An Efficient Path to a Company's Adoption of HALT and HASS - A Case Study

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The best way to illustrate the use of HALT and HASS, and the warranty-reduction benefit that can be realized by adopting the new paradigm, is to present a case study from a company with significant results.

A manufacturer in the mid-1990's was looking for more efficient and effective reliability development of their power conversion products and had heard of HALT and HASS processes.

Education of Management

The path the manufacturer followed in adopting HALT and HASS methods was why the program became so successful for them. It began with a discussion of the methods with the Reliability department manager, followed by an hour-long one-on-one dialogue with the CEO. They had a good understanding of the causes of unreliability in their products. They had detailed documentation of the failure mechanisms, which at the time were mainly various workmanship errors. Management recognized that many of the failures could likely have been detected during vibration and thermal cycling; therefore, there was a high probability of precipitation and detection of these latent defects when subjected to combined stresses in a HASS process.

The next step in bringing HALT and HASS methods to the manufacturer was to bring together all the key executives from engineering, manufacturing, marketing, and finance for a brief overview of the methods. It was critical for all of the upper management to have a clear understanding that HALT and HASS would be a significant change from their current and classical reliability development methods. Not only would HALT and HASS require new thinking, but they would also require significant changes to manufacturing flow and new capital equipment expenditures. Having all the leaders of the company at a HALT and HASS overview presentation, they heard the common questions and answers together, providing simultaneous education and preventing much of the misunderstanding and fear of change that the paradigm shift called HALT and HASS represents.

Since the manufacturer had good root cause records of failures, this data was presented to the executives, showing why vibration and thermal cycling would be much more effective than their current process of "burn-in". would provide much better probabilities of detecting it much easier to support. The detailed history of the root causes of field failures also enabled a business case for HALT-to-HASS development.

Given the history of failures, we determined that approximately 85% of the causes of field failures would most likely have been detected in a HASS process, and that the full payback for the purchase and setup of a HALT/HASS chamber would be in 6 to 9 months.

The first product line to undergo HALT and HASS was a power supply. The particular model that was the first HALT to HASS candidate had two versions that had been shipping for approximately 2 years, and so there were good records of the underlying root causes of field failures. We will refer to model A and model B in this case history.

During the previous two years of production, both models of manufactured units underwent a 72-hour "burn-in" consisting of operating them under load in a closed test room. After four days of burn-in the units were inspected and then shipped. The manufacturing process with steady-state burn-in screening had an annual warranty return rate of 5% during the last two years it shipped.

HALT evaluation

The initial sample size for beginning HALT was three units. These units were easily accessed as they had been in production for some years.

The thermal protection circuits were manually disabled, allowing the units to reach an inherent or raw-stress operational limit rather than the designed-in protection temperature set point.

Thermocouples were placed on key components to reference and compare temperature distributions between samples.

Each UUT underwent each step of HALT: first cold, then hot, then vibration. Each sample was subjected to HALT individually. Each UUT was inserted into the chamber and connected to external electrical power and loads to operate the unit at its maximum rated power.

The HALT procedure began with a cold step stress at 10°C, decreasing in 10°C steps with a 10-minute dwell to reach thermal equilibrium before the next step. This process was repeated for hot steps, with each step increasing by 10°C and 10-minute dwells. At each step, the unit was power-cycled and then run at full-load output. Each sample was disassembled and inspected for any visually detected damage.

HALT Results and Product Margin Improvement

The first samples of the two models to be subjected to HALT were the Model A versions. The HALT of all the Model A samples resulted in thermal operation and destruct limits above 90°C and below -50°C, and vibration limits above 50 Grms measured at the vibration table. It was determined that there was no need for thermal or vibration margin capability to develop a good HASS process for the first of the two models.

The lower-temperature thermal HALT operational limit was found to be consistent across samples in both model A and B, and the units would recover when warmed to ambient temperature. No low-temperature destruct limit was found.

HALT evaluation of the Model B was a significantly different story. High-temperature HALT of Model B samples resulted in the operational limit being the destructive or catastrophic failure limit. The next three samples were found to have operation/destruct limits at 60°C, 75°C, and 90°C. In all cases the Model B unit's upper thermal operation/destruct limit was due to a power component that had a manufacturers rating that was rated approximately 30% less power than the same component in the same circuit application used in Model A. Fortunately, the lower power component used in Model B and the higher power rated component used in the model A units were in identical packages, with the same mounting points and electrical contacts. This fact made it very easy to replace the lower-rated power component in model B with the higher-rated component used in model A. The cost difference between the higher-rated component and the lower-rated component was very small relative to the product costs.

The upper thermal destruct limit of the lower power-rated component has a wide deviation of 30°C. The 30°C difference is significant. With the small sample size, the mean upper operation limit (UOL) temperature cannot be determined. Yet, with this small sample size, we can see a wide distribution of the UOL across these samples. If this wide deviation in UOL extends to larger production quantities, some units may experience operational problems at or near the end-use specification of 35°C.

