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Standard Guide for
Analysis of Overtest Data in Radiation Testing of Electronic Parts[1]

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1. Scope

1.1 This guide covers the use of overtesting in order to reduce the required number of parts that must be tested to meet a given quality acceptance standard. Overtesting is testing a sample number of parts at a stress level higher than their specification stress in order to reduce the amount of necessary data taking. This guide discusses when and how overtesting may be applied to forming probabilistic estimates for the survival of electronic piece parts subjected to radiation stress. Some knowledge of the probability distribution governing the stress-to-failure of the parts is necessary, although exact knowledge may be replaced by over-conservative estimates of this distribution.

2. Referenced Documents

2.1 *Military Standards:*

MIL-PRF 19500 Semiconductor Devices, General Specifications for[2]

MIL-PRF 38535 Integrated Circuits (Microcircuit Manufacturing)[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Confidence*—the probability, *C*, that at least a fraction, *P*, of the electronic parts from a test lot will survive in actual service; since radiation testing of electronic parts is generally destructive, this probability must be calculated from tests on selected specimens from the lot.

3.1.2 *Rejection Confidence*—the probability, *R*, that a lot will be rejected based on destructive tests of selected specimens if more than a specified fraction, *P*, of the parts in the lot will fail in actual service.

3.1.3 *Discussion of Preceding Terms*—Strictly speaking, most lot acceptance tests (be they testing by attributes or variables) do not guarantee survivability, but rather that inferior lots, where the survival probability of the parts is less than probability, *P*, will be rejected with confidence, *C*. In order to infer a true confidence, it would require a Bayes Theorem calculation. In many cases, the distinction between confidence and rejection confidence is of little practical importance. However, in other cases (typically when a large number of lots are rejected) the distinction between these two kinds of confidence can be significant. The formulas given in this guide apply whether one is dealing with confidence or rejection confidence.

4. Summary of Guide

4.1 This guide is intended to primarily apply to sampling by attribute plans typified by Lot Tolerance Percent Defective (LTPD) tables given in MIL-PRF 38535 and MIL-PRF 19500, and contains the following:

4.1.1 An equation for estimating the effectiveness of overtesting in terms of increased probability of survival,

4.1.2 An equation for the required amount of overtesting given a necessary survival probability, and

4.1.3 Cautions and limitations on the method.

5. Significance and Use

5.1 *Overtesting should be done when* (*a*) testing by variables is impractical because of time and cost considerations or because the probability distribution of stress to failure cannot be estimated with sufficient accuracy, and (*b*) an unrealistically large number of parts would have to be tested at the specification stress for the necessary confidence and survival probability.

6. Interferences

6.1 *Probability Distributions*—In overtesting, a knowledge of the probability distribution governing stress to failure is required, though it need not be specified with the same accuracy necessary for testing by variables. For bipolar transistors exposed to neutron radiation, the failure mechanism is usually gain degradation and the stress to failure is known to

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[2] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

follow a lognormal distribution.[3] For bipolar transistors exposed to total dose the use of the lognormal distribution is also fairly accurate.[4] For more complex electronics and other kinds of radiation stress, the lognormal distribution is widely used in estimating the failure probabilities of electronic piece parts, and therefore this standard governs the use of a lognormal distribution. However, caution should be exercised when the probability distribution of stress to failure is not well established. Nevertheless, even if the lognormal distribution does not strictly apply, the equations given in Section 7 will hold as long as a sufficiently conservative estimate was made of the variability of the parts within the stress range of interest.[5]

6.2 *Time Dependent Post Radiation Effects*—In total dose testing annealing and rebound effects can affect the results.

7. Equations and Tabulations for Overtesting

7.1 Let R_T and R_S be the respective overtest (radiation level at which the test is performed) and specification stresses (specification radiation level). Let $\sigma_{\ln}(\max)$ be an estimated maximum standard deviation in the natural logarithms of the stress to failure, and let P_T and P_S be the respective survival probabilities with confidence, C, at the overtest and stress levels. Then,

$$P_S = F\left[\bar{F}\,(P_T) + \frac{\ln(R_T/R_S)}{\sigma_{ln}(\max)}\right], \tag{1}$$

where:

F = the cumulative standard normal probability distribution, and

$\bar{F}$ = the anti-function of F where $\bar{F}[F(X)] = X$.

Most probability texts tabulate the cumulative standard normal probability distribution function, F, and its antifunction (sometimes denoted by Z_p).

