

# Reliability Engineering – Part 8

## Reliability Testing - A

Reliability tests are performed to ensure new designs, products, and systems meet performance requirements including quality, reliability, safety, and if applicable, regulatory requirements. Extensive testing reduces a business' exposure to financial and operational risks.

In general the amount of testing required is proportional to the amount of uncertainty and variability in the design and manufacturing of a product. More uncertainty in the design and/or higher variability in manufacturing processes, components, and materials necessitate more testing.

From an economical point of view, testing adds value. It has been estimated that correcting a design flaw, discovered early in the design phase of a new product, will be ten times less expensive than correcting it in manufacturing, and 100 times less expensive than fixing it after the product has been launched.

Testing alone cannot prevent costly product failures. Product designers must have a thorough understanding of the operational environment in which the product will be used. Many potential problems can be identified and eliminated early in the development process using engineering tools such as Failure Modes and Affects Analysis, Thermal Stress and Vibration Analysis, Fatigue Analysis, Finite Element Modeling, Dynamic Simulations, etc.

## Types of Reliability Tests

Reliability testing can be broken down into two categories:

- a) Design & Product Evaluation testing. Tests in which failures are desirable.
- b) Design & Product Verification/Validation testing. Tests to demonstrate that the new design/product “works.”

The primary purpose of design & product evaluation testing is to detect and correct weaknesses in the design or manufacturing process before the production phase is started. This can only be achieved realistically by generating failures. Therefore, the objective of a design & product evaluation test should be to stimulate failures, not to show that the product performs well under normal operating conditions. However, the latter is the preferred test mode for verification and validation testing.

The purpose of design & product verification/validation testing is to demonstrate the product meets all specifications under normal operation conditions, or in other words, to demonstrate success. Regulated industries (medical technology, pharmaceutical, aeronautical, nuclear energy, etc.) in particular are subject to rigorous validation testing requirements. Regulated industries must provide documented evidence that their products meet specifications.

## Design/Product Evaluation Test Methods

In order to generate failures units under test must be overstressed. This is a basic premise in design/product evaluation testing. Merely testing inside the normal operating range of a product is rather ineffective. Most modern day products are designed to operate without failures for many years. Therefore few test units will fail in a test of practical duration at normal use conditions. To reduce the test time and cost, highly reliable products are forced to fail by testing at much higher stresses than seen under normal application conditions.

Simply increasing the sample size can also accelerate reliability tests and reduce test time. However, increasing the severity of the test is a more logical approach when large samples cannot be provided or are not economical feasible.

Two basic methods of overstress testing commonly used in industry are:

1. Accelerated Life Testing (ALT)
2. Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS).

### Accelerated Life Testing (ALT)

A basic assumption of an accelerated life test is that a product, operating under higher levels of stress, will experience the same failure mechanism as seen when used at normal stress level. The only difference is that the failures "happen faster". It is assumed that the (single) failure mechanism is kept unchanged in its nature when passing from use to stress condition.

Accelerated test conditions are typically created by testing units at high levels of temperature, electrical voltage/current, humidity, pressure, shock and vibration, load, cycling or use rate, etc.

The data obtained at the more severe or accelerated test conditions, are extrapolated by means of an appropriate model to the normal conditions to obtain an estimate of the life distribution under normal use conditions.

If the failure mode at high stress level is exactly as at lower stresses, and only the time to failure has changed, we can say that we have obtained true acceleration. True acceleration is signified by a transformation of the time scale. The acceleration factor in true, linear acceleration is defined by:

$$A_F = \frac{t_u}{t_s} \quad \text{in which:} \quad t_u = \text{time to failure under normal conditions}$$
$$t_s = \text{time to failure under stress conditions}$$

Three widely used acceleration models are the **Arrhenius** model for thermal stresses, the **Inverse Power Law** model for non-thermal stresses, and the **Eyring** model for multiple stresses (thermal plus other non-thermal stresses). In the next parts we will review some of the ALT models in more detail.

## Highly Accelerated Life Testing (HALT) and Highly Accelerated Stress Screening (HASS)

Highly Accelerated Life Testing and Highly Accelerated Stress Screening are quite different from standard life testing, and end-of-production testing. HALT is a process developed to uncover design defects and weaknesses in products using a unique triaxial vibration system, combined with rapid high and low temperature changes. It is a technique that addresses reliability issues at an early stage in product development. HALT offers certain advantages over traditional test techniques. However, HALT does not provide quantitative reliability information. Unlike Accelerated Life Test data, HALT data cannot be extrapolated to actual use conditions. Despite some shortcomings HALT and HASS are powerful and effective tools for improving product quality, reliability and reducing warranty costs.

The essence of HALT is to over-stress the product and to very quickly induce failures. A typical HALT will take only 3 to 5 days. By applying stresses in a controlled, stepped-up fashion, while continuously monitoring the product for failures, the testing results in the exposure of the weakest links in the design. At the completion of HALT, the functional and destruct limits of the product are known, and design and process limitations, including corrective actions, are defined.

The key value of the testing lies in the failure modes that are uncovered and the speed with which they are uncovered. Any HALT is considered a success when failures are induced, failure modes are understood, corrective actions have been taken, and the physical limits of the product are defined and extended as far as possible. Although failures are induced by stresses in excess of specification, they are typically valid failure modes that could show up in the product in the field. Unlike design verification/validation testing, HALT is not a pass/fail test. It's a process of early discovery and design optimization.

HALT and HASS are not intended to replace design verification/validation testing. HALT will not provide you with the documented evidence needed to prove that your product meets specification. By doing HALT before design verification/validation testing is started, you will make it very likely that the final design verification/validation testing will be completed in one pass, with no defects found. This will greatly reduce the time to market and prevent costly defects after the product has been launched.

In the next parts we will review some of the HALT and HASS techniques.

### References:

- Accelerated Testing - Wayne Nelson
- Accelerated Reliability Engineering, HALT and HASS - Gregg Hobbs
- HALT, HASS & HASA Explained: Accelerated Reliability Techniques - Harry McLean
- Test Engineering - Patrick O'Connor