VANTIS

BEYOND PERFORMANCE

Product Reliability Monitoring Program

INTRODUCTION

Vantis is committed to providing products with unequaled product reliability. Throughout the life of our products, from technology development and product design to volume manufacturing, the reliability is constantly monitored to ensure our products meet exacting standards. The core of the production monitoring process is the Qualification Maintenance Program.

Vantis Qualification Maintenance Program (QMP)

Vantis' Qualification Maintenance Program is used to measure the reliability of all process technologies used on a regular basis. This program monitors the EEPROM wafer fabrication technologies used to manufacture Programmable Logic Devices. The program also provides extensive coverage of packaging technologies through environmental stress tests. Typically about 2500 devices per month are subjected to a battery of reliability stress tests with interval electrical testing.

The Qualification Maintenance Program has two purposes:

1. Improved Reliability Performance

Vantis maintains a Zero Tolerance mentality regarding defective units identified during reliability testing. Every reject is analyzed to determine the root cause of failure in order to drive continuous improvement through the implementation of corrective actions. Improvements in processing and device design are developed from the analysis of failed devices.

2. Generation of Reliability Data

QMP test results are used to assess the benefits of production burn-in, estimates of typical lifetimes, model field applications, and determine suitability of plastic packaging in various temperature and humidity environments.

Qualification maintenance testing is conducted on representative samples of devices from each wafer fabrication process technology. Samples are pulled from each process technology on a monthly basis. The sampling plan includes all technologies from all wafer foundry locations to ensure complete coverage. Devices are selected on the basis of complexity, production volume, and strategic importance. Process, package and product reliability qualification are used to determine device selection.

Devices that represent a design and technology family per EIA/JEDEC specifications are used on high volume technologies. This process and design grouping results in larger sample sizes so reliability assessment is statistically significant.

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QMP TESTS AND TEST CONDITIONS

A variety of stress testing is used to measure device reliability. The stress test employed and the test conditions used are shown in the table below.

Table 1. Reliability Monitor Stress Conditions

Stress	Readpoints	Sample Size (Typical)	Ambient Conditions	
			Hermetic	Plastic
Early Life	48,168 hours	600	150°C	150°C (Note 1), 125°C
HAST	96 hours	50	N/A	85% RH, 18 PSI, 130°C
Inherent Life	1000 hours	120	150°C	150°C (Note 1), 125°C
Temperature Cycle	100,1000 cycles	50	-65°C to 150°C	-65°C to 150°C, -40°C to 150°C (SMT)
Temperature Humidity Bias	1000 hours	50	N/A	85°C & 85% RH, 5V
Steam Pressure Pot	168 hours	50	N/A	121°C, 15 psig, no bias

Note:

1. *Devices dissipating low power are life tested at 150°C*

Plastic surface mount devices are pre-conditioned prior to undergoing temperature cycling and biased temperature and humidity stressing. Pre-conditioning is required in order to simulate the stresses that the packaged parts are subjected to during shipping, storage, board assembly and cleaning operations. A convection reflow profile and the pre-conditioning flow are shown below.