7.1.1 When P_S is given and P_T is known, the overtest factor is:

$$R_T/R_S = \exp\left\{\sigma_{\ln}(\max)\left[\bar{F}(P_S) - \bar{F}(P_T)\right]\right\} \tag{2}$$

7.2 For neutrons, 0.5 is a good estimate of $\sigma_{\ln}(\max)$.[5,6]

7.2.1 *Example:*

Suppose bipolar transistors are tested at a neutron fluence three times the specification fluence and it is determined that with 90 % confidence, at least 80 % of the transistors will survive the overtest fluence. Then from Eq 1, at the specification fluence, with 90 % confidence, the survival probability is as follows:

$$P_S = F\left[\bar{F}(P_T) + \ln(3)/0.5\right] = F[0.84 + 2.20] = F[3.04] = 0.999,$$

where we used the following facts governing the normal distribution:

Standard probability tables such as those shown in M.G. Natrella, "Experimental Statistics," NBS Handbook 91, U.S. Dept. of Commerce (1966) shows that $\bar{F}(0.8) = 0.84$. The 80 percentile point of the distribution is 0.84 standard deviations above the mean of the distribution (80 % of the distribution is below 0.84 standard deviations above the mean).

The number 3.04 is approximately the 99.9 percentile of the distribution. This result means that lots will be rejected with 90 % confidence unless 99.9 % of these parts survive one times the specification fluence. The three times overtest has thus raised the requirement on the lot quality to a value which would otherwise require testing an excessively large number of parts.[5]

7.3 Table 1 gives examples of the estimated survival probability as a function of R, where R depends on the overtest factor and the estimated maximum logarithmic standard deviation in stress-to-failure as follows:

$$\mathrm{R} = \frac{\ln(R_T/R_S)}{\sigma_{\ln}(\max)} \tag{3}$$

7.3.1 *Sample Use of Table 1:*

If an overtest were performed with $R = 1.5$, and if it is known that a certain part type has stresses-to-failure that never vary up or down by more than a factor of 4, that is $\sigma_{\ln}(\max) = \ln(4)$, then the overtest level would be $1.5 = {}^{\ln(\mathrm{RT/RS})}\!/\!_{\ln 4}$ and $R_T/R_S = e^{1.5\ln 4} = 8$ or $4^{\,1.5} = 8$ times the specification level. If it were determined that with 90 % confidence, C, 80 % of the parts would survive the overtest level, then since the table shows that at the specification level, with confidence, C, the table shows that 0.990400 or an estimated 99 % of the parts would survive. Alternatively, given the data at the specification level, the desired part survivability and a factor that bounds the variability of the parts, this table can be used to determine an overtest level.

7.3.2 *Cautions for Using Table 1:*

Be aware that clearly a survival probability of 1.0 is

TABLE 1 Survival Probability at Specification Level Versus *R* and Survival Probability at Overtest Level

	Specification Level Probability for:					
Overtest Level Probability	R = 0.5	R = 1.0	R = 1.5	R = 2.0	R = 3.0	R = 5.0
0.50	0.691462	0.841345	0.933193	0.977250	0.998650	1.000000
0.80	0.910140	0.967235	0.990400	0.997756	0.999939	1.000000
0.90	0.962588	0.988742	0.997295	0.999484	0.999991	1.000000
0.95	0.984016	0.995913	0.999169	0.999866	0.999998	1.000000

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[3] Messenger, G. C., Steele, E. L., "Statistical Modeling of Semiconductor Devices for the TREE Environment,'' *Transactions on Nuclear Science* NS-15, 1968, p. 4691.

[4] Stanley, A. G., Martin, K. E., and Price, W. E., "Hardness Assurance for Total Dose Radiation—Final Report,'' No. 730-2, Jet Propulsion Laboratory, Pasadena, CA 1977.

[5] Namenson, A. I., "Hardness Assurance and Overtesting,'' *IEEE Transactions on Nuclear Science* NS-29, 1982, p. 1821.

[6] Namenson, A. I., "Statistical Treatment of Damage Factors for Semiconductor Devices,'' *IEEE Transactions on Nuclear Science* NS-26, 1979, p. 4691.

unrealistic, and where it appears, the table should be interpreted to mean that there would be no point in going to a higher level of overtest than the one indicated in the table. In general, very high probabilities of survival should not be taken literally because errors in the assumed probability distribution, unexpected results, maverick parts, simulation fidelity, and human error, all affect a practical situation. An experienced user would have some idea of the maximum credible survivability for the particular application. It is suggested here that probabilities of over 0.999999 are not credible unless massive experience shows that tests, part processing, and the personnel are reliable to at least that level of confidence. Nevertheless, if a very high level of survival is predicted, the information suggests that any weak point in a system is most likely somewhere else.

8. Keywords

8.1 confidence; rejection; overtest data; statistical analysis

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