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**Information technology — Digitally  
recorded media for information  
interchange and storage — Test method  
for the estimation of the archival lifetime  
of optical media**

*Technologies de l'information — Supports enregistrés numériquement  
pour l'échange et le stockage d'information — Méthode d'essai pour  
l'estimation de la durée de vie d'archivage des supports optiques*

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## Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 10995 was prepared by Ecma International (as ECMA-379) and was adopted, under a special “fast-track procedure”, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in parallel with its approval by national bodies of ISO and IEC.

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## Introduction

Markets and industry have developed the common understanding that the property referred to as the archival life of data recorded to optical media plays an increasingly important role for the intended applications. The existing standard test methodologies for recordable media include magneto-optical media and recordable compact disk systems. It was agreed that the project represented by this International Standard be undertaken in order to provide a methodology that includes the testing of newer, currently available products.

The Optical Storage Technology Association (OSTA) initiated work on this subject and developed the initial drafts. Following that development, the project was moved to Ecma International TC 31 for further development and finalization. OSTA and Ecma wish to thank the members and organizations in NIST, CDs21 Solutions, and DCAj for their support of the development of this International Standard.

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# Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of the archival lifetime of optical media

## 1 Scope

This International Standard specifies an accelerated aging test method for estimating the life expectancy for the retrievability of information stored on recordable or rewritable optical disks.

This test includes details on the following formats: DVD-R/-RW/-RAM, +R/+RW. It may be applied to additional optical disk formats with the appropriate specification substitutions and may be updated by committee in the future as required.

This International Standard includes the following:

- stress conditions;
- assumptions;
- ambient conditions:
  - controlled storage condition, e.g. 25 °C and 50 % RH, using the Eyring model,
  - uncontrolled storage condition, e.g. 30 °C and 80 % RH, using the Arrhenius model;
- evaluation system description;
- specimen preparation;
- data acquisition procedure;
- data interpretation.

The methodology includes only the effects of temperature (T) and relative humidity (RH). It does not attempt to model degradation due to complex failure mechanism kinetics, nor does it test for exposure to light, corrosive gases, contaminants, handling, and variations in playback subsystems. Disks exposed to these additional sources of stress or higher levels of T and RH are expected to experience shorter usable lifetimes.

## 2 Conformance

Media tested by this methodology shall conform to all normative references specific to that media format.

### 3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 16448:2002, *Information technology — 120 mm DVD — Read-only disk*

ISO/IEC 16449:2002, *Information technology — 80 mm DVD — Read-only disk*

ISO/IEC 17341:2006, *Information technology — Data Interchange on 120 mm and 80 mm Optical Disk using +RW Format – Capacity: 4,7 Gbytes and 1,46 Gbytes per Side (Recording speed up to 4X)*

ISO/IEC 17342:2004, *Information technology — 80 mm (1,46 Gbytes per side) and 120 mm (4,70 Gbytes per side) DVD re-recordable disk (DVD-RW)*

ISO/IEC 17344:2006, *Information technology — Data Interchange on 120 mm and 80 mm Optical Disk using +R Format – Capacity: 4,7 Gbytes and 1,46 Gbytes per Side (Recording speed up to 16X)*

ISO/IEC 17592:2004, *Information technology — 120 mm (4,7 Gbytes per side) and 80 mm (1,46 Gbytes per side) DVD rewritable disk (DVD-RAM)*

ISO/IEC 23912:2005, *Information technology — 80 mm (1,46 Gbytes per side) and 120 mm (4,70 Gbytes per side) DVD Recordable Disk (DVD-R)*

ISO/IEC 25434:2007, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +R DL format — Capacity: 8,55 Gbytes and 2,66 Gbytes per side (recording speed up to 8x)*

ISO/IEC 26925:2006, *Information technology — Digital storage media for information interchange — Data Interchange on 120 mm and 80 mm Optical Disk using +RW HS Format — Capacity: 4,7 Gbytes and 1,46 Gbytes per Side (Recording speed 8X)*

ISO/IEC 29642:2007, *Information technology — Data Interchange on 120 mm and 80 mm optical disk using +RW DL format – Capacity: 8,55 Gbytes and 2,66 Gbytes per side (recording speed 2,4x)*

### 4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

#### 4.1 archival

ability of a medium or system to maintain the retrievability of recorded information for a specified extended period of years

#### 4.2 Arrhenius method

accelerated aging model based on the effects of temperature

#### 4.3 baseline

initial test analysis measurements (e.g. initial error rate) after recording and before exposure to a stress condition; measurement at stress time  $t=0$  hours

**4.4****bootstrap method**

statistical method for estimating the sampling distribution by re-sampling with replacement from the original sample

NOTE See Annex E.

**4.5****Eyring Method**

accelerated aging model based on the effects of temperature and relative humidity

**4.6****error rate**

rate of errors on the sample disk measured before error correction is applied

**4.7****incubation**

process of enclosing and maintaining controlled test sample environments

**4.8****life expectancy****LE**

length of time estimation that information is predicted to be retrievable in a system while in a specified environmental condition

**4.9****maximum error rate**

maximum of the error rate measured anywhere in one of the relevant areas on the disk

NOTE 1 For DVD-R/RW and +R/+RW this is the Maximum PI Sum 8.

NOTE 2 For DVD-RAM this is the Maximum BER.

**4.10****retrievability**

ability to recover physical information as recorded

**4.11****stress**

temperature and relative humidity variables to which the sample is exposed for the duration of test incubation intervals

**4.12****system**

combination of hardware, software, storage medium and documentation used to record, retrieve and reproduce information

**4.13****uncorrectable error**

error in the playback data that was not corrected by the error correcting decoders

NOTE For DVD-R/RW, +R/+RW, and DVD-RAM, this is an error that is uncorrected by the Reed-Solomon product code defined in ISO/IEC 16448 for DVD ROM systems.

## 5 Conventions and notations

### 5.1 Representation of numbers

A measured value is rounded off to the least significant digit of the corresponding specified value. For instance, it implies that a specified value of 1,26 with a positive tolerance of + 0,01 and a negative tolerance of - 0,02 allows a range of measured values from 1,235 to 1,275.

### 5.2 Names

The names of entities, e.g. specific tracks, fields, zones, etc. are given a capital initial.

## 6 List of acronyms

|     |                              |
|-----|------------------------------|
| BER | byte error rate              |
| LCL | lower confidence limit       |
| LE  | life expectancy              |
| PI  | parity (of the) inner (code) |

## 7 Measurements

### 7.1 Summary

#### 7.1.1 Stress Incubation and Measuring

A sampling of disks will be measured at 4 stress conditions plus a control disk at room ambient condition. A minimum number of 20 disks will be included as a group for each stress condition as shown in Table 2.