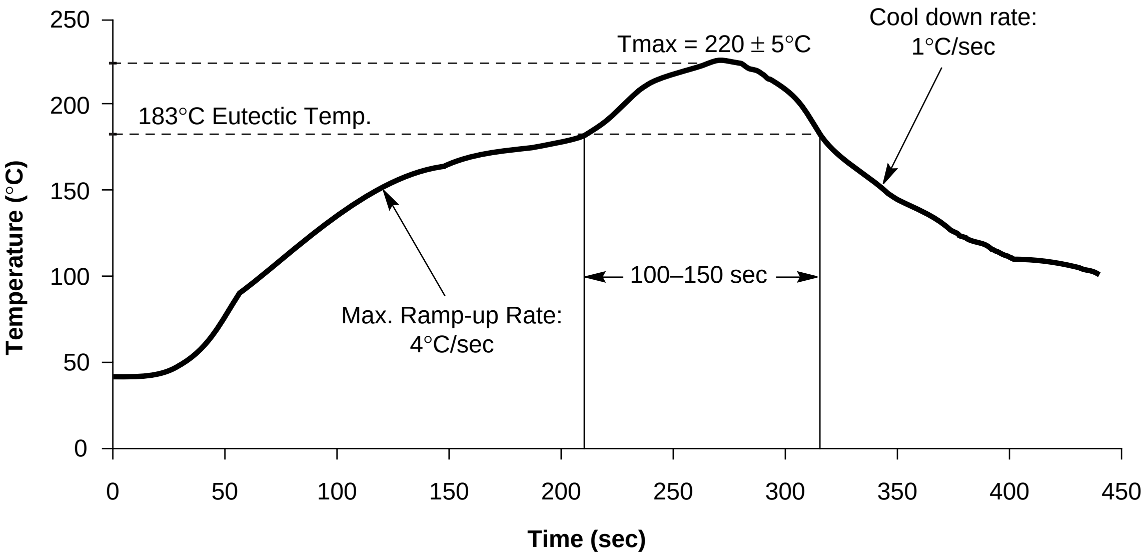

Figure 1. Reflow Soldering Profile for IR & Convection Oven

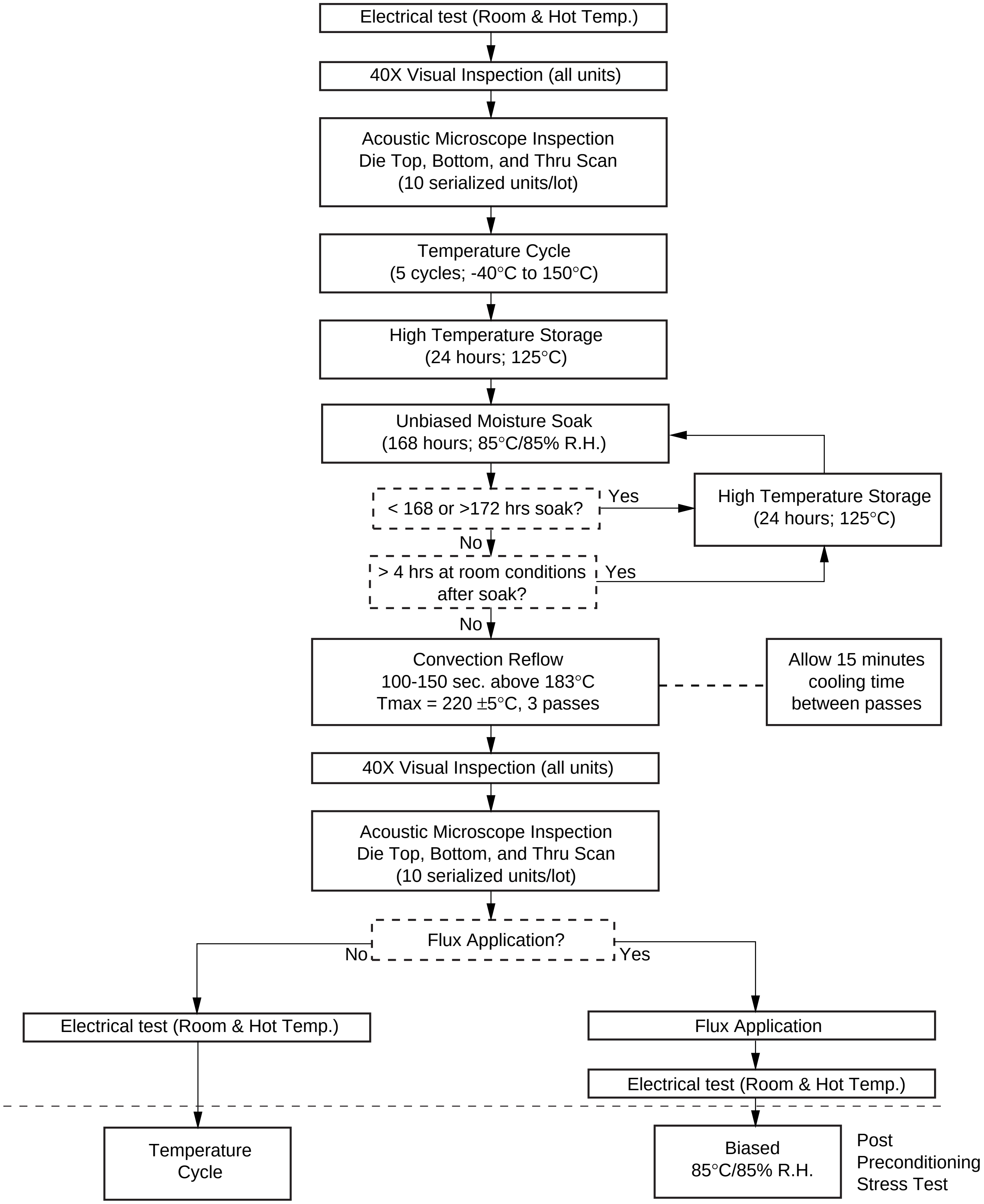

Figure 2. Standard Preconditioning Flow for Non-Dry-Packaged Packages

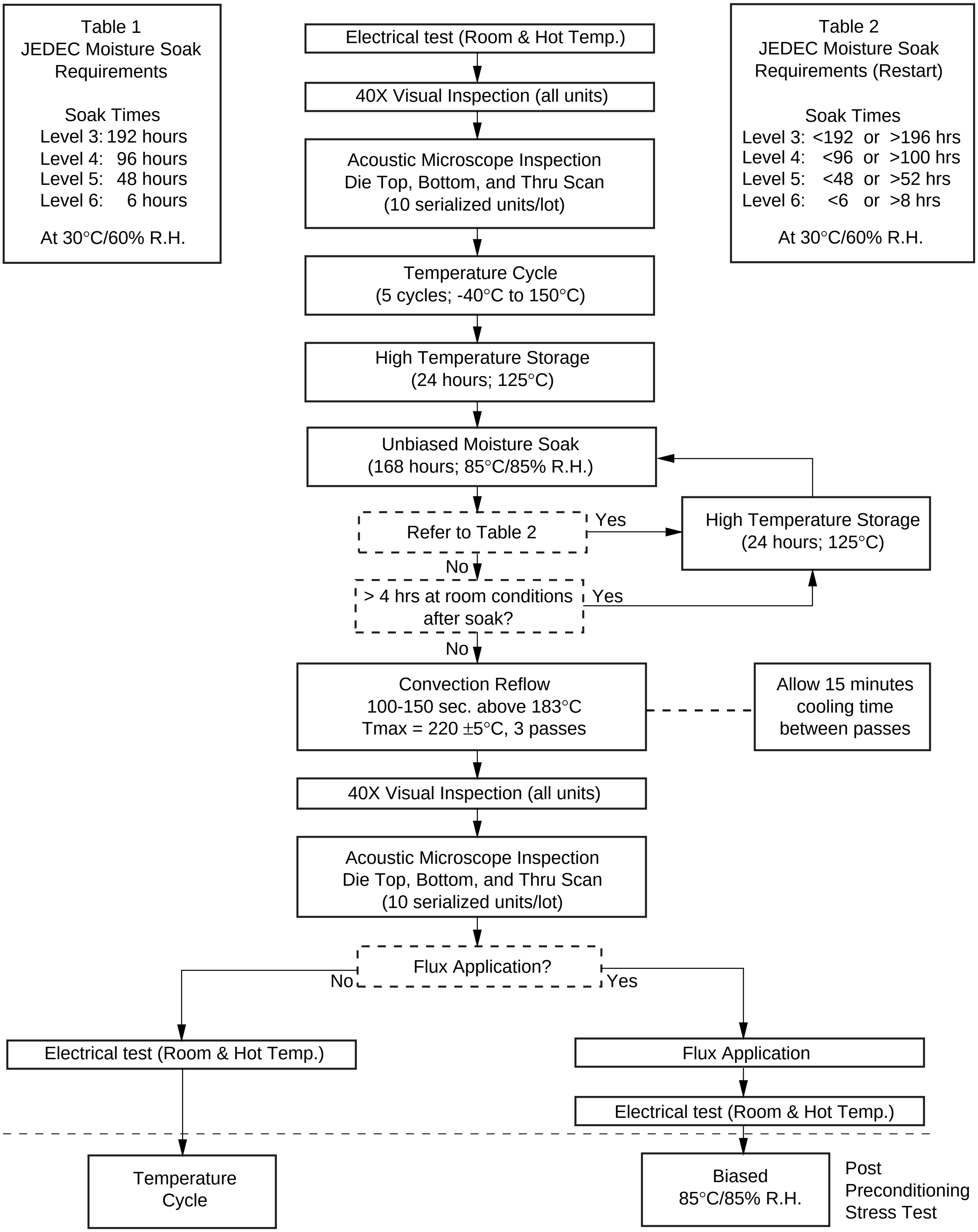

Figure 3. Standard Preconditioning Flow for Dry-Packaged Packages

FAILURE ANALYSIS

Every reject that is encountered during the course of QMP stress testing provides an opportunity for continuous improvement through identification and elimination of root cause. Additionally, there is a significant opportunity to understand the cause of variance in products, even while they meet specifications.

