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... THE LEADING EDGE

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This High pressure, high temperature, biased and unbiased humidity testing (HAST) is proving to be a useful electronic component evaluation technique. At KEMET, HAST in conjunction with subsequent solder reflows has been used very successfully to assess the effects of adverse storage conditions followed by surface mounting on the integrity of molded packages.

Our efforts to relate HAST results with electrical performance of solid tantalum capacitors during a conventional biased humidity test have had more mixed results. This month's article discusses our experience with this test.

Dr. John Piper
Vice President – Technology

HAST (Highly Accelerated Stress Testing)

by John J. Moore

The electronics industry has always strived to provide its customers with high quality products that are depend-able and reliable. To determine how these products will perform in "real life" situations, the industry has established a series of environmental tests that simulate certain failure modes. For tantalum capacitors, typical environmental tests include 1000 hours of humidity and temperature at voltage to simulate ionic migration type failure mechanisms; cyclic exposures to hot and cold environments that simulate thermal shock to characterize thermally induced stress type failure mechanisms; and elevated temperature exposures with applied voltage to test the ability of the dielectric in resisting breakdown failure. By subjecting samples to these tests during development and production, the components industry confirms the quality and performance of its products before they reach the customer.

However, environmental testing has two main drawbacks: it's expensive and time-consuming. Because of the thousands of hours needed to obtain test results, environmental testing cannot provide immediate feedback for adjusting the manufacturing process. The same is true for evaluating planned changes in materials, processes, or equipment during the normal life cycle of a product. Implementation of these projects is often delayed pending the results of long-term testing. Because of this, the industry constantly strives to accelerate the test procedures by increasing the severity of the test and performing it over a much shorter time with a smaller sample. The advantages of accelerated testing are obvious, but it does create problems: accelerated conditions may change the original failure mechanism so that the performance doesn't mean the same thing, or even introduce different failure mechanisms which will again confuse the results.

One of the relatively new methods of accelerated testing that attempts to simulate long-term humidity testing is the Highly Accelerated Stress Test (HAST). HAST equipment can subject test samples to various temperatures, pressures and relative humidities with or without D.C. bias for extended periods of time. It provides rapid feedback, and by intensifying the test parameters, predicts failure rates. HAST is a valuable tool for improving process control, developing new materials, and monitoring product performance. Figure 1 contains a KEMET HAST unit and procedure.

The capacitor industry has tried to correlate the results of leakage failure rates to some form of HAST testing. Failure due to ionic migration (as determined by 1000 hours of load humidity testing at 85°C, 85%RH, and rated voltage) is usually traceable to impurities in the materials of construction, contaminants introduced into the product through handling during its assembly, or fluxes used during the board assembly process. With surface-mount components, this last source of ionic contamination is very critical due to the close proximity of the flux to the parts, the difficulty of effectively cleaning underneath surface mount components, and the more extreme mounting conditions. KEMET research has established that HAST does not produce a duplication of leakage performance as compared to long-term load humidity testing (Figure 2), but is a useful "first approximation."

An example of this is evident in Figure 3, which contains tantalum chip development test data obtained over time in 1991. Although the failure rates generated by HAST and by long-term testing are not exactly the same, HAST is a good indicator of how the test sample will perform on the long-term test. Instead of waiting 1000 hours for the results of an experiment, the researcher reduces the cycle time between scouting experiments and confirmation runs by using HAST. There is the added benefit of knowing that the HAST process may be a little more severe than the 1000-hour load humidity test. With this, the researcher feels more confident in subjecting parts to 1000-hour testing.

One of the main purposes of accelerated testing is to stress the parts enough to produce some failures so that the test results can differentiate good from bad product, but also to impose test conditions sufficiently more severe than actual use conditions to ensure that no failures will occur in the field (see Figure 4). Stress can be accelerated in these tests in two ways: by simply moving the failure rate curve into a more intensive stress area, or by actually changing the shape (slope) of the curve. Moving into a more highly stressed area always carries the risk of changing or adding failure mechanisms. But by changing the shape of the failure rate curve, higher failure rates can be detected at relatively low stress intensities. This higher failure rate ensures better detection of problems and better reaction to control issues, while the lower stress intensity eliminates failure mechanism ”noise”. HAST testing appears to simulate a change in the shape of the failure rate curve.

In addition to its advantage as a time saver for development work, HAST has provided a means of short-term process control feedback. HAST results can be monitored on bellwether part types to provide “real time” feedback data on a product’s load humidity performance. This is a tremendous advantage in maintaining process control, because test results are available very quickly after manufacture, as compared to months of delay inherent with long-term humidity testing. With rapid feedback, it is easier to detect and correct the root cause of a control problem.