Each stress condition's total time will be divided into interval time periods. Each disk in each group of disks will have their initial error rates measured before their exposure to stress conditions. Thereafter, each disk will be measured for their error rates after each stress condition incubation time interval. The control disk will also be measured following each incubation time interval.

#### 7.1.2 Assumptions

This Standard makes the following assumptions for applicability of media to be tested:

- specimen life distribution is appropriately modelled by a statistical distribution,
- the Eyring model can be used to model acceleration with the two stresses involved (temperature and relative humidity),
- the dominant failure mechanism acting at the usage condition is the same as that at the accelerated conditions,
- the compatibility of the disk and drive combination will affect the disk's initial recording quality and the resulting archival test outcome,
- a hardware and software system needed to read the disk will be available at the time the retrievability of the information is attempted,
- the recorded format will be recognizable and interpretable by reading software.

### 7.1.3 Error Rate

Of all specimen media the Error rate shall be measured in the disk testing locations as defined in 6.5. For each sample the Maximum error rate shall be determined.

Each DVD-R/RW, +R/+RW disk will have their maximum PI Sum 8 (Max PI-8) determined.

Each DVD-RAM disk will have its maximum byte error rate (Max BER) determined.

Other disk formats not referenced in this document will have the maximum of their defined error rates determined.

Data collected at each time interval for each individual disk are then used to determine the estimated lifetime for that disk at that stress condition.

#### 7.1.3.1 PI Sum 8

Per ISO/IEC 16448:2002, a row in an ECC block that has at least 1 byte in error constitutes a PI error. PI Sum 8 is measured over 8 ECC blocks. In any 8 consecutive ECC blocks the total number of PI errors, also called PI Sum 8, before error correction shall not exceed 280.

#### 7.1.3.2 BER

The number of erroneous symbols shall be measured at any consecutive 32 ECC blocks in the first pass of the decoder before correction. The BER is the number of erroneous symbols divided by the total number of symbols included in the 32 consecutive ECC blocks. The maximum value of the BER measured over the area specified in 6.5 shall not exceed  $10^{-3}$ . (See Annex F).

### 7.1.4 Data Quality

Data quality is checked by plotting the median rank of the estimated time to failure values with a best fit line for each stress condition. The lines are then checked for reasonable parallelism.

### 7.1.5 Regression

The time-to-failure values at each stress condition are then regressed to find a histogram of the time-to-failure values at ambient condition using the bootstrap method.

The mean lifetimes are regressed against temperature and relative humidity according to an Eyring acceleration model.

## 7.2 Test specimen

The disk sample set shall represent the construction, materials, manufacturing process, quality and variation of the final process output.

Consideration shall be made to shelf life. Disks with longer shelf time before recording and testing may impact test results. Shelf time shall be representative of normal usage shelf time.

## 7.3 Recording conditions

Before entering media into accelerated aging tests, they shall be recorded as optimally as is practicable, according to the descriptions given in the related standard. OPC (optimum power control) during writing process shall serve as the method to achieve recorded media minimum error rates. It is generally understood that optimally recorded media will yield the longest predicted life results. Media is deemed acceptable for entry into the aging tests when its error rate and all other media parametric specifications are found to be within its respective standard's specification limits.

Recording hardware is at the discretion of the recording party. It may be either commercial drive-based or specialty recording tester based. It shall be capable of producing recordings that meet all specifications.

The maximum recording speed shall be at the media's highest rated speed and this speed shall be reported.

### **7.3.1 Recording test environment**

When performing the recordings, the air immediately surrounding the media shall have the following properties:

|                       |                   |
|-----------------------|-------------------|
| temperature:          | 23 °C to 35 °C    |
| relative humidity:    | 45 % to 55 %      |
| atmospheric pressure: | 60 kPa to 106 kPa |

No condensation on the disk shall occur. Before testing the disk shall be conditioned in this environment for 48 h minimum. It is recommended that before testing the entrance surface is cleaned according to the instructions of the manufacturer of the disk.

### **7.3.2 Recording method**

Specimen disks shall be recorded at a single session and finalized.

## **7.4 Playback conditions**

### **7.4.1 Playback tester**

All media shall be read by the playback tester as specified in each of the medium's standard and at their specified test conditions.

Specimen media shall be read as described in the format standards identified in Clause 3.

### **7.4.2 Playback test environment**

When measuring the error rates, the air immediately surrounding the disk shall have the following properties:

|                       |                   |
|-----------------------|-------------------|
| temperature:          | 23 °C to 35 °C    |
| relative humidity:    | 45 % to 55 %      |
| atmospheric pressure: | 60 kPa to 106 kPa |

Unless otherwise stated, all tests and measurements shall be made in this test environment.

### **7.4.3 Calibration**

The test equipment shall be calibrated as prescribed by its manufacturer using calibration disks approved by said manufacturer and as needed before disk testing.

A control disk shall be maintained at ambient conditions and its error rate measured at the same time the stressed disks are measured initially and after each stress interval.

The mean and standard deviation of the control disk shall be established by collecting at least five measurements. Should any individual error rate reading differ from the mean by more than three times the standard deviation, the problem shall be corrected and all data collected since the last valid control point shall be re-measured.

## 7.5 Disk testing locations

Testing locations shall be a minimum of three bands spaced evenly from inner, middle and outer radius locations on the disk as indicated in Table 1. The total testing area shall represent a minimum of 5 % of the disk. Each of the three test bands shall have more than 750(2EEh) ECC Blocks for 80 mm disks, and 2 400(960h) ECC Blocks for 120 mm disks.

**Table 1 - Nominal radii of the three test bands**

|        | DVD-R/RW, +R/+RW disk<br>(Single Layer / Dual Layer) |        | DVD-RAM disk |           |
|--------|--|--------|--------------|-----------|
|        | 80 mm  | 120 mm | 80 mm        | 120 mm    |
| Band 1 | 25,0   | 25,0   | 24,1-25,0    | 24,1-25,0 |
| Band 2 | 30,0   | 40,0   | 29,8-30,8    | 39,4-40,4 |
| Band 3 | 35,0   | 55,0   | 34,6-35,6    | 54,9-55,8 |

## 8 Accelerated stress test

### 8.1 General

Information properly recorded on an archival quality optical disk should have a life expectancy exceeding a predetermined number of years. Accelerated aging studies are used in order to conclude that a life expectancy exceeds the predetermined minimum number of years. This test plan is intended to provide the information necessary to satisfactorily evaluate the particular optical disk system including proposed archival quality optical disks.