Failure analysis in the semiconductor industry has evolved towards a more thorough understanding of the device physics of the underlying process technologies. Different skills, knowledge and tools are also required to analyze defects that exhibit no morphology using conventional failure analysis techniques.

Electrical failure analysis of Vantis finished products is done by five Device Analysis Laboratories located around the world. A cooperative arrangement with suppliers of device analysis services allows Vantis to provide this capability world-wide. Two analysis sites are located in the United States: Austin and Sunnyvale; two are located in Asia Pacific: Penang, Malaysia and Bangkok, Thailand; and one in Frimley, England. These laboratories serve our local sites and customer base by providing analytical services on packaged devices. This includes analysis of our sub-micron products from qualification stresses, qualification monitor stresses, quality test failures, customer returns, and engineering evaluations.

All five of the laboratories have Scanning Electron Microscopes (SEMs) with X-ray analysis systems (EDX) attached. Sunnyvale and Austin have Field Emission SEMs with significantly enhanced resolution capability and windowless EDX detectors for extended analytical capability. Most sites have Scanning Acoustic Microscopes (SAMs) and X-ray capability for package evaluation. Austin, Sunnyvale, and Penang have e-beam microprober capability, which provides access to signals deep within a device. The same laboratories also have Focused Ion Beam (FIB) capability, which is used during new device debug (cutting and deposition of metal lines allowing for circuit modification) and for failure analysis where probe points can be created and where micro precision cuts aid in cross sectioning.

Other tools common to all labs include automatic decapsulation capability for plastic devices, both wet chemical and dry delayering (plasma and Reactive Ion Etch), optical microscopes with cameras, mechanical probe stations to electrically examine inside a device being evaluated, laser systems for circuit isolation, and polishing wheels for die and package cross sectioning. Each lab has a Layout Tool to provide engineers access to the physical layout drawings of the device that they are evaluating.

RELIABILITY DATA/ANALYSIS

The reliability data generated from the Qualification Maintenance Program (QMP) is used to predict field reliability. A detailed description of the modeling procedure used for estimating reliability under field conditions follows.

Average failure rates are calculated for time periods related to both early life and inherent life. The early life period corresponds to approximately the first 4,000 hours at field use conditions. The inherent life corresponds to the useful life beyond the first 4,000 hours of field operation. For these calculations, device operation temperature is assumed to be 55°C ambient. Voltage acceleration factors are used in the analysis wherever applicable.

The Exponential Distribution

The exponential distribution is simple to use, well understood and as valid as any for life tests with large sample sizes and few failures. No actual distribution can be implied as there is seldom enough data to determine one. The exponential distribution, characterized by a constant failure rate, is a special case of the Weibull. The average failure rate is the same as the instantaneous failure rate for the exponential distribution because the failure rate is constant.

The exponential distribution is the only one for which a MTTF (mean time to failure) value may easily be estimated, and it is simply the reciprocal of the failure rate (λ). In addition, it is the only one for which a confidence level may be readily assigned to the failure rate calculation.

The best way to understand the concept of confidence levels is to consider this example. Assume that a life test on a 100-piece sample from a certain product population had one failure and a 60% confidence level was desired. The chi square value corresponding to one failure at 60% confidence is 2.02. This means that one has a 60% confidence that the “true” value of the population’s defect rate is between zero (or some very small value) and 2.02%.

The conventional expression for the failure rate, λ, is:

$$\lambda = \frac{\chi^{2}(2n+2, 1-\alpha) \times 10^{9}}{2 \times ss \times t \times AF}$$

where λ is the failure rate in FITs (failures per billion unit-hours), $\boldsymbol{\chi^{2}(2n+2,1-\alpha)/2}$ is the upper confidence value for “**n**” failures and upper confidence limit, α (expressed as a decimal value), **SS** is the sample size, **t** is the test duration in hours, and **AF** is the acceleration factor relating the life test junction temperature to a assumed field junction temperature

The χ^{2} (chi square) value for 2n+2 degrees of freedom and the probability, 1-α, can be obtained from a table or calculated using Microsoft Excel chi squared inverse function [=CHIINV(1-α,2n+2)].

