Accelerated Reliability Testing

Today's manufacturers face strong pressure to develop new, cutting edge technology products in record time, while improving productivity, product field reliability and overall quality. The requirements of higher reliability have increased the need for more up-front testing of materials, components and systems [1].

Estimating the failure-time distribution or long-term performance of components of high-reliability products is particularly difficult. Most modern products are designed to operate without failure for years, decades, or longer. Thus few units will fail or degrade appreciably in a test of practical length at normal use conditions. For example, the design and construction of a communication satellite may allow only 8 months of testing components that are expected to be in service for 10 or 15 years [2]. For such applications, accelerated tests are used in manufacturing industries to assess component and subsystems reliability, to certify components and to detect failure modes so that they can be corrected. Accelerated tests are becoming increasingly important because of rapidly changing technologies, more complicated products with more components, higher customer expectations for better reliability, and the need for rapid product developments [3].

Fundamentals of Reliability

Reliability is defined as the probability that an item will perform a required function under specified conditions for a stipulated period of time [4]. This definition identifies three important independent concepts:

1. Duration of time
2. Environmental conditions of use
3. Functioning parameter value or range

Some of the factors that make it essential that a product goes through a reliability enhancement program are as follows:

1. Rapid evolution of new materials, components and process
2. Complexity of the product being manufactured
3. Need to meet customer demands such as availability, safety, warranty
4. To meet desired mean time between failures and product cost
5. Compliance with the regulation

Inspecting a product against a specification or set of attributes makes an essential contribution to the reliability of the product. However, this concept is not time-dependent. Reliability is generally concerned with failures during the life of a product.

The Bathtub Curve

The life of a population of units can be divided into three distinct stages. Figure 1 shows the reliability "bathtub curve" , which models the cradle-to-grave instantaneous failure rates vs. time. If we follow the slope from the start to where it begins to flatten out, this can be considered the early life period where weaker units die off leaving a population that

is more rigorous. This is also called infant mortality stage. The next stage is the normal life or useful life where the slope is flat. Failures are random but predictable. The final stage is known as wear-out stage where the units become old and the rate of failure increases [4].

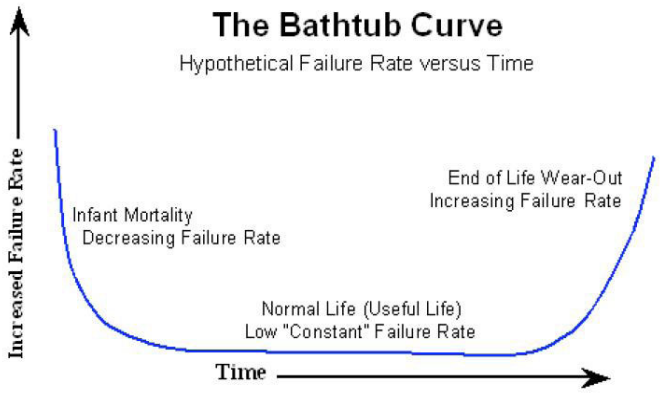

Figure 1. Reliability Bathtub Curve [4]

Accelerated Tests

There are three basic types of accelerated tests [4]:
1. Accelerated Life Tests
2. Reliability Enhancement Tests
3. Environmental Stress Screening

Environmental Stress Screening (ESS) is aimed at exposing infant mortality failures which would otherwise occur early in the life of the product. Reliability Enhancement Testing (RET) is conducted to find early failures related to the product design, but is also used to determine the robustness of the product with respect to the random failures of the useful life period. The purpose of accelerated life testing is to find out how, when, and why wear out failures occur in the product.

Figure 2 shows how accelerated life testing, reliability enhancement testing, and environmental stress screening fit into the product design, development, and manufacturing cycle. The on-line processes are shown as rectangles. On-line processes are those which are part of the