### 8.2 Stress conditions

#### 8.2.1 General

Stress conditions for this test method are increases in temperature and relative humidity. The stress conditions are used to accelerate the chemical reaction rate from what would occur normally at ambient or usage conditions. The chemical reaction is considered degradation in desired material property that eventually leads to disk failure.

Four stress conditions and the minimum number of specimens for those stress conditions that shall be used are shown in Table 2. Additional specimens and conditions may be used if desired for improved precision.

The total time for each stress condition as given in Table 2 is divided into four equal incubation durations. The temperature and relative humidity during each incubation cycle shall be controlled as depicted in Table 3 and Figure 1. After each cycle of incubation all specimens shall be measured.

**Table 2 - Stress conditions for use with the Eyring Method**

| Test cell number | Test stress condition (inc) |     | Number of specimens | Incubation duration<br>hours | Total time<br>hours | Intermediate RH<br>%RH | Min equilibration duration<br>hours |
|------------------|-----------------------------|-----|---------------------|------------------------------|---------------------|------------------------|-------------------------------------|
|                  | Temp (°C)                   | %RH |                     |                              |                     |                        |                                     |
| 1a               | 85                          | 85  | 20                  | 250                          | 1 000               | 30                     | 7                                   |
| 2a               | 85                          | 70  | 20                  | 250                          | 1 000               | 30                     | 6                                   |
| 3a               | 65                          | 85  | 20                  | 500                          | 2 000               | 35                     | 9                                   |
| 4a               | 70                          | 75  | 30                  | 625                          | 2 500               | 33                     | 11                                  |

**8.2.2 Temperature (T)**

The temperature levels chosen for this test plan are based on the following:

- there shall be no change of phase within the test system over the test-temperature range. This restricts the temperature to greater than 0 °C and less than 100 °C,
- the temperature shall not be so high that plastic deformation occurs anywhere within the disk structure.

The typical substrate material for media is polycarbonate (glass transition temperature ~150 °C). The glass transition temperature of other layers may be lower. Experience with high-temperature testing of DVDs and +R/+RW disks indicates that an upper limit of 85 °C is practical for most applications.

**8.2.3 Relative humidity (RH)**

Experience indicates that 85 % RH is the generally accepted upper limit for control within most accelerated test cells.

**8.2.4 Incubation and Ramp Profiles**

The relative humidity transition (ramp) profile is intended to avoid moisture condensation within the substrate, minimize substantial moisture gradients in the substrate and to end at ramp down completion with the substrate equilibrated to ambient condition. This is accomplished by varying the moisture content of the chamber only at the stress incubation temperature, and allowing sufficient time for equilibration during ramp-down based on the diffusion coefficient of water in polycarbonate.

**Table 3 - T and RH transition (ramp) profile for each incubation cycle**

| Process step  | Temperature<br>°C   | Relative humidity<br>% | Duration<br>hours |
|---------------|---------------------|------------------------|-------------------|
| Start         | at T <sub>amb</sub> | at RH <sub>amb</sub>   | —                 |
| T, RH ramp    | to T <sub>inc</sub> | to RH <sub>int</sub>   | 1,5 ± 0,5         |
| RH ramp       | at T <sub>inc</sub> | to RH <sub>inc</sub>   | 1,5 ± 0,5         |
| Incubation    | at T <sub>inc</sub> | at RH <sub>inc</sub>   | See Table 2       |
| RH ramp       | at T <sub>inc</sub> | to RH <sub>int</sub>   | 1,5 ± 0,5         |
| Equilibration | at T <sub>inc</sub> | at RH <sub>int</sub>   | See Table 2       |
| T, RH ramp    | to T <sub>amb</sub> | to RH <sub>amb</sub>   | 1,5 ± 0,5         |
| end           | at T <sub>amb</sub> | at RH <sub>amb</sub>   | —                 |

amb = room ambient T or RH (T<sub>amb</sub> or RH<sub>amb</sub>)

inc = stress incubation T or RH (T<sub>inc</sub> or RH<sub>inc</sub>)

int = intermediate relative humidity (RH<sub>int</sub>) that at T<sub>inc</sub> supports the same equilibrium moisture absorption in polycarbonate as that supported at T<sub>amb</sub> and RH<sub>amb</sub>

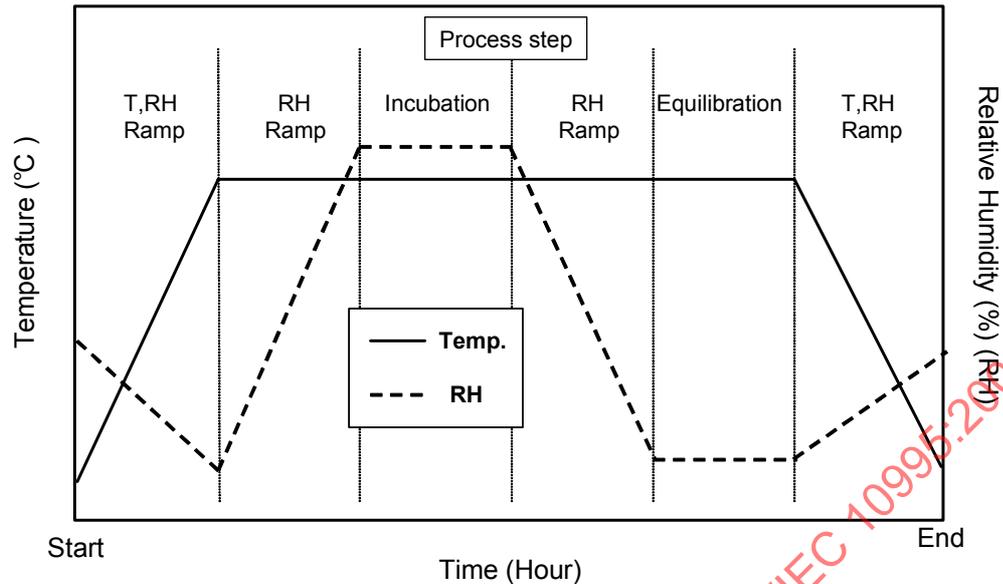


Figure 1 - Graph of typical transition (ramp) profile

### 8.3 Measuring Time intervals

For data collection, PI Sum 8 (DVD-R, DVD-RW, +R, +RW), or BER (DVD-RAM) measurements for each disk will occur: 1) before disk exposure to any stress condition to determine its baseline measurement and 2) after each cycle of incubation. The length of time for intervals is dependant on the severity of the stress condition.

Using each disk's regression equation, the failure time for each disk shall then be computed for the stress condition it was exposed to.