Failure Distributions

The lognormal and Weibull CDF’s are the distributions most often used to represent reliability failure mechanisms. The exponential distribution, characterized by a constant failure rate, is a special case of the Weibull. The lognormal distribution is specified by two parameters: T50, the median time to failure, and sigma, the shape parameter. The Weibull distribution, which can be written in closed form as:

$$F(t) = 1-\exp[-(t/c)^{m}],$$

is characterized by a characteristic life, c, and a shape parameter, m. The value of the shape parameter determines whether the failure rate is increasing (m>1), decreasing (m<1), or constant (m=1). The exponential distribution:

$$F(t) = 1-\exp\,[-(t/c)],$$

is specified completely by the one parameter, c, called the mean time to failure (MTTF). Figures 4 and 5 show failure rates for several values of the scale parameters of the lognormal and Weibull distributions, respectively.

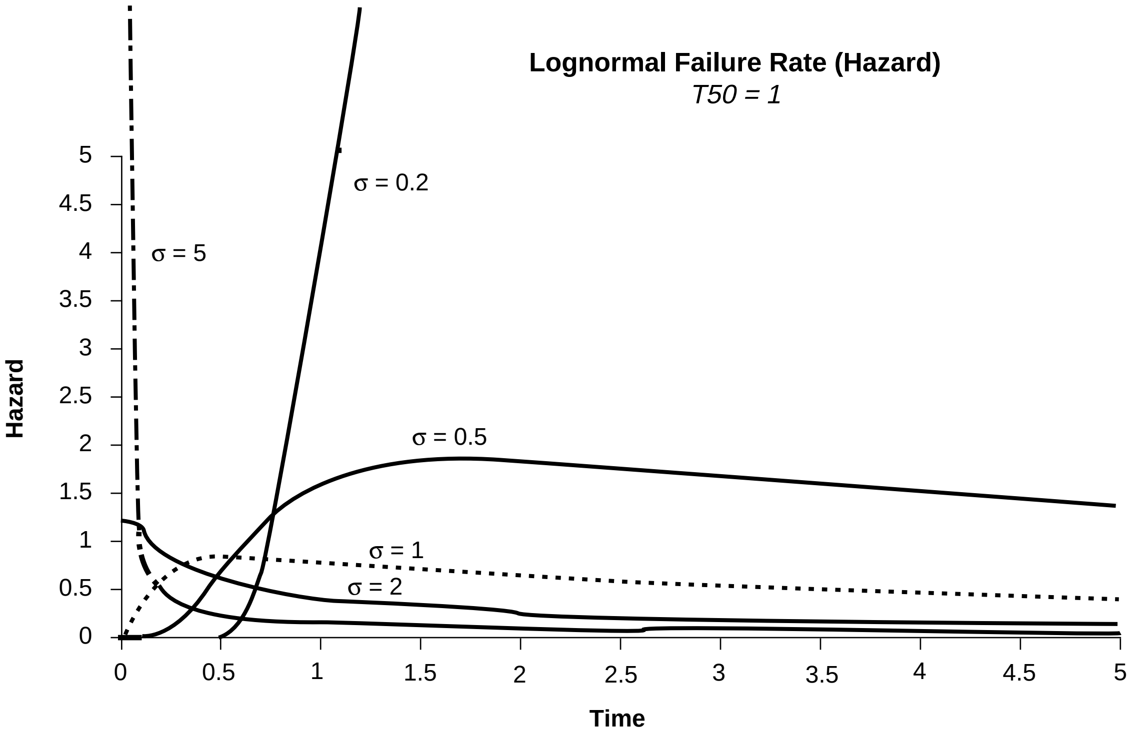

Figure 4. Lognormal Distribution

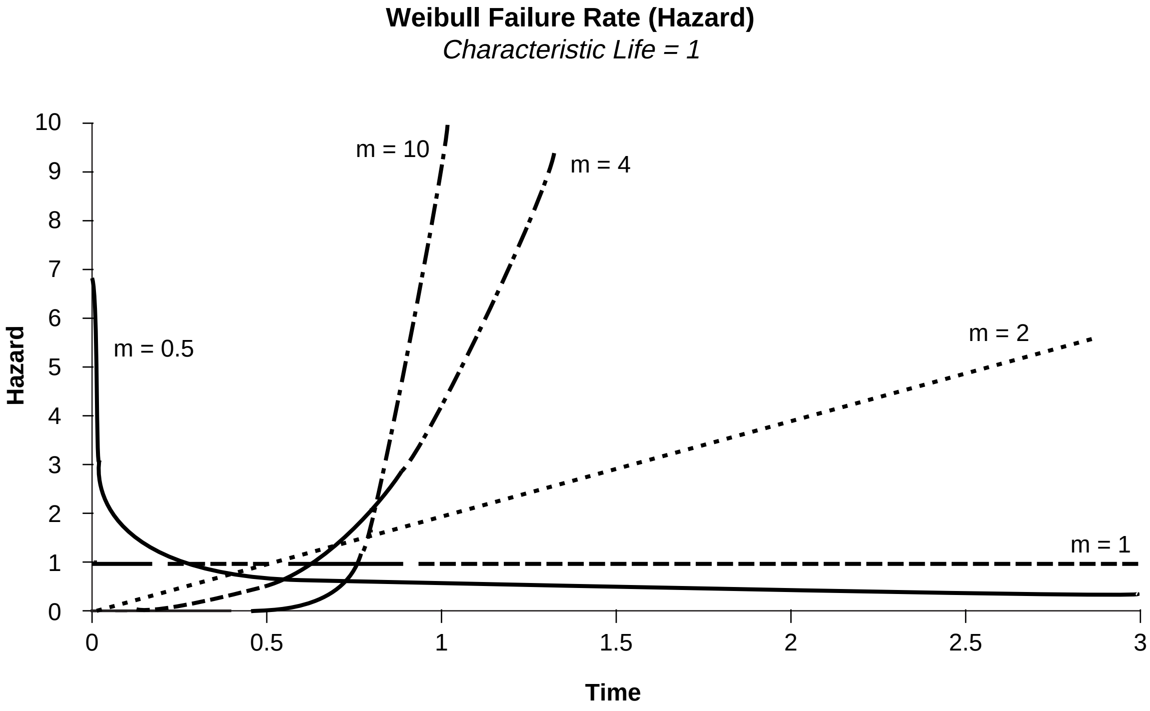

Figure 5. Weibull Distribution

Calculations of Failure Rates

To estimate field failure rates from reliability studies, many factors must be considered. One primary requirement is the identification of individual failure mechanisms in order to ascribe the failures to the proper categories used in the Vantis reliability model.

Considerations and Assumptions

1. Defective subpopulations and Early Life failures:

   In any production lot, a defective subpopulation may exist. These are devices that fail by a mechanism not common to the general population which is usually the result of some processing error or defect. These failures usually occur early and consequently are called Early Life failures. Early Life (EL) is defined as 4,000 field equivalent hours (FEH) -- actual life test hours multiplied by the acceleration factor for the mechanism.

   The early life failure rate will be reported in FITs (failures per billion unit-hours).

   Early Life failures will also be reported as DPM (defects per million) for 4,000 hours. The DPM value is obtained by multiplying the EL failure rate in FITS by 4,000 and dividing the result by 1,000 to obtain the EL failure rate as defects per million.

