LIFETIME ANALYSIS OF TO-STYLE INFRARED EMITTERS

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OBJECTIVE:

To develop a statistical estimate of the expected lifetime of a Kanthal filament based IR lamp in an Argon backfilled TO-style package.

METHOD:

The model used to describe the probability of failure of individual lamps is the exponential probability distribution. This model is appropriate when there are no significant wear out mechanisms such as with the Argon backfilled TO-package. The Argon prevents oxidation degradation of the Kanthal filament so the failure rate, λ, is expected to be constant over time. Consequently, there is no memory of how long the lamp has been operating. The Mean Time To Failure (MTTF) is defined as the reciprocal of the failure rate (see Appendix).

$$MTTF = \frac{1}{\lambda}$$

TEST DESIGN:

50 units were selected and operated continuously and simultaneously in ambient atmosphere at maximum input voltage (with heat sinks installed) for two months or 60 days (1440 hours). No failures were observed with failures defined as burn-out or significant degradation of lamp performance.

ANALYSIS:

The single parameter to estimate in the exponential distribution is the failure rate, λ, where,

$$\lambda = \frac{Number\ of\ failures}{Total\ number\ of\ test\ hours}$$

In addition, it is also necessary to calculate a confidence interval about the point estimate. For example, a 90% confidence interval means that if the same experiment were repeated many times with the same method to define an interval for λ, 90% of those intervals would contain the true λ. Thus, for our single experiment there is a 90% probability that the true value of λ lies within the interval.

However, when there are no failures the point estimate, λ, is zero which is not realistic. An upper 100 x (1-α) confidence limit for λ is then given by,

$$\lambda_{100 \times (1-\alpha)} = \frac{-\ln \alpha}{nT}$$

where, α = 0.1 corresponds to a 90% confidence interval and n and T are the number of units and the test time, respectively. The total number of test hours is then nT. For our data we have

$$\lambda_{90\%} = \frac{-\ln 0.1}{50 \; x \; 1440}$$

$$= \frac{2.303}{72000}$$

$$= 3.2 \times 10^{-5}$$

The upper bound for λ becomes the lower bound for the reciprocal, or MTTF, so that we have

$$\text{MTTF} = \frac{1}{\lambda} = \frac{1}{3.2 \; x \; 10E{-}5} = \underline{31{,}263} \text{ hours}$$

Similarly, at a 95% confidence level we have,

$$\lambda_{95\%} = \frac{-\ln 0.05}{72000}$$

$$= \frac{2.996}{72000}$$

$$= 4.16 \times 10^{-5}$$

and,

$$\text{MTTF} = \underline{24{,}034} \text{ hours}$$

The total number of hours in a year is 24 x 365 = 8760 hours so that

Confidence level	90%	95%
MTTF	31,263	24,034
Years	3.57	2.74

CONCLUSIONS:

A lower bound estimate of the expected lifetime of the Kanthal filament lamps is estimated to be 2.74 years at a 95% confidence level operating at full input power with a heat sink attached. Because there were no failures an upper bound or limit for the lifetime could not be estimated. A more complete experiment might have extended the test time to include at least one failure. The test sample was apparently more robust than could be thoroughly analyzed with the current test plan.

APPENDIX – EXPONENTIAL DISTRIBUTION BASICS

The exponential probability distribution is expressed by the equation,

$$f(t) = \lambda e^{-\lambda t} \qquad 0 \leq t < \infty$$

where, λ is a constant. The Mean Time To Failure (MTTF) is the average time calculated as

$$\text{MTTF} = \int_0^\infty t\lambda e^{-\lambda t}\, dt$$

Integrating by parts gives,

$$\text{MTTF} = \frac{1}{\lambda}$$

where, λ is now the failure rate.