### 8.4 Stress Conditions Design

Table 2 specifies the temperatures, relative humidities, time intervals, minimum total test time, and minimum number of specimens for each stress condition. A separate group of specimens is used for each stress condition.

All temperatures may deviate  $\pm 2$  °C of the target temperature; all relative humidities may deviate  $\pm 3$  % RH of the target relative humidity.

The intermediate relative humidity ( $RH_{int}$ ) in Table 2 is calculated assuming 25 °C and 50 % RH ambient conditions. If the ambient is different, the intermediate relative humidity to be used is calculated using the equation:

$$RH_{int} = \frac{0,24 + 0,0037 \times T_{amb}}{0,24 + 0,0037 \times T_{inc}} \times RH_{amb}$$

where

$T_{amb}$  and  $T_{inc}$  are respectively the ambient and incubation temperature in units of °C;

$RH_{amb}$  is the ambient relative humidity;

$RH_{int}$  is the intermediate relative humidity.

The stress conditions tabulated in Tables 2 and 3 offer sufficient combinations of temperature and relative humidity to satisfy the mathematical requirements of the Eyring model to demonstrate linearity of either Max PI Sum 8, or Max BER or their logs respectively, versus time, and to produce a satisfactory confidence level to make a meaningful conclusion.

## 8.5 Media Orientation

Media subjected to this test method shall be maintained in a vertical position with a minimum of 2 mm separation between disks to allow air flow between disks and to minimize deposition of debris on disk surfaces which could negatively influence the error rate measurements.

## 9 Data Evaluation

### 9.1 Time-to-failure

All disks subjected to stress conditions shall have their time-to-failure calculated at the stress condition they have been subjected to. Failure criteria values are: Max PI Sum 8 exceeding 280 for DVD-R/RW, +R/+RW, and Max BER exceeding  $10^{-3}$  for DVD-RAM.

Material degradation manifests itself as data errors in the disk, providing a relationship between disk errors and material degradation. The chemical changes are generally expected to cause test data to have a distribution that follows an exponential function over time. Therefore, test data values of PI Sum 8 or BER as a function of time are expected to exhibit an exponential distribution.

The best function fitting an error trend can be found by regression of the test data against time, for example, with a least squares fit. The time-to-failure per disk type can be calculated using the error trend function and the failure criteria.

### 9.2 Eyring acceleration model (Eyring Method)

Using the Eyring model, the following equation is derived from the laws of thermodynamics and can be used to handle the two critical stresses of temperature and relative humidity.

$$t = AT^a e^{\Delta H/kT} e^{(B+C/T) \times RH}$$

where

- $t$  is the time to failure;
- $A$  is the pre-exponential time constant;
- $T^a$  is the pre-exponential temperature factor;
- $\Delta H$  is the activation energy per molecule;
- $k$  is the Boltzmann's constant ( $1,3807 \times 10^{-23}$  J/molecule degree K);
- $T$  is the temperature (in Kelvin);
- $B, C$  is the RH exponential constants;
- $RH$  is the relative humidity.

For the temperature range used in this test method, "a" and "C" shall be set to zero. The Eyring model equation then reduces to the following:

$$t = Ae^{\Delta H/kT} e^{B \times RH}, \text{ or}$$

$$\ln(t) = \ln(A) + \frac{\Delta H}{kT} + B \times RH$$

### 9.3 Data analysis

Data Analysis is contained in the following Annexes:

- Annex A: Data Analysis Steps Outline for Calculation of Media Life
- Annex B: Analysis for Calculation of Media Life
- Annex C: Uncontrolled Ambient Condition Media Life Calculation
- Annex D: Truncated Test Method (Determination of Media Life Lower Bound)
- Annex E: Bootstrap Method

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## Annex A (normative)

### Data Analysis Steps Outline for Calculation of Media Life

The following is an outline of steps to estimate the life expectancy value, as a function of ambient temperature and relative humidity, and used to determine if a disk will or will not exceed a life expectancy of X-years.

1. For each specimen, compute (via linear regression), the predicted time-to-failure.
2. (Steps 2 and 3 are for data quality check)  
For each stress condition, determine the median rank of each specimen, and plot the median rank versus time-to-failure on a lognormal graph.
3. Verify that the plots for all stress conditions are reasonably parallel to one another. Note: In the case where the plots are not determined to be reasonably parallel, 6.1.2 Assumptions shall be checked.
4. Using the *reduced* Eyring equation, carry out a least squares fit to the log failure times across all specimens and stress conditions.
5. Employ bootstrapping, using the residuals from the fit in step 4, to generate a simulation sample of 1 000 predicted times-to-failure at ambient condition.
6. For the ambient condition, plot a histogram of these 1 000 predicted times-to-failure.
7. For the ambient condition, compute the estimated 5 % point of the 1 000 predicted times-to-failure.

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## Annex B (normative)

### Analysis for Calculation of Media Life

#### Step 1

Determine the time-to-failure for each specimen at the stress applied following the procedure as described below. Error rates to be measured are as defined in 6.1.3:

For DVD-R/RW, +R/+RW: PI Sum 8  
For DVD-RAM: BER

Use the initial error rate measured prior to accelerated aging plus the error rates measured after each specified accelerated aging incubation interval.

For each specimen a linear regression is performed with the  $\ln$  (measured error rates), as the dependent variable and time as the independent variable. The time-to-failure of the specimen is calculated from the slope and intercept of the regression as the time at which the specimen would have a Max PI Sum 8 of 280, or a Max BER of  $10^{-3}$ .

For example data, a purely hypothetical data set was generated. These values were completely fabricated for this assumption. The data is offered solely as an example of the mathematical methodology used in this test procedure.

