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TECHNICAL TIDBITS

MATERION PERFORMANCE ALLOYS

Life in the fast lane! – Using short-term testing to estimate long-term failure rates.

- Accelerated Life Testing
- Reliability Engineering
- Bathtub Curve
- Highly Accelerated Stress Screening (HASS)
- Burn-In
- Highly Accelerated Life Testing (HALT)
- Quantitative Accelerated Life Testing (QALT)
- Acceleration Factor

The next issue of Technical Tidbits will discuss learning from engineering failures.

ACCELERATED **LIFE TESTING**

Accelerated life testing is critical in today's engineering world. Engineers do not have the luxury of testing under real-world conditions for the desired lifetime of a component.

Imagine a new automobile with an expected lifetime of 10 years. Now imagine that the automobile could not be produced or sold until its prototypes have been successfully road-tested for 10 years. Any technological features in the prototype would be obsolete by the time the car would be ready for production! Clearly, we need to be able to estimate the reliability of a design over its expected life by testing in much shorter periods of time.

A product does not usually fail immediately upon first use, unless it is defective coming out of the box, or it is grossly misused. As a product gets older, the likelihood of failure increases. There are several distinct mechanisms which may render a perfectly adequate part defective over time. The only way to prevent such failures before the product's desired end of life is to use statistical analysis to learn what causes these failures and to control those influences. This discipline is called **reliability engineering.**

The **Bathtub Curve** in Figure 1 is a common way to express the useful life of a product. It illustrates the effects of 3 failure modes. The first is infant mortality (green curve) which is caused by defects in materials or processes. The failure rate starts out high and slowly diminishes. The second is random failures (blue curve), which occur at a constant, yet low rate. Usually these are the results of occasional random overstress events. The third failure mode is wear-out at end-of-life of the product (purple curve). This failure mode starts out with a very low rate, but gradually grows to become the dominant failure mode as time progresses.

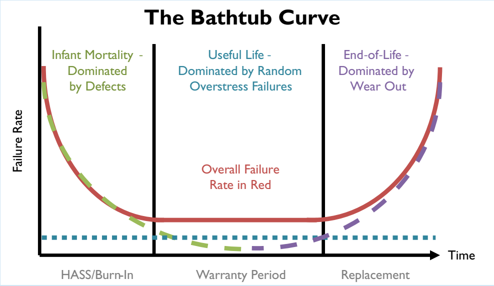

Figure 1. The Bathtub Curve. Time dependent failures are often described with the Bathtub Curve. There is an initial high but decreasing failure rate, as defective parts fail early. This is followed by a slower, constant failure rate, where randomly istributed failures dominate. At the end of life, the failure rate increases again as parts begin to wear out. The goal of any engineer is to keep the bathtub as wide and deep as possible, by screening out the infant mortality failures and controlling the time-dependent failure mechanisms that dominate the end-of-life sections of the curve.

When the 3 curves are added together (red curve), the familiar bathtub shape emerges. Failures in the late part of the curve (wear-out) are expected by the consumer. Failures in the middle part of the curve might make consumers unhappy, but are generally covered by product warranties. Failures in the early part of the curve (infant mortality section), would generally make consumers very unhappy, leading to bad reviews and loss of business. It the curve is kept as wide and deep as possible, consumers would be more likely to replace a worn-out product with the same model, or with another product from the same manufacturer.

ACCELERATED **LIFE TESTING** (CONTINUED)

Highly Accelerated Stress Screening (HASS) tests are used to filter defective products before shipping them to the consumer. By subjecting a statistically significant portion of the products to severe overstress conditions, the defective products that fail in the infant mortality stage are identified and removed. In this case, stress does not necessarily refer exclusively to mechanical stress, but can include environmental/chemical stress, thermal stress, electrical stress, etc. If all the products, not just a statistically representative portion are tested this way, the testing is called burn-in. By screening out the infant mortality failures, the net result is to move the bathtub curve to the left, so the consumers or customers never see the high initial failure rate. Of course, the wear out failures would then occur earlier, but the customers would be more likely to accept failures due to wear-out than defects.

The following stress conditions are known to accelerate the process of failure, and can be useful in accelerated life testing:

- Elevated temperature
- High humidity
- Excessive loading (mechanical stress, strain, pressure, current, voltage, etc.)
- Fast loading rate or shock loading (mechanical stress, strain, thermal shock, etc.)
- Vibration or cyclical loading
- Highly acidic or alkaline environments
- Exposure to corrosive gasses/liquids

Highly Accelerated Life Testing (HALT) is similar to HASS, in that it uses overstress conditions to determine the probable failure modes of a part in service. Engineers can then use that information to better design the products to withstand the likely failure modes and would also use that information to design the HASS tests.

Quantitative Accelerated Life Testing (QALT) is used to estimate the life of the product in service. The key to QALT is to subject the component to conditions that are more severe than it would experience in the real world, and then determine the reliability or failure rate under those conditions. Those results are then used to estimate the reliability or failure rate under actual service conditions. Usually, testing is repeated in order to come up with a correlation between the time in the test and the useful life in service. This is known as the acceleration factor. For example, in mixed flowing gas testing, 1 year of service life can be simulated by 2 days in the test chamber, per Dr. Bob Mroczkowski.

If any of this sounds similar to the discussion on Larson-Miller extrapolation in the most recent prior issue of Technical Tidbits, it is because the same types of analysis based on Arrhenius rate equations is used. Data taken during accelerated life testing is statistically analyzed and fit to the proper equations, so that expected life in the field can be calculated from the accelerated life testing results.

Reliability engineering and accelerated life testing is a very broad, detailed subject. This discussion is a very high-level overview. I encourage you to peruse the listed resources to learn more.

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http://www.weibull.com/ Reliability engineering Resources

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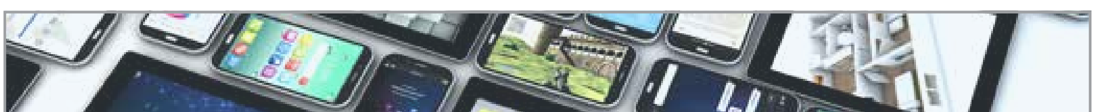
Health and Safety
Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Materion Performance Alloys or your local representative.



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