Understanding HALT/HASS System Specifications

Specmanship vs. Useful Data

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Understanding HALT/HASS System Specifications

Specmanship vs. Useful Data

by Tom Peters

For those who are not HALT/HASS experts and are surveying the market for the best value in HALT/HASS chambers for the first time the industry is full   bewildering and confusing specmanship claims:

- 100ºC/ minute ramp rate
- 100 gRMS table vibration
- XYZ ratio of <X, PSD (Power Spectral Density) plots
- Highly damped segmented table vs "rigid" table
- Humidity in a HALT chamber

The following information should help clarify the specifications used in HALT/HASS chambers.

The goal of HALT/HASS is to subject a product to cold step stress, hot step stress, rapid thermal cycles, 6DoF (Degree Of Freedom) vibration at ambient temperature and a combination test using rapid thermal cycles combined with vibration simultaneously. All the time subjecting the device under test (DUT) to product specific stresses.

To the uninitiated, or those raised in the ED (electro dynamics) industry, on the surface, more seems to be better. But as in the story "Alice in Wonderland" what you see is not always as it appears, or "useful", in real life testing.

TEMPERATURE RAMP RATE

...what you see is not always as it appears, or "useful", in real life testing.

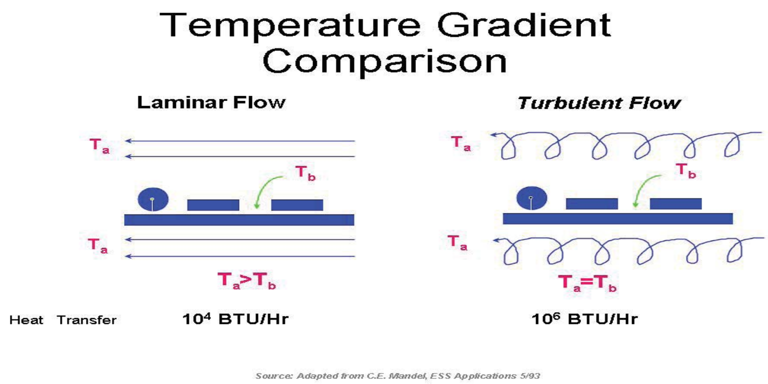
There are claims anywhere from 50ºC/min to 100ºC/min. This specification can be based on just air temperature change or based on some designated mass. In the application of HALT/HASS, product response is always the key metric. In other words, the chamber must be able to move the product temperature at a very high rate of change in order to detect product weaknesses in a compressed time environment.

Is one better then the other? We will explain why more may not be better.

Let's take a look and see how this relates to actual product HALT testing. HALT chambers are built much differently then a standard thermal humidity chamber.

The typical air velocity in a standard thermal humidity chamber is around 400 to 700ft/min. The air flow in high performance HALT chambers is around 4,000ft/min. This difference in air flow is crucial to the thermal ramp rate performance of the chamber but does not tell the whole story. The air management system also is key to the thermal performance of a chamber. The air velocity must be turbulent air flow in order to extract the greatest BTU change rate on a product. In other words the air boundary layer on the components and assemblies must be overcome in order to change product temperatures rapidly as required in HALT/HASS processes. See graph 1.

The only way to get the needed thermal change rates is with a purpose built HALT/HASS chamber. A unit with mechanical refrigeration and LN2 boost cannot attain the needed product ramp rates. A specification that would be useful in order to make valid chamber comparisons would be one that is based on a mass that closely represents the product to be tested. Since most chambers are designed to address a broad segment of the electronic, electro-mechanical industries a ramp rate specification based on a mass similar to an electronic product may be more germane to the actual use of a HALT/HASS chamber. This information would allow a more accurate judgment of the thermal capabilities of the various chambers as it applies to the actual use of the chamber.