**Table B.1 - Estimated time to failure for example data**

| Group 1a | 85°C/85%RH |     |     |     |       | Hours to Failure |
|----------|------------|-----|-----|-----|-------|------------------|
|          | Hours      |     |     |     |       |                  |
| Disc #   | 0          | 250 | 500 | 750 | 1 000 |                  |
| A1       | 16         | 78  | 116 | 278 | 445   | 788              |
| A2       | 25         | 64  | 134 | 342 | 532   | 743              |
| A3       | 26         | 94  | 190 | 335 | 642   | 685              |
| A4       | 26         | 111 | 247 | 343 | 718   | 647              |
| A5       | 27         | 89  | 185 | 246 | 466   | 762              |
| A6       | 21         | 111 | 207 | 567 | 896   | 607              |
| A7       | 26         | 121 | 274 | 589 | 781   | 588              |
| A8       | 31         | 108 | 223 | 315 | 745   | 654              |
| A9       | 24         | 118 | 285 | 723 | 754   | 578              |
| A10      | 12         | 85  | 178 | 312 | 988   | 669              |
| A11      | 28         | 111 | 167 | 312 | 771   | 671              |
| A12      | 24         | 136 | 267 | 444 | 719   | 614              |
| A13      | 35         | 76  | 265 | 567 | 610   | 626              |
| A14      | 19         | 53  | 112 | 278 | 534   | 778              |
| A15      | 28         | 88  | 158 | 308 | 654   | 704              |
| A16      | 27         | 68  | 120 | 263 | 432   | 807              |
| A17      | 18         | 87  | 176 | 302 | 558   | 723              |
| A18      | 26         | 109 | 238 | 421 | 641   | 645              |
| A19      | 26         | 111 | 253 | 378 | 638   | 649              |
| A20      | 31         | 91  | 206 | 367 | 728   | 656              |

| Group 2a | 85°C/70%RH |       |     |     |     |       |                  |
|----------|------------|-------|-----|-----|-----|-------|------------------|
|          | Disc #     | Hours |     |     |     |       | Hours to Failure |
|          |            | 0     | 250 | 500 | 750 | 1 000 |                  |
| B1       | 10         | 20    | 67  | 112 | 156 | 1 117 |                  |
| B2       | 8          | 20    | 47  | 84  | 188 | 1 118 |                  |
| B3       | 12         | 26    | 72  | 185 | 421 | 880   |                  |
| B4       | 20         | 43    | 120 | 166 | 219 | 999   |                  |
| B5       | 32         | 45    | 76  | 103 | 267 | 1 126 |                  |
| B6       | 21         | 37    | 104 | 222 | 368 | 870   |                  |
| B7       | 21         | 30    | 89  | 155 | 221 | 1 035 |                  |
| B8       | 22         | 26    | 72  | 125 | 267 | 1 043 |                  |
| B9       | 25         | 46    | 124 | 182 | 224 | 994   |                  |
| B10      | 17         | 38    | 67  | 179 | 378 | 911   |                  |
| B11      | 28         | 58    | 88  | 120 | 268 | 1 065 |                  |
| B12      | 8          | 15    | 36  | 144 | 189 | 1 059 |                  |
| B13      | 10         | 27    | 89  | 175 | 385 | 880   |                  |
| B14      | 23         | 54    | 111 | 148 | 221 | 1 037 |                  |
| B15      | 28         | 39    | 125 | 172 | 278 | 959   |                  |
| B16      | 25         | 53    | 88  | 130 | 188 | 1 149 |                  |
| B17      | 20         | 43    | 75  | 166 | 256 | 999   |                  |
| B18      | 22         | 26    | 50  | 172 | 229 | 1 058 |                  |
| B19      | 13         | 38    | 78  | 124 | 189 | 1 078 |                  |
| B20      | 10         | 19    | 28  | 121 | 268 | 1 046 |                  |

| Group 3a | 65°C/85%RH |       |     |       |       |       |                  |
|----------|------------|-------|-----|-------|-------|-------|------------------|
|          | Disc #     | Hours |     |       |       |       | Hours to failure |
|          |            | 0     | 500 | 1 000 | 1 500 | 2 000 |                  |
| C1       | 14         | 23    | 58  | 112   | 278   | 2 057 |                  |
| C2       | 10         | 17    | 55  | 165   | 263   | 1 948 |                  |
| C3       | 11         | 56    | 88  | 138   | 189   | 2 078 |                  |
| C4       | 18         | 28    | 78  | 117   | 243   | 2 106 |                  |
| C5       | 17         | 45    | 78  | 143   | 189   | 2 167 |                  |
| C6       | 10         | 14    | 45  | 154   | 231   | 2 031 |                  |
| C7       | 31         | 53    | 111 | 156   | 211   | 2 151 |                  |
| C8       | 29         | 54    | 106 | 154   | 218   | 2 128 |                  |
| C9       | 22         | 32    | 65  | 89    | 126   | 2 799 |                  |
| C10      | 29         | 36    | 78  | 145   | 188   | 2 297 |                  |
| C11      | 21         | 38    | 89  | 148   | 227   | 2 075 |                  |
| C12      | 24         | 45    | 68  | 134   | 211   | 2 236 |                  |
| C13      | 28         | 57    | 78  | 132   | 190   | 2 352 |                  |
| C14      | 19         | 47    | 61  | 117   | 150   | 2 486 |                  |
| C15      | 25         | 65    | 89  | 184   | 256   | 1 972 |                  |
| C16      | 10         | 18    | 57  | 113   | 178   | 2 189 |                  |
| C17      | 21         | 34    | 45  | 98    | 121   | 2 845 |                  |
| C18      | 12         | 20    | 34  | 112   | 176   | 2 308 |                  |
| C19      | 28         | 56    | 108 | 176   | 243   | 2 001 |                  |
| C20      | 29         | 36    | 57  | 143   | 238   | 2 207 |                  |

| Group 4a | 70°C/75%RH |       |     |       |       |       |                  |
|----------|------------|-------|-----|-------|-------|-------|------------------|
|          | Disc #     | Hours |     |       |       |       | Hours to failure |
|          |            | 0     | 625 | 1 250 | 1 875 | 2 500 |                  |
| D1       | 25         | 34    | 64  | 92    | 167   | 3 240 |                  |
| D2       | 25         | 93    | 134 | 154   | 211   | 2 596 |                  |
| D3       | 7          | 23    | 97  | 103   | 178   | 2 615 |                  |
| D4       | 10         | 20    | 56  | 89    | 155   | 2 920 |                  |
| D5       | 5          | 20    | 78  | 132   | 187   | 2 496 |                  |
| D6       | 5          | 15    | 52  | 112   | 167   | 2 644 |                  |
| D7       | 22         | 34    | 67  | 132   | 188   | 2 851 |                  |
| D8       | 12         | 17    | 56  | 78    | 108   | 3 318 |                  |
| D9       | 22         | 34    | 67  | 132   | 189   | 2 847 |                  |
| D10      | 23         | 27    | 54  | 121   | 152   | 3 129 |                  |
| D11      | 11         | 20    | 41  | 87    | 115   | 3 249 |                  |
| D12      | 15         | 18    | 43  | 88    | 118   | 3 343 |                  |
| D13      | 19         | 21    | 38  | 82    | 135   | 3 435 |                  |
| D14      | 18         | 22    | 86  | 178   | 245   | 2 456 |                  |
| D15      | 22         | 26    | 73  | 145   | 252   | 2 582 |                  |
| D16      | 18         | 18    | 29  | 66    | 127   | 3 649 |                  |
| D17      | 22         | 26    | 93  | 145   | 178   | 2 761 |                  |
| D18      | 18         | 27    | 56  | 88    | 134   | 3 316 |                  |
| D19      | 11         | 32    | 44  | 97    | 143   | 3 051 |                  |
| D20      | 12         | 56    | 66  | 124   | 249   | 2 550 |                  |
| D21      | 14         | 34    | 54  | 77    | 112   | 3 500 |                  |
| D22      | 20         | 23    | 25  | 50    | 181   | 3 593 |                  |
| D23      | 11         | 16    | 27  | 54    | 160   | 3 275 |                  |
| D24      | 17         | 24    | 25  | 58    | 108   | 4 034 |                  |
| D25      | 11         | 25    | 22  | 62    | 130   | 3 488 |                  |
| D26      | 17         | 24    | 25  | 70    | 123   | 3 707 |                  |
| D27      | 21         | 39    | 63  | 78    | 163   | 3 304 |                  |
| D28      | 20         | 28    | 45  | 111   | 243   | 2 787 |                  |
| D29      | 15         | 21    | 38  | 65    | 134   | 3 453 |                  |
| D30      | 10         | 34    | 54  | 96    | 176   | 2 841 |                  |

