HALT/HASS Explaining Accelerated Aging

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Accelerated aging is the utilization of specific environments to age products logarithmically. This state-of-the-art evaluation tool allows designers and test engineers to evaluate product-life survivability in two weeks or less.

Accelerating life to a calculated time—usually two weeks or less for a five- or 10-year expected life—allows prototype and production units to be validated in real time. For this discussion, a 10-year product life equates to 36,500 hours.

Can 36,500 hours of normal life be reduced to an accelerated test of less than two weeks and yield the same failure mechanisms as experienced by customers? The answer is yes. Accelerated aging can validate in 336 hours, the equivalent of 36,500 system hours, with a 95% reliability confidence level (Table 1). This shortened test cycle enhances design maturity, allowing production units to be fabricated with little to no line losses, scrap, rework, retest, or customer returns. Accelerated aging minimizes product liability. This process has been applied to electronic, electromechanical, mechanical, and rotating components; plastic assemblies, and more.

Accelerated aging exposes products to thermal profiles that may exceed the design performance limits.

Accelerated-aging profiles usually fall within the design-forgiveness region and do not enter the destruct region.

This is a finite performance and time region. Excessive exposure pushes the product beyond the design life. As a result, the aging factor must be known for the expected life of the product, and this must be compared to the calculated accelerated-aging factor (Table 1). Note that the aging factor of 1,521 corresponds to 10 years, while the aging factor of 1,541 corresponds to only six days of testing. This is logarithmic or accelerated aging. Table 1 shows five test scenarios. The baseline displays an aging factor of 1,521 for 36,500 hours of life. The remaining scenarios have aging factors greater than the baseline, and test times are reduced to as low as four days. With this type of accelerated aging, you can validate that the precipitated anomalies or defects are the same as those seen in warranted returns. When a 10-year life test can be reduced to four days, you have time to maximize reliability while lowering cost.

Test scenarios 1 through 4 in Table l show accelerated aging occurring as you vary the temperature range, the number of thermal cycles or exposure hours, or the mass °C per minute rate of change beyond normal use. In all cases, the aging factor and the relative age over 10 years exceed the baseline.

How do you achieve product maturity—by design or chance? Screens used over the past 30 years have ranged from steady-state, high-temperature burn-in to high/low thermal transitions with change rates of several degrees per minute, to liquid thermal shock. Often, test programs took products into destruct regions and engineers did not know it, resulting in redesigns with all of the complications. Successes were hard to come by and often were the result of trial and error.

Industry tried to develop robust designs by implementing various test programs such as qualification, durability, endurance, life, reliability, and environmental stress screening (ESS). But companies are having difficulties selecting the right environmental screen. Accelerated aging is the precise use of screens that allow you to know where you are in the product life cycle without over-designing. Accelerated aging reduces design time and time to market; lowers production costs; improves reliability while reducing rework, repair, and retest, and minimizes scrap.

The Environment

All products age as a direct function of the environment in which they are used. If the environment is benign, the product can have a life expectancy of 60 years or more. However, if the same product is used in a very robust environment, it may only survive 100 operating hours. Table 2 shows the life expectancy of a computer in four environments: storage, office, commercial aircraft, and military aircraft.
The office is the baseline for the computer in Table 2. Note how the aging factor changes as a function of the use or storage environments. The age at the end of one calendar year is 2,600 hours of operation or 0.352 years. The same computer in a commercial aircraft can be used 7,000 hours in one year and has the equivalent age of 8.16 years as compared to the baseline environment. This age differential is attributed directly to the use environment. The military aircraft compresses 15.6 years of life into 500 hours as related to office use. The comprehensive test scenario that should be used must be more robust than the aircraft environment, and this can be performed in 168 hours.

Thermal Test Profiles

Thermal accelerated-aging test profiles are derived from the conditions in the logarithmic aging process. The four components that cause logarithmic aging are mass rate of change (Rc), thermal range (Tr), number of cycles (Nc), and total hours of exposure (Th). The most significant of the four environmental elements in the aging process is the Rc. If improperly used, Rc results in products being driven into the destruct region of the design. Properly selecting Rc, Tr, Nc, and Th while avoiding the destruct region will yield the desired test profile. The accelerated-aging test profile will constantly fall between the outer design limits and the start of the destruct region. This is the logarithmic aging region.