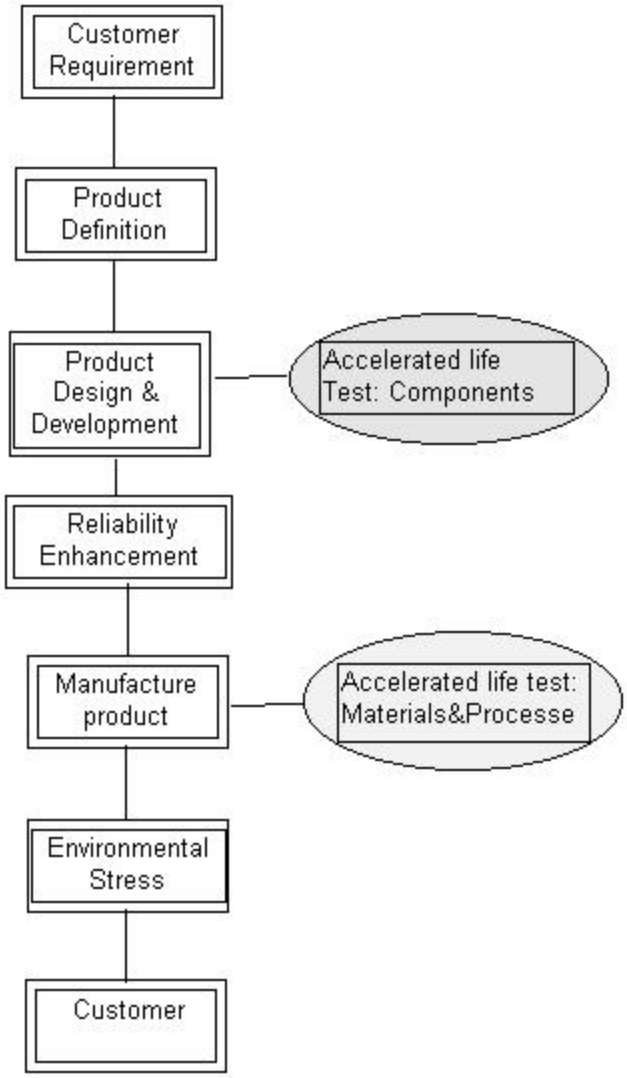

Figure 2. Accelerated Testing for Product Reliability Assurance [5]

product design and production cycle. They are conducted with samples of the actual product. Off-line processes are those which are not part of the design and production cycle. They are usually not conducted on actual product samples, but on generic samples representing the materials, components, or processes used to manufacture the product. Two out of the three types of accelerated tests (reliability enhancement testing and environmental stress screening) shown above are on-line processes and the third (accelerated life testing) is an off-line process [5].

Accelerated Life Test

Accelerated Life Tests (ALT) are conducted on components, materials and manufacturing processes (e.g. formation of a plated through hole) to determine their useful life in the required product application. Their purpose is not to expose defects, but to identify and quantify the failures and failure mechanisms which cause products to wear out at the end of their useful life. Because of this, Accelerated Life Tests must last long enough to cause the samples under test to fail by wear out. The test time may typically vary from a few weeks to a few months.

The purpose of accelerated life testing is to use the results of tests conducted for short times at high stress levels to predict the lifetimes of products at lower stress levels. This is done with mathematical acceleration models. There are an infinite number of acceleration models available, but many of them are variations of three basics models [6]

1. The Arrhenius Equation
2. The Inverse Power Law
3. The Eyring Model

To find more details about the models, please refer to Accelerate Life Testing by Condra L. W [4]

The benefits of ALT are:

1. The ability to estimate the useful life of the product
2. It also allows the designer/manufacturer of the products to identify, improve and control the critical components, materials and processes so that the final product is robust and mature.

Reliability Enhancement Testing

The purpose of RET is to determine the types and levels of environmental stresses which cause failures in a product, given that there are no defects in the materials and components used in manufacturing it. In this sense, RET is a type of inspection test for the product design, processes. Because RET is not directed toward finding infant defects, the sample size can be very small. The ideal time to conduct RET is at the end of the design cycle, when the expected design, materials, components, and manufacturing processes are available, production has not yet begun. RET is not a qualification test, since its purpose is to find weak spots and correct them before production begins [4].

RET is usually conducted by applying the expected environmental and operating stresses (singly, sequentially, or simultaneously) initially at low levels, and then increasing them in steps until one of the three things occur:

1. All samples fail
2. Stress levels are reached which are well above those expected in service, or
3. Irrelevant failures occur

An important benefit of RET is to survey and determine the products upper and lower limits. This is useful in determining the robustness of the product design. The ESS levels should not be changed to reflect these limits as it could overkill the product. Test, Analyze and Fix (TAAF) is crucial to a well-developed RET.

Environmental Stress Screening

Environmental Stress Screening (ESS) is useful in minimizing the early failures of manufactured products by screening latent defects. ESS is one of the most widely used reliability tests. The overall purpose of ESS is to assure that, once a product is qualified, there will be no uncontrolled variations in the individual items during the production phase [7]. The application of stresses is necessary to detect some defects which cannot be observed by functional or visual observation. The defects are those introduced into the product during manufacturing, since design-related defects should have been detected and eliminated by reliability enhancement testing during the design phase. ESS is effective only for a product with an infant mortality region, which is indicated by decreasing

initial failure rates in Fig.1. ESS should be based on an understanding of the potential types of latent defects in the product, the failure mechanisms and the stresses that cause them. ESS conditions are set up to precipitate those defects and the data are used to determine their causes and to take preventive actions.