## Step 2

For each stress condition, specimens are ordered by increasing time-to-failure values.

The median rank of the specimens is calculated using the estimate  $(i - 0,5)/n$ , where  $i$  is the time-to-failure order and  $n$  is the total number of specimens at the stress condition.

The data can be plotted in different ways. If lognormal graph paper is employed, the data is plotted with time-to-failure on the abscissa and median rank on the ordinate.

NOTE On most lognormal graph paper, the actual ordinate scale is the probability of failure; the median rank is converted to the probability of failure by multiplying by 100.

If linear axes are desired, the data can be linearized by plotting the critical value for the normal cumulative distribution of the median rank on the ordinate and the natural logarithm of the time-to-failure on the abscissa.

The critical value for the normal cumulative distribution of the median rank is the value of  $t$  for which  $F(t)$  (the cumulative distribution function) equals the median rank.

**Table B.2 - Median rank and the critical value for estimated time to failure**

| Group 1a               |        | 85°C/85%RH |     |     |     |       |                     |                 |             |                |
|------------------------|--------|------------|-----|-----|-----|-------|---------------------|-----------------|-------------|----------------|
| ascending order number | Disc # | Hours      |     |     |     |       | Hours to Failure(H) | ascending ln(H) | median rank | critical value |
|                        |        | 0          | 250 | 500 | 750 | 1 000 |                     |                 |             |                |
| 1                      | A9     | 24         | 118 | 285 | 723 | 754   | 578                 | 6,3596          | 0,025       | -1,960         |
| 2                      | A7     | 26         | 121 | 274 | 589 | 781   | 588                 | 6,3767          | 0,075       | -1,440         |
| 3                      | A6     | 21         | 111 | 207 | 567 | 896   | 607                 | 6,4085          | 0,125       | -1,150         |
| 4                      | A12    | 24         | 136 | 267 | 444 | 719   | 614                 | 6,4200          | 0,175       | -0,935         |
| 5                      | A13    | 35         | 76  | 265 | 567 | 610   | 626                 | 6,4394          | 0,225       | -0,755         |
| 6                      | A18    | 26         | 109 | 238 | 421 | 641   | 645                 | 6,4693          | 0,275       | -0,598         |
| 7                      | A4     | 26         | 111 | 247 | 343 | 718   | 647                 | 6,4723          | 0,325       | -0,454         |
| 8                      | A19    | 26         | 111 | 253 | 378 | 638   | 649                 | 6,4754          | 0,375       | -0,319         |
| 9                      | A8     | 31         | 108 | 223 | 315 | 745   | 654                 | 6,4831          | 0,425       | -0,189         |
| 10                     | A20    | 31         | 91  | 206 | 367 | 728   | 656                 | 6,4862          | 0,475       | -0,063         |
| 11                     | A10    | 12         | 85  | 178 | 312 | 988   | 669                 | 6,5058          | 0,525       | 0,063          |
| 12                     | A11    | 28         | 111 | 167 | 312 | 771   | 671                 | 6,5088          | 0,575       | 0,189          |
| 13                     | A3     | 26         | 94  | 190 | 335 | 642   | 685                 | 6,5294          | 0,625       | 0,319          |
| 14                     | A15    | 28         | 88  | 158 | 308 | 654   | 704                 | 6,5568          | 0,675       | 0,454          |
| 15                     | A17    | 18         | 87  | 176 | 302 | 558   | 723                 | 6,5834          | 0,725       | 0,598          |
| 16                     | A2     | 25         | 64  | 134 | 342 | 532   | 743                 | 6,6107          | 0,775       | 0,755          |
| 17                     | A5     | 27         | 89  | 185 | 246 | 466   | 762                 | 6,6359          | 0,825       | 0,935          |
| 18                     | A14    | 19         | 53  | 112 | 278 | 534   | 778                 | 6,6567          | 0,875       | 1,150          |
| 19                     | A1     | 16         | 78  | 116 | 278 | 445   | 788                 | 6,6695          | 0,925       | 1,440          |
| 20                     | A16    | 27         | 68  | 120 | 263 | 432   | 807                 | 6,6933          | 0,975       | 1,960          |
| median                 |        |            |     |     |     |       | 663                 | 6,4960          |             |                |

