Reliability Testing

In addition to the parametric testing performed on every switch and relay that leaves the Coto factories, we subject samples of all our products to rigorous life testing. Products are tested at various current and voltage loads, including inrush current profiles where necessary. We frequently tailor these loads to our customers' special technical requirements. The sample sizes and the number of test cycles are chosen to allow accurate assessment of MCBF (mean cycles before failure) and other reliability statistics – often involving sample sizes of 64 or 128 test parts and several billion test cycles over many weeks.

Coto Technology uses Weibull distribution analysis for predicting MCBF, expected life before 1% part failure, estimation of expected infant mortality and wearout characteristics, and other pertinent reliability data.

Weibull distribution

This distribution is widely described in reliability literature. The number of cycles to failure for a sample of relays or switches is fitted by least-squares techniques using the two-parameter Weibull distribution function F(t), where

$$F(t) = 1 - e^{-(t/\eta)^{\beta}}$$

Here, F(t) is the unreliability function, t = time or cycles to failure, η and β are the Weibull distribution parameters.

This equation can be linearized by plotting $y = \log_e(\log_e(1/(1-F(t))))$ on the y-axis and $x = \log_e(t)$ on the x-axis. After linear regression of y on x, the slope of the regression line = β and the intercept = $\beta \log_e(\eta)$.

Given a set of cycles to failure for a particular sample of relays, F(t) values are calculated with Benard's approximation for median ranks:

$$F(t) = (j - 0.3) / (N + 0.4)$$

where j = the rank order number for the failure and N = total number of failures. Special precautions are taken to deal with censored data from parts that survive the test without failure.

The product's MCBF and its confidence limits are then calculated from the fitted Weibull parameters η and β. The Weibull slope parameter β is particularly useful, since its magnitude relates to the wearout characteristics of the product being tested. A value of $\beta < 1$ indicates "infant mortality" failures, that can potentially be reduced by manufacturing improvements, or screened out by burn-in testing. Values of $\beta > 1$ are more desirable, since they indicate a normal mechanism of wearout after a stable period of reliable operation.

The MCBF can also be expressed as a failure rate; one is simply the reciprocal of the other. Thus, a switch with an MCBF of 250 million cycles has an average failure rate of 4.0E-09 per cycle. This does not necessarily infer that a part has a constant failure rate throughout its life; for example, a part that shows wearout characteristics (large Weibull beta) will demonstrate an increasing failure rate as it nears the end of its service life.

What is a failure?

Reed relays eventually fail in one of three ways. They do not open when they should ("sticking"), they fail to close when they should ("missing"), or their static contact resistance gradually drifts up to an unacceptable level. At light loads, failure may not occur until several billion closure cycles have occurred. The first two listed mechanisms can be further subdivided into "soft" and "hard" failures. A soft failure is recorded when a switch is found to have missed or stuck a few milliseconds after coil activation or de-activation, but it is then found to have recovered from the problem when checked a short time later. If recovery from the initial soft failure has not occurred by the time the second check is made, the failure is classified as permanent or "hard".

Since even one soft failure can be problematic in critical applications such as ATE, Coto records failures for "expected life" estimation as the **first, soft** failure due to sticking, missing or excessive contact resistance. This is a deliberately conservative criterion. Comparison with the reliability data published by other relay manufacturers is difficult, because they may be less rigorous in their choice of failure criteria or less scrupulous in presenting statistical reliability data.