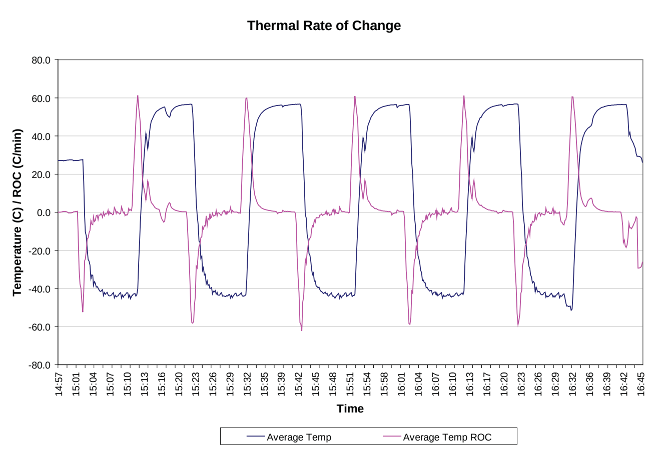


The thermal specification can be determined in many ways and it is important to understand the methodology used. For example, at Qualmark the thermocouple is located in the center of the table with no ducting and the chamber thermal ramp rate is measured between +150ºC to -50ºC for cooling ramp rate and between -50ºC to +150ºC for heating ramp rate. Also the chamber may be slightly derated for different utility power input voltage.

Graph 2 shows the average rapid thermal response of eighteen thermocouples on an electronic product. The red line is the rate of change of the averaged thermal response. This graph demonstrates that the product is experiencing ≈60ºC/min. thermal rate of change in both the hot and cold direction.

In order for a chamber to provide product rapid thermal response it not only needs high velocity air flow but must have a plenum and ducting to maximize that air flow on the product.

Air management is a consideration for thermal performance. Some chambers are more efficient then others in transferring BTU to the DUT (Device Under Test). By comparing the thermal ramp rate and the utility required to achieve that ramp rate it is possible to quickly be able to deduce those chambers that are going to cost more to operate then others. For instance, Qualmark's Typhoon-4.0 has a rated ramp rate of 70Cº/min and is able to achieve that performance with 100AMP service. Other comparable chambers on the market require 160AMPs to achieve the similar ramp rates.



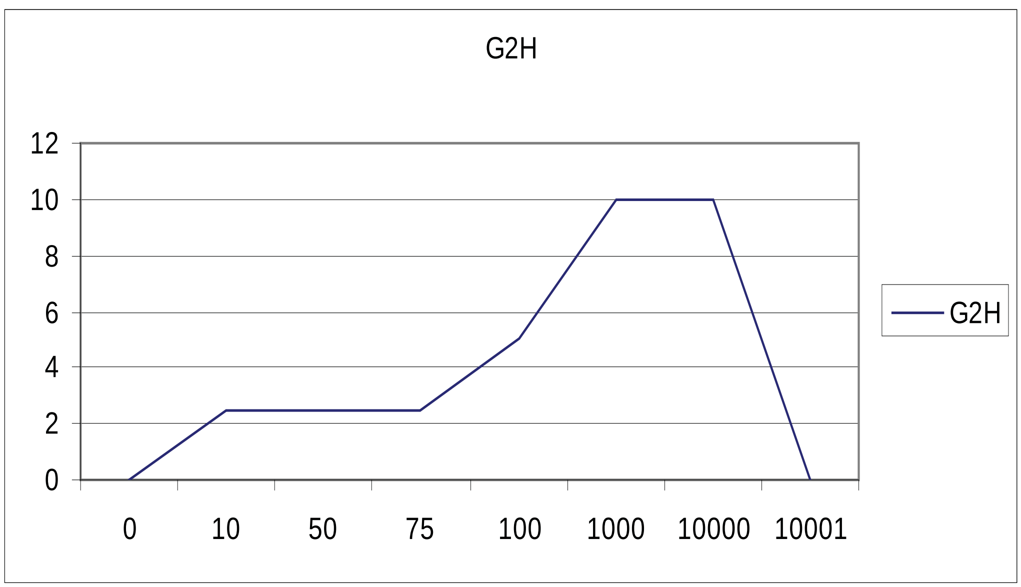
100G TABLE VIBRATION

Random vibration specifications are the most confusing of any specification published for HALT/HASS chambers. The following should help clarify some of the information published in the specification sheets of chambers.

The maximum vibration of the system is usually expressed in units of gRMS. This value represents the RMS value of the acceleration of the vibration system at maximum control setpoint over some defined frequency band. This is usually based on an empty unloaded table. The maximum gRMS value will change with a loaded table. (Tom Peters' axiom. " gRMS data on an empty table is useful only for an empty table"). The truth is this specification has no useful information contained in it.

The gRMS value does not give information as to the energy distribution or consistency within the specified frequency range on a loaded table. This is data that is needed to properly evaluate a vibration system. See graphs 3A and 3B.