| Group 2a     |        | 85°C/70%RH |     |     |     |       |                     |                 |             |                |
|--------------|--------|------------|-----|-----|-----|-------|---------------------|-----------------|-------------|----------------|
| order number | Disc # | Hours      |     |     |     |       | Hours to Failure(H) | ascending ln(H) | median rank | critical value |
|              |        | 0          | 250 | 500 | 750 | 1 000 |                     |                 |             |                |
| 1            | B6     | 21         | 37  | 104 | 222 | 368   | 870                 | 6,7685          | 0,025       | -1,960         |
| 2            | B3     | 12         | 26  | 72  | 185 | 421   | 880                 | 6,7799          | 0,075       | -1,440         |
| 3            | B13    | 10         | 27  | 89  | 175 | 385   | 880                 | 6,7799          | 0,125       | -1,150         |
| 4            | B10    | 17         | 38  | 67  | 179 | 378   | 911                 | 6,8145          | 0,175       | -0,935         |
| 5            | B15    | 28         | 39  | 125 | 172 | 278   | 959                 | 6,8659          | 0,225       | -0,755         |
| 6            | B9     | 25         | 46  | 124 | 182 | 224   | 994                 | 6,9017          | 0,275       | -0,598         |
| 7            | B4     | 20         | 43  | 120 | 166 | 219   | 999                 | 6,9068          | 0,325       | -0,454         |
| 8            | B17    | 20         | 43  | 75  | 166 | 256   | 999                 | 6,9068          | 0,375       | -0,319         |
| 9            | B7     | 21         | 30  | 89  | 155 | 221   | 1 035               | 6,9422          | 0,425       | -0,189         |
| 10           | B14    | 23         | 54  | 111 | 148 | 221   | 1 037               | 6,9441          | 0,475       | -0,063         |
| 11           | B8     | 22         | 26  | 72  | 125 | 267   | 1 043               | 6,9499          | 0,525       | 0,063          |
| 12           | B20    | 10         | 19  | 28  | 121 | 268   | 1 046               | 6,9527          | 0,575       | 0,189          |
| 13           | B18    | 22         | 26  | 50  | 172 | 229   | 1 058               | 6,9641          | 0,625       | 0,319          |
| 14           | B12    | 8          | 15  | 36  | 144 | 189   | 1 059               | 6,9651          | 0,675       | 0,454          |
| 15           | B11    | 28         | 58  | 88  | 120 | 268   | 1 065               | 6,9707          | 0,725       | 0,598          |
| 16           | B19    | 13         | 38  | 78  | 124 | 189   | 1 078               | 6,9829          | 0,775       | 0,755          |
| 17           | B1     | 10         | 20  | 67  | 112 | 156   | 1 117               | 7,0184          | 0,825       | 0,935          |
| 18           | B2     | 8          | 20  | 47  | 84  | 188   | 1 118               | 7,0193          | 0,875       | 1,150          |
| 19           | B5     | 32         | 45  | 76  | 103 | 267   | 1 126               | 7,0264          | 0,925       | 1,440          |
| 20           | B16    | 25         | 53  | 88  | 130 | 188   | 1 149               | 7,0466          | 0,975       | 1,960          |
| median       |        |            |     |     |     |       | 1 040               | 6,9470          |             |                |

| Group 3a     |        | 65°C/85%RH |     |       |       |       |                     |                 |             |                |  |
|--------------|--------|------------|-----|-------|-------|-------|---------------------|-----------------|-------------|----------------|--|
| order number | Disc # | Hours      |     |       |       |       | Hours to failure(H) | ascending ln(H) | median rank | critical value |  |
|              |        | 0          | 500 | 1 000 | 1 500 | 2 000 |                     |                 |             |                |  |
| 1            | C2     | 10         | 17  | 55    | 165   | 263   | 1 948               | 7,5746          | 0,025       | -1,960         |  |
| 2            | C15    | 25         | 65  | 89    | 184   | 256   | 1 972               | 7,5868          | 0,075       | -1,440         |  |
| 3            | C19    | 28         | 56  | 108   | 176   | 243   | 2 001               | 7,6014          | 0,125       | -1,150         |  |
| 4            | C6     | 10         | 14  | 45    | 154   | 231   | 2 031               | 7,6163          | 0,175       | -0,935         |  |
| 5            | C1     | 14         | 23  | 58    | 112   | 278   | 2 057               | 7,6290          | 0,225       | -0,755         |  |
| 6            | C11    | 21         | 38  | 89    | 148   | 227   | 2 075               | 7,6377          | 0,275       | -0,598         |  |
| 7            | C3     | 11         | 56  | 88    | 138   | 189   | 2 078               | 7,6392          | 0,325       | -0,454         |  |
| 8            | C4     | 18         | 28  | 78    | 117   | 243   | 2 106               | 7,6525          | 0,375       | -0,319         |  |
| 9            | C8     | 29         | 54  | 106   | 154   | 218   | 2 128               | 7,6629          | 0,425       | -0,189         |  |
| 10           | C7     | 31         | 53  | 111   | 156   | 211   | 2 151               | 7,6737          | 0,475       | -0,063         |  |
| 11           | C5     | 17         | 45  | 78    | 143   | 189   | 2 167               | 7,6811          | 0,525       | 0,063          |  |
| 12           | C16    | 10         | 18  | 57    | 113   | 178   | 2 189               | 7,6912          | 0,575       | 0,189          |  |
| 13           | C20    | 29         | 36  | 57    | 143   | 238   | 2 207               | 7,6994          | 0,625       | 0,319          |  |
| 14           | C12    | 24         | 45  | 68    | 134   | 211   | 2 236               | 7,7124          | 0,675       | 0,454          |  |
| 15           | C10    | 29         | 36  | 78    | 145   | 188   | 2 297               | 7,7394          | 0,725       | 0,598          |  |
| 16           | C18    | 12         | 20  | 34    | 112   | 176   | 2 308               | 7,7441          | 0,775       | 0,755          |  |
| 17           | C13    | 28         | 57  | 78    | 132   | 190   | 2 352               | 7,7630          | 0,825       | 0,935          |  |
| 18           | C14    | 19         | 47  | 61    | 117   | 150   | 2 486               | 7,8184          | 0,875       | 1,150          |  |
| 19           | C9     | 22         | 32  | 65    | 89    | 126   | 2 799               | 7,9370          | 0,925       | 1,440          |  |
| 20           | C17    | 21         | 34  | 45    | 98    | 121   | 2 845               | 7,9533          | 0,975       | 1,960          |  |
|              |        | median     |     |       |       |       | 2 159               | 7,6577          |             |                |  |