Typical Example of Life Data Analysis and Interpretation

The Weibull regression plots shown In Figure 12 were generated from a life test of 64 Coto ATE-grade relays compared to an equal number of commercially available competitive parts. The test was run at 200 Hz,

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using a 5V, 10 mA resistive load. It was continued until all 128 parts had failed at about one billion cycles and 55 days of continuous testing. The MCBF for each relay type can be approximately estimated from the intercept of each fitted reliability plot with the 50% unreliability ordinate, or more accurately determined by numerical methods beyond the scope of this catalog. Shown on the plot as a vertical dotted line projected onto the x-axis, the estimated MCBF for the competitive relay is 66 million cycles, compared to 450 million for the Coto relay. The dotted lines indicate the 90% confidence limits for each plot - since these do not overlap at any point, the parts clearly have significantly different reliability levels with a 90% confidence level. Another useful reliability statistic is the expected life before 1% failure; the plots show that estimated 1% life is between 1 and 4 million cycles for the competitive relay, compared to 30 to 70 million for the Coto relay. The explanation of this bigger reliability differential is the steeper slope of the Weibull plot for the Coto part, indicating a more pronounced wearout characteristic than the random failures exhibited by the competitor. Since the cost to locate, remove and replace a failed relay can greatly exceed the actual purchase price of the part, steeper Weibull slopes and higher MCBF's mean lower maintenance and replacement costs, and fewer expensive "infant mortality" failures.

Published life expectancy data

In the relay product specifications listed in this catalog, the term "Expected Life" is synonymous with MCBF or mean cycles before failure. Since the confidence limits associated with MCBF estimates are usually quite broad, the life estimates are rounded to an appropriate number of significant figures to avoid implied over-accuracy. Relay reliability data are only given for 1V, 10 mA or 1V 1 mA resistive loads. Switch life data is given at several different loads, depending on the application. Contact Coto Technology for life data at other loads. We have an extensive database of life test data, and may be able to predict reliability under other load conditions or set up a special life test meeting your requirements.

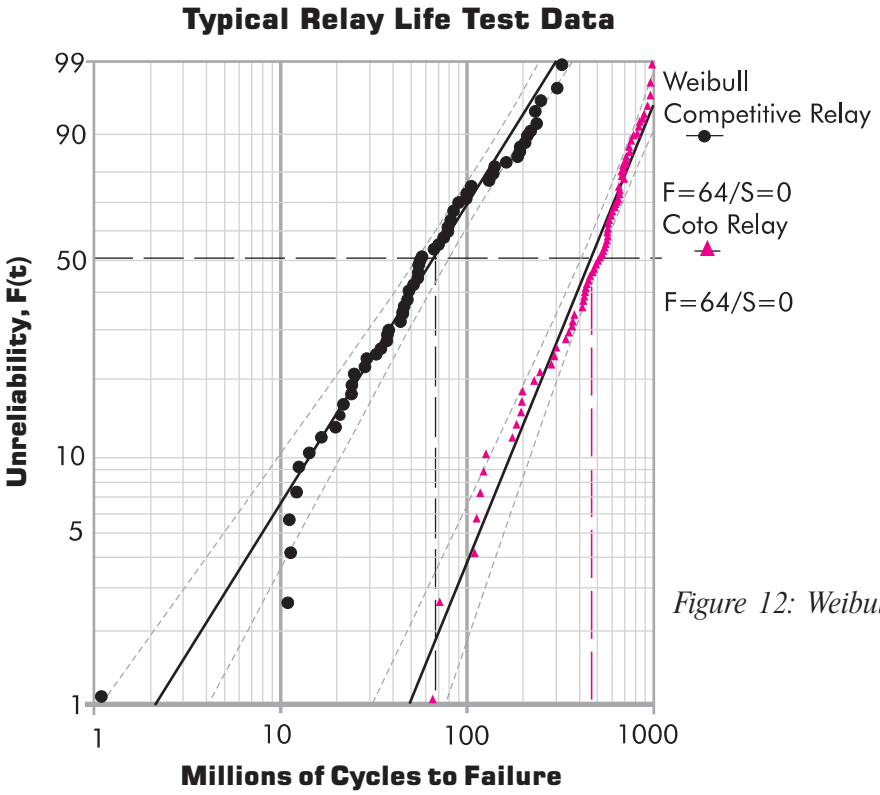

Figure 12: Weibull Regression Plots