Summary

Accelerated Reliability Testing provides valuable data about the expected wear out mechanisms of a product. This is critical in today's marketplace, since more and more customers are placing useful life requirements on products they purchase. The ability to estimate useful life is only one of the benefits of accelerated life testing. It also allows those who design and manufacture products to understand them better, so that the critical components, material and processes can be identified, improved and controlled; and it produces data which give both the producer and the user confidence that the product will serve its intended purpose.

Care must be taken to avoid misinterpreting results. Obtaining and interpreting results can be quite challenging, but it is not beyond the ability of those who truly wish to understand and improve their products. As these tests are very expensive and time consuming, they must be understood and planned carefully. Key components of the product, from a reliability point of view, must be identified; potential failure mechanisms must be known; and the stress environment of the product must be understood. Specific acceleration models must be available, or obtainable, for each failure mechanism; and the results must be interpreted properly. Many manufacturers do not have this level of understanding, or are not willing to obtain it. Those who do so have been well-rewarded, in the form of more reliable products and competitive market position.

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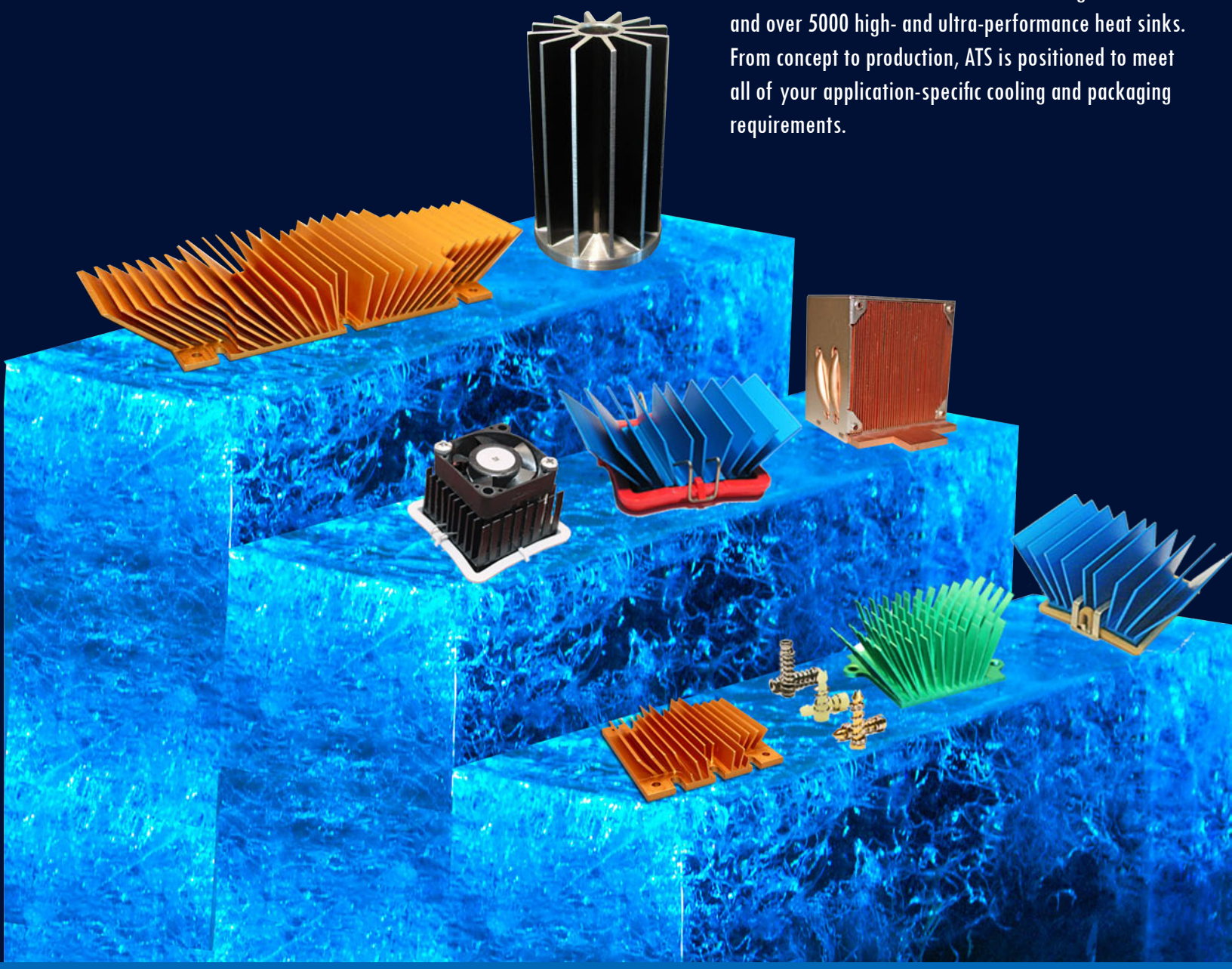

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