When thermal HALT was applied to the model B units with the high-rated-power component replaced with the lower-rated-power component, the UOL shifted significantly higher. The new UOL for the high current component is shown in Figure A5-1. The UOL's in the high current units also have a smaller deviation from the mean, which would lead to a lower distribution less likely to extend into the worst-case end-use thermal stress and potential failure.

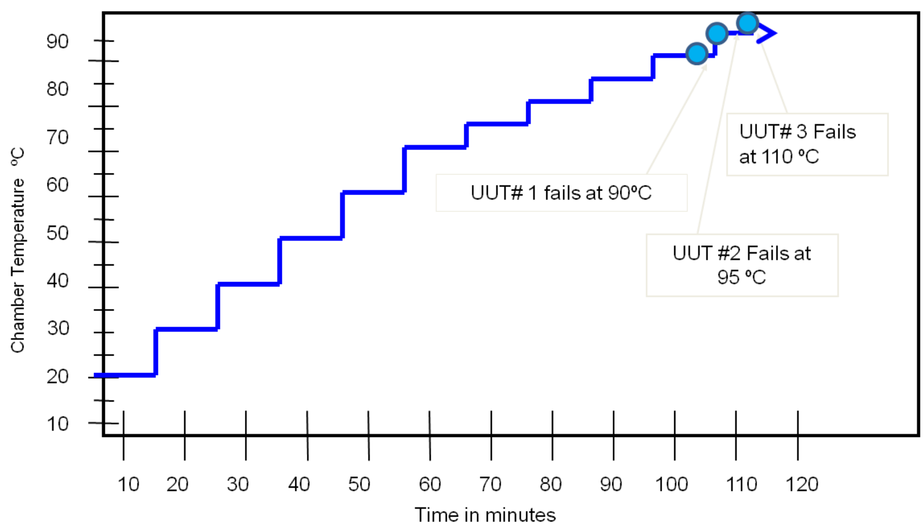

Fig A5-1. New upper operating limits for model B units with high current component

HASS Development from HALT results

The higher the thermal span and vibration levels, the more effective the HASS process is at precipitating latent defects, which, of course, is the central goal of HASS. A general rule of thumb and goal for the thermal span of a good HASS process has been a minimum of 100°C, although more is better. Another general rule of thumb for developing a HASS process is that we use 80% of the 90°C to -50°C range, resulting in a 110 °C delta between high and low screening temperatures. The higher-rated component in model B enabled HASS temperature cycling above 100 °C. The cost difference between the lower-power-rated and high-current component was a few dollars, only a slight increase in the total cost of building.

Not all Management Agrees with increasing thermal limits

It would be helpful for the reader to include a brief, common comment on the field relevance of failing the component in HALT. The engineering manager responsible for model A and model B argued that he had reviewed the failure analysis records of the field returns of the model B units, and there were no incidences of the returned model B unit with the lower power-rated component damaged, as we had seen in the HALT evaluation. It was agreed that the component was probably not a cause of field failures, but without the higher-rated component substitution in model B, the thermal portion of the HASS would be very limited and not as efficient. The manager agreed to replace the lower-rated component with the higher-rated component to allow a 100°C delta for thermal cycles in HASS. The engineering change was made to model B units, with the high-current component substituted for the lower-power-rated component in the original design.

These limits allowed a thermal HASS to be run from 70°C to -40°C. In both models A and B. Both models A and B were subjected to vibration HALT and were found to have operation and destruct limit levels greater than 50 Grms, the maximum table input vibration. The HASS vibration level is typically set to one-half of the destruct limit discovered in HALT. Although the units survived the 50 Grms input level, the maximum HASS level was set to 25 Grms by default, corresponding to the table vibration input.

The proposed HASS process began with a stress regimen of 2 thermal cycles from -40 °C to 70 °C, with modulated vibration up to 25 Grms. Modulated vibration, discussed in Chapter 7, was applied to shift or sweep the vibration's harmonic peaks so that all potential defect sites resonate at their natural frequencies.

Applying HASS

The HASS process was implemented within a month after HALT was completed and the engineering changes were implemented for the manufacture of model B.

To run the HASS process, units were placed in the HALT/HASS chamber and attached to input power, and the output of the units was attached to a load. The loading and setup time was approximately 20 minutes, and the run time for the HASS was 40 minutes.

The Safety of Screen (SoS) for the proposed HASS was applied. The SoS consisted of 10 applications on two new systems, with the production process running at full load in the HASS chamber. After the SoS, the units were fully functionally tested and visually inspected throughout the assembly. No flaws or damage were found, and the units passed the final functional tests.

Resulting Warranty Rate Reduction

After completing the SOS on the model A and model B DC units, the HASS process was applied on 100% of the production units.

The annual warranty return rate was 5% before the HALT/HASS process was applied. Within 3 months the combined warranty return rate dropped by 90% to an annual failure rate of 0.5% on the two models of power conversion systems that were subjected to HALT and then the HASS process. They had done an ROI analysis of the HASS process and found that they had an almost 3-to-1 return on the costs of the HASS process versus the pre-HASS warranty costs. This analysis was based on the conservative estimate that 75% of the HASS precipitated failures would actually have resulted in field failures.

It has now been over two decades since this case history occurred and since that time the company now has HALT and HASS as a standard part of their reliability development process.