The recent movement in the circuit board assembly industry from through hole to surface mount components has created new uses for HAST. There are problems associated with cracking in plastic molded IC packages for which HAST offers the researcher and process control engineer a quick, well controlled method of prediction. In this test, a component is saturated with moisture, then subjected to IR or vapor phase reflow. The resultant swelling and cracking of the molded case is then measured. Without HAST, researchers would have to wait a week or so while the parts naturally absorbed moisture at ambient conditions. This reduction in experimental cycle time is vital to problem solving.

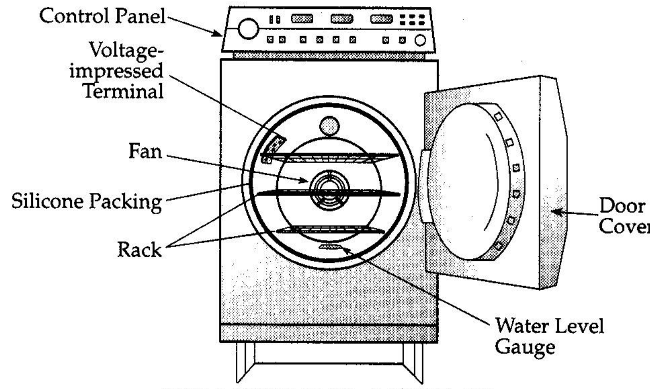
KEMET research engineer Girdhar Arora has developed a time/temperature equation that uses short-term HAST data to predict shifts in 100 kHz ESR of tantalum chips on 1000-hour humidity testing. The equation is:

$$ESR_{(Load\ Humidity)} = At^{\alpha}\ EXP\ (B*T) + ESR_{(Initial)}$$

where “t” is time in hours, “T” is temperature in centigrade of the HAST chamber and “A”, ‘B” and “α” are constants dependent on physical characteristics of resin systems used in the various counter-electrode layers of the tantalum capacitor. The shift in ESR directly correlates to the amount of moisture absorbed by the internal layers of the capacitor. If the moisture absorption can be minimized or eliminated, the leakage performance should improve.

As more and more research and control engineers endeavor to use the HAST process, the industry’s knowledge of this test method will grow along with its acceptance of HAST as a valid tool for both performance testing and cycle time reduction. The possible uses of the HAST system for process control, materials development, and basic re-search are already evident from KEMET’s initial experiences with this test. HAST is just one of the many tools available to help the components industry improve its performance while reducing the cost and time necessary to manufacture the highest quality product.

Figure 1



TABAI ESPEC Model TCP-421

Temperature	121° C
R. H.	85%
Pressure	1.776 kg./sq. cm
Time	24 Hours
D. C. Bias	Yes or No

Figure 2

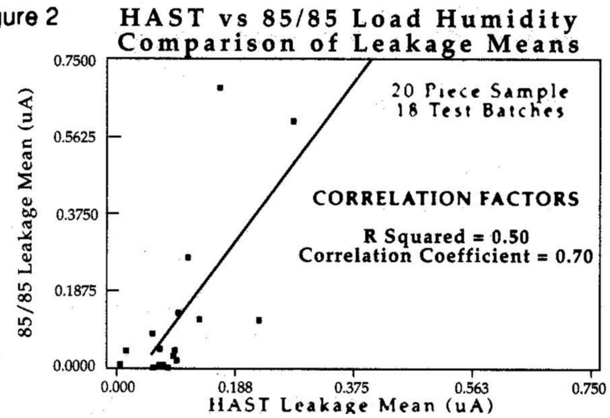


Figure 3

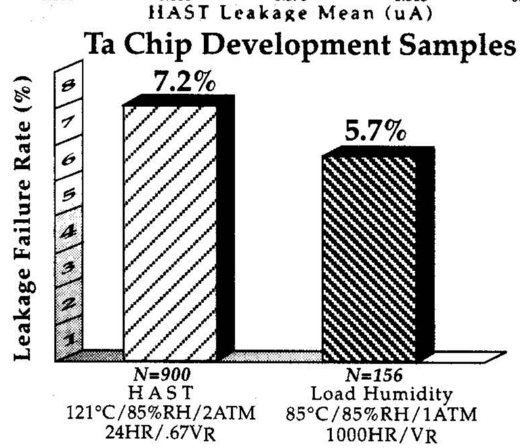


Figure 4