Graph 3A



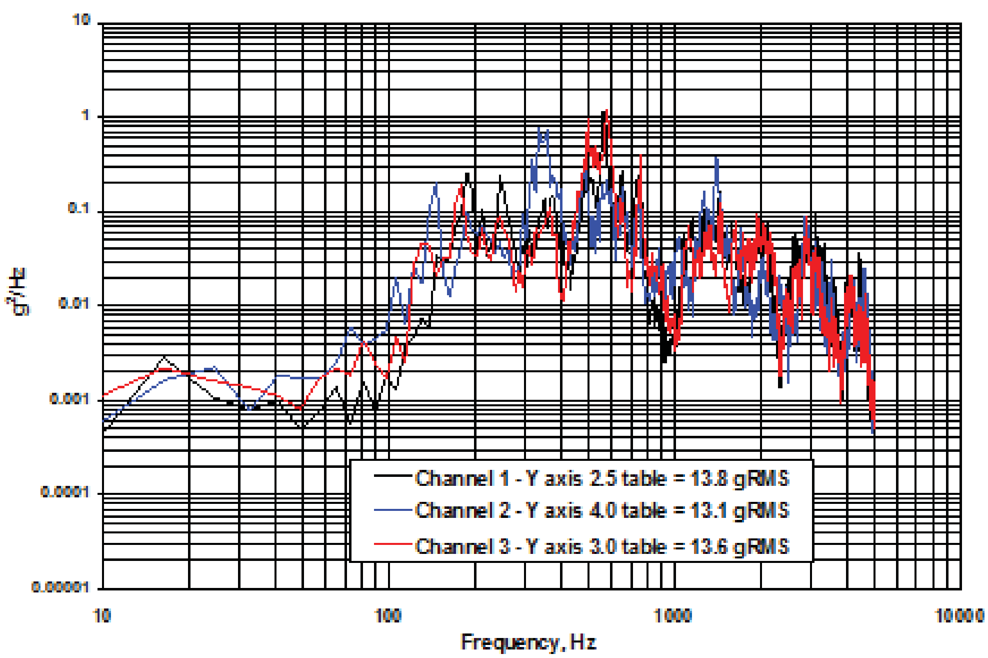
Graph 3B

The two graphs above both represent a gRMS value of 30 gRMS. However, the energy distribution is very different. An infinite variety of PSD's can represent a given gRMS value. A simple gRMS specification does not provide any useful information on the PSD.

PSD

PSD will be examined and the differences explained.
A gRMS specification is important in the E.D. world but not in the R.S. world.
In an ED vibration system the amplitude/intensity is user controlled at each frequency so it is possible to have a vibration profile, commonly called a PSD (Power Spectral Density) plot, that is flat across a given frequency band determined by the system capability. In a RS system the frequency vs intensity relationship is fixed by the vibration system design and is not adjustable or controllable by the operator. Only the overall intensity is controlled by the user. Please see graph 4.

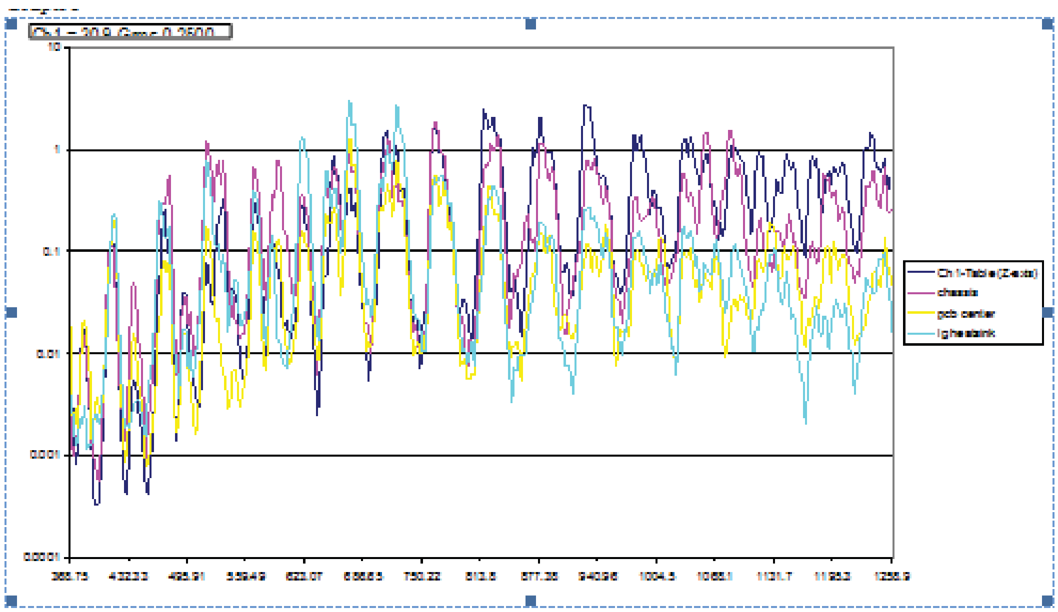
The graph below is a typical PSD of RS systems.



