intended to be a blanket condemnation of that process. After all, this kind of testing has played a key role in the evolution of today's highly-reliable products. Instead, this examination of certain weaknesses in classical environmental testing can be helpful in understanding how new testing methods, in particular HALT and HASS testing, can lead to even greater levels of product quality and reliability.

THE STRENGTHS OF HALT AND HASS TESTING

Highly-Accelerated Life Testing (HALT) exposes the product to a step-by-step cycling in environmental variables such as temperature, shock and vibration. HALT involves vibration testing in all three axes using a random mode of frequencies. Finally, HALT testing can include the simultaneous cycling of multiple environmental variables, for example, temperature cycling plus vibration testing. This multi-variable testing approach provides a closer approximation of real-world operating environments.

Unlike conventional testing, the goal of HALT testing is to <u>break</u> the product. When the product fails, the weakest link is identified, so engineers know exactly what needs to be done to improve product quality. After a product has failed, the weak component(s) are upgraded or reinforced. The revised product is then subjected to another round of HALT testing, with the range of temperature, vibration, or shock further increased, <u>so the product fails again</u>. This identifies the next weakest link.

By going through several iterations like this, the product can be made quite robust. With this informed approach, only the weak spots are identified for improvement. This type of testing provides so much information about the construction and performance of a product, that it can be quite helpful for newer engineers assigned to a product with which they are not completely familiar.

HALT testing must be performed during the design phase of a product to make sure the basic design is reliable. But it is important to note that the units being tested are likely to be hand-made engineering prototypes. At Trace, we have found that HALT testing should also be performed on actual production units, to ensure that the transition from engineering design to production design has not resulted in a loss of product quality or robustness.

Some engineers may consider this approach as scientifically reasonable, but financially unrealistic. However, our customers have repeatedly found that the cost of HALT testing is much less than the cost of field failures, service calls, blanket re-calls, and/or loss of credibility or loss of business due to poor product quality. One of our clients even includes HALT testing as a line item on their bill of materials, to make sure this testing is included in the product cost, right from the beginning.

Highly-Accelerated Stress Screening (HASS) is an abbreviated form of HALT testing. HASS testing is an on-going screening test, performed on regular production units. Here, the idea is not to damage the product, but rather to verify that actual production units continue to operate properly when subjected to the cycling of environmental variables used during the HASS test. The limits used in HASS testing are based on a skilled interpretation of the HALT testing parameters.

The importance of HASS testing can be appreciated when one considers today's typical manufacturing scenario. Circuit boards are purchased from a vendor who uses materials purchased from other vendors. Components and sub-assemblies are obtained from manufacturers all over the world. Often, the final assembly of the product is performed by a sub-contractor. This means that the quality of the final product is a function of the quality (or lack thereof) of all the components, materials, and processes which are a part of that final product.

These components, materials, and processes can and do change over time, thereby affecting the quality and reliability of the final product. The best way to ensure that production units continue to meet reliability objectives is through HASS testing.

The benefits of HALT/HASS testing can be seen in two case histories:

CASE HISTORY 1-- POWER SUPPLY MANUFACTURER

A manufacturer of custom power supplies used in telecom switching systems wanted to ensure reliability in the field, so they contacted Trace Labs for HALT testing to verify and refine their basic design. After several iterations, the basic design was made reliable. The power supplies were HALT tested over the temperature range of -50^{o}C to +130^{o}C, with vibration levels ranging from 0 to 10G_{rms}.

The next step was for the manufacturer to develop the hand-made units into production designs. We recommended the designed-for-production units be HALT tested, but this recommendation was declined.

Unfortunately, when the first production units entered the field and were placed in service, there were many failures. Eventually, some production units were brought into the lab, and a cursory examination revealed that the production units had smaller heat sinks, the chassis were made of thinner metal, and the amount of structural bracing had been reduced, compared to the original engineering design which had been subjected to HALT testing.

It turned out that in developing the design for production, the power supply manufacturer reacted to price pressure from their customer, cost-reduced various aspects of the production design, and had inadvertently compromised the high reliability of the original design.

Now facing a serious field failure problem, the manufacturer submitted actual production units for HALT testing. After five iterations, the design of the production units had been refined to provide good field reliability. Ironically, the new cost of the re-designed production units was only 2% more than the amount specified in the original contract--a cost the customer was willing to pay.

However, damage had been done to the power supply vendor's relationship with its customer. The customer next required 100% HASS testing of all power supplies from this manufacturer, and they were not invited to submit quotes on subsequent RFQs. The entire problem could have been avoided in the first place if the manufacturer had been willing to spend the upfront costs for HALT testing of the original production units.

Fortunately, this story does have a happy ending. After 3 years of producing reliable power supplies, proven through the HASS testing as well as successful field experience, the manufacturer is once again regarded as a primary vendor and they are selling more power supplies to their customer than ever before.

CASE HISTORY 2 -- AUTOMOTIVE LAMP ASSEMBLY MANUFACTURER

A manufacturer of automotive lamp assemblies (headlight, brake light and 3rd brake light units) provides an example of the benefits of using HALT/HASS throughout the development of a new product.

An engineer at this company had some familiarity with HALT testing and decided to submit a production sample for an abbreviated suite of HALT testing. The unit failed and it was re-designed. When it was submitted for a re-test, a full HALT test was performed, with the power to the bulbs in the assemblies cycled on and off during the testing process. During HALT testing, temperatures were varied over the range of $-100^{o}C$ to $+85^{o}C$, with vibration parameters of 0 to $50G_{rms}$.

Special fixtures were made to hold the assemblies at the exact same angle and under the exact conditions they would experience when installed in a car. The manufacturer was careful to test actual production units, to ensure that the test results were an accurate reflection of product quality.

Automakers have been champions of sophisticated quality testing for years. When they saw the test set-up and the test results from this lamp assembly manufacturer, they were so impressed that they made the manufacturer a prime vendor for these assemblies, and the automaker started requiring HALT testing from all their vendors.

CONCLUSION

"Classic" vibration and temperature testing have definitely helped improve product quality over the years, but today's very high standards for product quality are requiring tests better able to reduce--or even eliminate--field failures.

HALT testing provides a controlled, repeatable method of determining product quality under conditions comparable to field operating conditions, and is critical for proving the basic design of a product. HASS testing is a quick, effective screening process which can be used to ensure production units continue to meet quality standards.

While it is true that HALT and HASS testing can add to the short-term manufacturing cost of a product, the increment is surprisingly small in most cases. In the long run, the cost of the testing is much less than the cost of field failures or the loss of business due to reliability problems.

BIOGRAPHY OF THE AUTHOR

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