2. Inherent Life failures:

   Failures that occur in excess of 4,000 equivalent field hours are usually by mechanisms related to defects that could occur in any product of this type. These are known here as Inherent Life (IL) failures. If the first read-time in a life test is equivalent to greater than 5,000 hours for a given mechanism, the data will be considered IL data, and unless there is no failure at this time, it will be considered that no data exists for this mechanism for Early Life. If this first read-time has zero fails, Early Life will be calculated at 4,000 hours assuming no fails.

3. Estimation of thermal acceleration factors:

   The best known activation energies for each mechanism are used in calculating the thermal acceleration using the standard Arrhenius equation for thermal acceleration. For each process group/package combination, representative acceleration factors were estimated based on the weighted average of acceleration factors of individual devices in that group.

4. Voltage acceleration:

   Certain failure mechanisms are accelerated by voltage stresses above normal operating voltage. The formula for voltage acceleration is shown below:

   $$VAF = exp[\{230\ \gamma\ (V_s - V_n)/T_{ox}\}]$$

   VAF is the voltage acceleration factor, $\mathbf{V_s}$ is the test voltage, $\mathbf{V_n}$ is the nominal operating voltage, $\mathbf{T_{ox}}$ is the oxide thickness in Å, and gamma (γ) is a constant of value “3” for oxide defect related mechanisms or “1” for intrinsic oxide related ones.

   For charge gain (floating gate devices), VAF varies just as the exponential of the voltage difference.

5. It is common in the reliability literature to see failure rates stated at a specified level of confidence:

   For example, a 60% upper confidence limit on the failure rate indicates that unless a 4 in 10 chance (40%) has occurred, the true population failure rate is less than the stated limit. The summation of individual failure rate components, each at 60% confidence, will however result in an overall failure rate at an unknown confidence level that may dramatically exceed 60%.