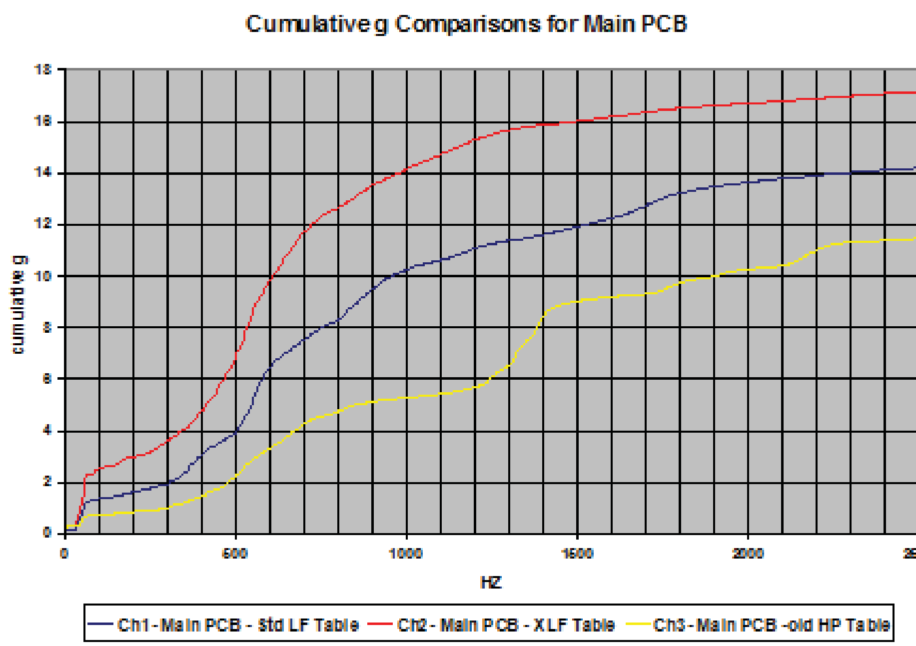
Graph 4

At first this may seem a detriment to the RS vibration system but in actual use it has a very definitive purpose.
ED systems are used to simulate end user environments and to test to a specification.
RS systems are designed to stimulate failures, with the main purpose of exciting all the resonances in a DUT (Device under Test) in order to induce fatigue and failure in the weakest links in a product. Typically electronic and electro-mechanical products have resonances from a few hundred Hz for discrete components such as transformers, heat sinks, torroids etc.to above 4,000Hz for SMT (Surface Mount Technology) components. In order for a vibration system to be effective it must produce excitation across a broad spectrum of frequencies. Ideally from 10Hz to >5,000Hz.

Graph 5 below shows a system that exhibits picket fencing. Picket fencing aptly describes the PSD appearance in that the energy has large gaps in the frequency spectra that have very little energy. This can happen on poorly designed systems and can also occur on systems that are dependent on pneumatic modulation in order to get good frequency distribution when they are run near maximum vibration levels. Again, a gRMS specification has no way of detailing the energy consistency.



Graph 5



Graph 6

Cumulative G Graph

Graph 6 compares three different table designs. It easy to see that the xLF system has much greater low frequency energy then the other two table designs as well as greater overall energy. In order to fatigue product weaknesses the vibration system must have good energy output at both the low and high end of the frequency spectrum as noted by the xLF table output.