There are other factors to consider when developing an accelerated aging profile: the mass size and distribution, density, weight, packaging, and insulation factors. This information will help determine the optimum point in the production cycle where this exposure should occur. Accelerated aging need not always be performed on the end product. It can be accomplished in stages. Failures occur as a direct function of the coefficient of expansions of materials. Rc exceeding 40°C causes abnormal skin/material movements, resulting in tearing effects. These types of failure mechanisms should not result in design or material changes

A frequently asked question is "What is the best environment in which to achieve accelerated aging?". The environment should be the one that precipitates defects.

Thermal and vibration environments will identify over 95% of design, parts, workmanship, and process deficiencies. Thermal accelerated aging removes over 65% of all defects and offers the greatest impact on saving time. It also shortens test time from six months to less than two weeks. So what about vibration? Well, most vibration exposures seldom require more than two to four weeks. Proper vibration profiles can help strengthen the design and can identify some 30% of latent anomalies.

The Process

The computerized formula developed by Advanced Reliability Engineering Technology (ARET) has validated logarithmic aging via empirical testing. Once you have established the aging factor during normal use, then the aging factor for the total number of years of life can be derived. You can extrapolate the optimum aging factor by manipulating the formula. The formula allows you to manipulate environments until you achieve the same aging factor in two weeks or less. With both the design and the accelerated environmental limits established, you can determine what performance requirements you need from the thermal chamber and the controller. The type of chamber and controller is as important as the profile to be used. Thermal limits and the Rc establish the chamber compressor horsepower ratings and the chamber size. When sizing a chamber, the cavity size must be large enough to allow good air circulation. Air circulation allows the mass to change without forming stresses on the product surfaces.

The product surfaces should move at a rate relative to each other as would be seen in normal use, but at an accelerated or logarithmic rate. The controller can be programmed to compensate for differences between the air and the Rc. The air outlet rate of change may increase from -50° C to +100° in one minute or less; however, the mass may move at less than 5° C per minute. This could occur because the compressor is not large enough to compensate for the mass of the chamber walls as well as the test load. A chamber cavity of 4 ft × 4 ft × 4 ft has a calculated mass of approximately 640 lb. Each square foot of wall has a 10-lb equivalent chamber mass. The compressor must overcome the thermal inertia of the air ducts, walls, shelving, and the test load with fixturing. The compressor must be able to move the test mass at the desired thermal rate.

When liquid nitrogen is used, do not direct a blast at the product-under-test. It could be subjected to a thermal gradient of +300°C instantaneously. This is destructive and not typical of the normal use environment.

About the Author:

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Table 1

Electronic Package	Temperature Range	Cycles Per Day	Exposure Hours	Mass ° C Per Minute Rate of Change	Test Time	Aging Factor	Relative Age Over 10 Years
Electronic Package (Baseline)	+18° C to +21° C	1 operating	3,650/yr 36,500/10 yr	< 1° C	10 yr	1,521	4.2 yr or 36,500 h
Accelerated Scenario #1	-50° C to +50° C	36/day	336 h	< 10° C	14 days	1,708	4.7 yr
Accelerated Scenario #2	-50° C to +50° C	42/day	168 h	< 20° C	7 days	1,833	5.0 yr
Accelerated Scenario #3	-50° C to +85° C	32/day	144 h	< 20° C	6 days	1,541	4.2 yr
Accelerated Scenario #4	-50° C to +85° C	48/day	96 h	< 25° C	4 days	1,693	4.6 yr

Table 2

Computer Environment	Temperature Range	Daily Operation	Number of Cycles	Mass Rate of Change	Hours/ Year	Aging Factor	Relative Age in Years
Storage	+18° C to +21° C	Nonoperating	365/yr	< 1° C, per minute	none	0.023	0.0001 (8 h)
Office (Baseline)	+15° C to +25° C	1/day	365/yr	< 2° C, per minute	2,600	128	0.352 yr (3,084 h)
Commercial Aircraft	-50° C to +50° C	5/day	1,825/yr	< 5° C per flight	7,000	2,979	8.16 yr
Military Aircraft[1]	-50° C to +85° C	2/day	6,667/yr[1]	10° to 30° C	500	5,706	15.6 yr
Test Scenario	-55° C to +105° C	168 h test exposure	672	35° C		6,198	17 yr

[1]Each flight of a fighter aircraft is calculated as 10 thermal cycles per flight at 45 minutes per flight.