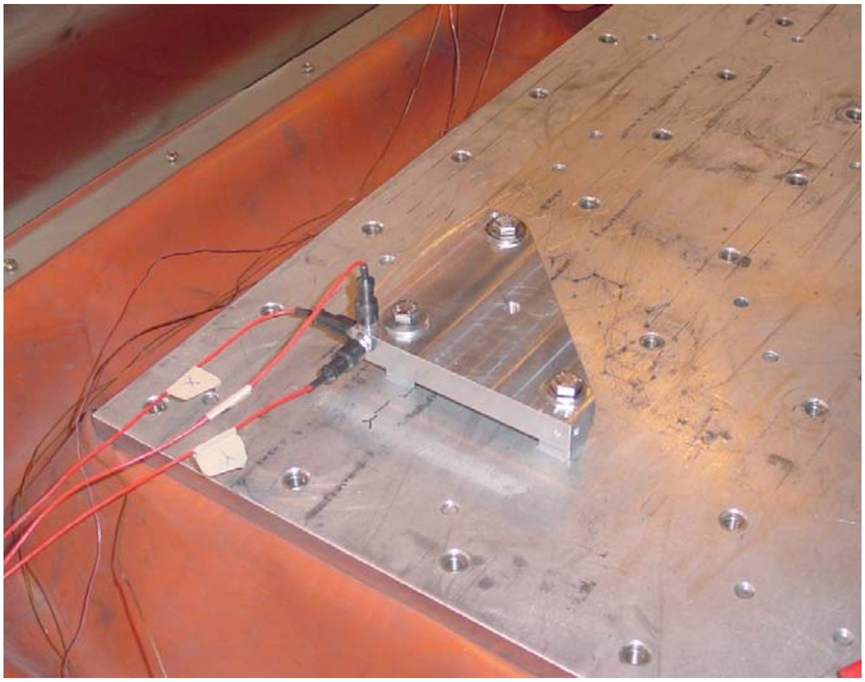
NOTE: The fixture used to couple the product to the table is the key to getting successful test results. A poor fixture will attenuate frequency bands coupled to the product causing some product weaknesses to be missed. The type of fixture design used on an E.D. vibration system should not to be used on an RS table as it will prevent the table from working properly and will cause poor test results.

A useful vibration specification would provide the following information on a specified loaded table:

1. The maximum useful gRMS value with a given pound load on the table.
2. The frequency vs energy consistency across a given bandwidth.
3. The flatness of the PSD in the most useful frequency band.
4. The energy in frequency bands so that an energy distribution profile can be determined.

NOTE: A cumulative G plot is easier to interpret for energy dispersion as it shows the energy distribution relative to frequency. But this information does not show the energy consistency. See the cumulative G chart in graph 6.

PSD plots taken on a single point basis on a vibration table do not provide useful information. The table has pneumatic hammers mounted underneath and depending how close or far the attachment point is from the hammer the more variation in PSD/gRMS value. In normal use a product is fixtured across an area of table surface and the product fixture averages the vibration values under the mounting area. The proper way to map a table is with a test fixture that emulates a product fixtured over a table area. Dell Computer©, in conjunction with QualMark Corp. has developed just such a table mapping device. This fixture (PN 771-1022) is available through Qualmark Corp. and is designed to be used with any manufactures vibration table. Using this device will provide consistent and useful PSD plots for mapping any RS table. It's also very useful as a maintenance tool to measure table aging over time.



Triaxial Table Mapping Fixture

A vibration system with a spec of 100 gRMS does not give an indication of the figure of merit of the energy of the table. A vibration system with 50 gRMS with good consistent energy across the frequency band of 10Hz to 5,000Hz will be better at finding product deficiencies then a vibration system with 100 gRMS but does not have good energy consistency and energy dispersion across the 10hz to 5,000Hz band.

VIBRATION CONSISTENCY ACROSS THE X, Y, Z AXIS

Again, this is usually specified on an empty table. It is more informative if it is specified on a loaded table. Ideally a table will have fairly equal energy in each of the three axis vectors. However, again in real life the specification may not provide useful information if the data is determined using an empty table. RS tables are mounted on isolation springs and the mounting location is the pivot point of the table. Remember this is not an

ED system that only has motion in the single axis. The RS table has motion in the X, Y and Z axis as well as pitch, roll and yaw, the rotational energies about the orthogonal axes.

The ratio of X and Y to Z will vary with the height above the table and with load. Again the specification does not indicate what the product will experience in each of the axis. Think of the RS table as the hull of a sailboat and the mast the distance above the table. The product configuration and fixture determines how far above the table surface the product will be mounted. It is easy to visualize that the higher up the mast, the higher above the table, the greater will be the X and Y motion relative to the table surface. If the X, Y and Z ratios are expressed at a set distance above the table surface the more relative it is to the product under test if it is fixtured at the same height above the table surface. The fixture will greatly affect the actual energy in each axis that the product will experience.

HIGHLY DAMPENED TABLE, SEGMENTED TABLE, RIGID TABLE

These specifications reference the table construction with each manufacture touting their design as the best o course. In today's market there are two basic types of tables. The segmented table which was only manufactured by one company. The rest are variations of the "Rigid" table. Ten years ago the normal rigid table was about 5" thick and was indeed very rigid. The majority of the energy distribution at that time was at the higher frequencies. This was state of the art at that time. see the Cumulative G graph 6 above to see the comparisons of the evolution of the table technology at Qualmark. The early HP (High Performance) design did a good job of finding faults but missed some of those at the lower resonant frequencies. Ten years ago the majority of components on an electronic product were through hole mounting and discrete. The segmented table worked well on early electronic products with large components that had lower resonant frequencies. The Rigid table at Qualmark has been replaced by the "semi-rigid' table construction. This design provides the advantage of both systems. It has enhanced low frequency energy as well as high frequency energy to excite the resonances in today's electronic products that are constructed using discrete and SMT construction. The broad spectrum and consistent energy produced by the semi-rigid table is extremely effective in precipitating product weaknesses.

HUMIDITY IN A HALT CHAMBER

People often wonder why HALT chambers don't have humidity capability like standard temperature humidity chambers.

There are a couple of reasons. The high performance HALT chambers are direct injection chambers. The LN2 is injected into the chamber plenum through spray nozzles that convert the liquid to gas. This phase change is what produces the large BTU cooling capability of the chamber. If the chamber were to use controlled humidity, the first time the chamber started a cooling cycle two things would happen. Any moisture in the chamber would immediately turn to ice, and any moisture in the chamber atmosphere would be immediately displaced by the dry nitrogen gas.

Another reason is that the typical HALT test is of short time duration. The typical humidity test is of a much longer duration, on the order of multiple weeks or months and run at steady state conditions. In HALT the environmental thermal and vibration stresses are constantly varied.

The majority of failures in the field are caused by thermal and vibration stresses. This is why the HALT process concentrates on these stresses. HALT provides the best ROI (Return On Investment), or as the old cliché says, the most "Bang for The Buck".

In summary the ideal way to choose a chamber is to take a product, seed it with known failures, and have each of the manufactures being considered subject the product through an abbreviated HALT test.
The best chamber will be the one that finds most or all of the failure modes.

Since, in many cases this is not practical the best way to start an evaluation is to ask for the detailed information noted in this paper, including the thermal efficiency of the unit. Develop a standard HALT test profile and ask each manufacture to calculate the energy consumption for the standardized test. After the technical information has been obtained visit each manufacture and evaluate how each chamber is designed and built and what support resources are available to help get the HALT/HASS process running and optimized in your organization.

With technically definitive data and manufacture's data informed rational decisions can be made as to which chamber and manufacture will best help you attain your reliability goals.

The chambers for HALT/HASS use extreme thermal stresses in addition to, and in combination, with RS vibration systems to very quickly stimulate design weaknesses to failure in order to allow the ruggedization of a product.

When evaluating HALT/HASS systems be conscious of the following:

- The RS vibration system is very different then an E.D. system and cannot be evaluated using the same metrics.
- The user must be aware of how each specification is determined by each manufacturer as they all use different methods to establish a specification.
- A larger value of itself does not guarantee better performance in actual use.
- Compare vibration PSD's, for all the attributes mentioned previously.
- Compare all vibration data on a loaded table with a properly fixtured load.
- Fixturing will determine how well the product responds to the table input.
- Table data by itself does not represent how the product will respond.
- Determine thermal responses on a given load.

SUMMARY

In summary the specifications usually supplied by a HALT/HASS chamber vendor are not sufficient in detail to allow proper evaluation of a system. Detailed information must be obtained, PSD data interpreted, and the idiosyncrasies of RS style tables understood in order to select the proper chamber and vendor to get optimum results from the HALT/HASS process. The thermal specification methodology must also be understood in order to evaluate the thermal response of a system.

Now that the chamber specifications have been examined be aware that the hardware is only a small portion of the reliability system that will be implemented within the organization. There is a whole other discussion on HALT/HASS process support, fixturing, Proof of Screen, etc. that must be addressed in addition to the chamber for a successful HALT/HASS process.

REFERENCES

1. Neill Doertenbach, *The Calculation of gRMS*, Qualmark Corp., 11/16/2003

ABOUT THE AUTHOR

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Qualmark is the largest global supplier of accelerated reliability testing systems for performing HALT (Highly Accelerated Life Tests) and HASS (Highly Accelerated Stress Screens) that improve product quality. Qualmark technology and services help companies in automotive, aerospace, medical, electronics and other manufacturing industries to introduce new products quickly, boost product reliability, slash warranty costs, and build lasting consumer relationships with quality products.

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