| Group 4a     |        | 70°C/75%RH |     |       |       |       |                     |                 |             |                |
|--------------|--------|------------|-----|-------|-------|-------|---------------------|-----------------|-------------|----------------|
| order number | Disc # | Hours      |     |       |       |       | Hours to failure(H) | ascending ln(H) | median rank | critical value |
|              |        | 0          | 625 | 1 250 | 1 875 | 2 500 |                     |                 |             |                |
| 1            | D14    | 18         | 22  | 86    | 178   | 245   | 2 456               | 7,8063          | 0,017       | -2,128         |
| 2            | D5     | 5          | 20  | 78    | 132   | 187   | 2 496               | 7,8224          | 0,050       | -1,645         |
| 3            | D20    | 12         | 56  | 66    | 124   | 249   | 2 550               | 7,8438          | 0,083       | -1,383         |
| 4            | D15    | 22         | 26  | 73    | 145   | 252   | 2 582               | 7,8563          | 0,117       | -1,192         |
| 5            | D2     | 25         | 93  | 134   | 154   | 211   | 2 596               | 7,8617          | 0,150       | -1,036         |
| 6            | D3     | 7          | 23  | 97    | 103   | 178   | 2 615               | 7,8690          | 0,183       | -0,903         |
| 7            | D6     | 5          | 15  | 52    | 112   | 167   | 2 644               | 7,8800          | 0,217       | -0,784         |
| 8            | D17    | 22         | 26  | 93    | 145   | 178   | 2 761               | 7,9233          | 0,250       | -0,674         |
| 9            | D28    | 20         | 28  | 45    | 111   | 243   | 2 787               | 7,9327          | 0,283       | -0,573         |
| 10           | D30    | 10         | 34  | 54    | 96    | 176   | 2 841               | 7,9519          | 0,317       | -0,477         |
| 11           | D9     | 22         | 34  | 67    | 132   | 189   | 2 847               | 7,9540          | 0,350       | -0,385         |
| 12           | D7     | 22         | 34  | 67    | 132   | 188   | 2 851               | 7,9554          | 0,383       | -0,297         |
| 13           | D4     | 10         | 20  | 56    | 89    | 155   | 2 920               | 7,9793          | 0,417       | -0,210         |
| 14           | D19    | 11         | 32  | 44    | 97    | 143   | 3 051               | 8,0232          | 0,450       | -0,126         |
| 15           | D10    | 23         | 27  | 54    | 121   | 152   | 3 129               | 8,0485          | 0,483       | -0,042         |
| 16           | D1     | 25         | 34  | 64    | 92    | 167   | 3 240               | 8,0833          | 0,517       | 0,042          |
| 17           | D11    | 11         | 20  | 41    | 87    | 115   | 3 249               | 8,0861          | 0,550       | 0,126          |
| 18           | D23    | 11         | 16  | 27    | 54    | 160   | 3 275               | 8,0941          | 0,583       | 0,210          |
| 19           | D27    | 21         | 39  | 63    | 78    | 163   | 3 304               | 8,1029          | 0,617       | 0,297          |
| 20           | D18    | 18         | 27  | 56    | 88    | 134   | 3 316               | 8,1065          | 0,650       | 0,385          |
| 21           | D8     | 12         | 17  | 56    | 78    | 108   | 3 318               | 8,1071          | 0,683       | 0,477          |
| 22           | D12    | 15         | 18  | 43    | 88    | 118   | 3 343               | 8,1146          | 0,717       | 0,573          |
| 23           | D13    | 19         | 21  | 38    | 82    | 135   | 3 435               | 8,1418          | 0,750       | 0,674          |
| 24           | D29    | 15         | 21  | 38    | 65    | 134   | 3 453               | 8,1470          | 0,783       | 0,784          |
| 25           | D25    | 11         | 25  | 22    | 62    | 130   | 3 488               | 8,1571          | 0,817       | 0,903          |
| 26           | D21    | 14         | 34  | 54    | 77    | 112   | 3 500               | 8,1605          | 0,850       | 1,036          |
| 27           | D22    | 20         | 23  | 25    | 50    | 181   | 3 593               | 8,1867          | 0,883       | 1,192          |
| 28           | D16    | 18         | 18  | 29    | 66    | 127   | 3 649               | 8,2022          | 0,917       | 1,383          |
| 29           | D26    | 17         | 24  | 25    | 70    | 123   | 3 707               | 8,2180          | 0,950       | 1,645          |
| 30           | D24    | 17         | 24  | 25    | 58    | 108   | 4 034               | 8,3025          | 0,983       | 2,128          |
| median       |        |            |     |       |       |       | 3 185               | 8,0659          |             |                |

**Step 3**

Best-fit straight lines are drawn through the plotted data. If the lines are judged to be sufficiently parallel, the assumption of equivalent log standard deviation among the individual data sets is verified.

An estimate of the log standard deviation can be obtained from the graphical treatment of the failure data. First, for each stress, estimate the times corresponding to 16 %, 50 %, and 84 % failure based on the best fit straight line through the time-to-failure data. The estimated log standard deviation is then calculated from the equation:

$$\sigma_1 = \ln \left[ \frac{1}{2} \left( \frac{t_{50\%}}{t_{16\%}} + \frac{t_{84\%}}{t_{50\%}} \right) \right]$$

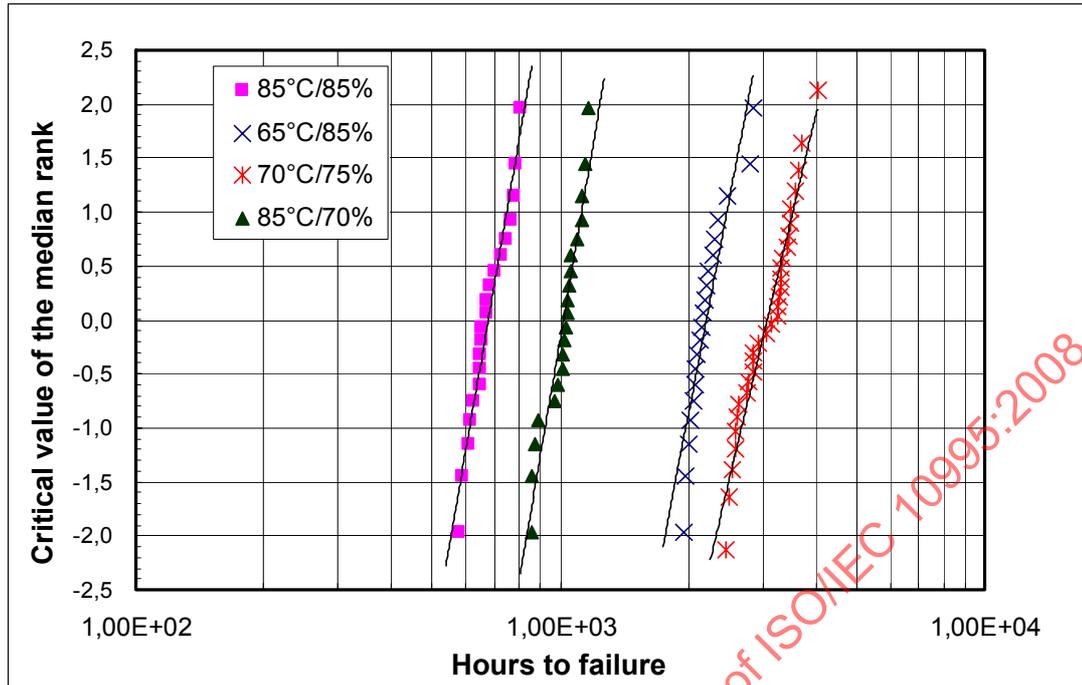


Figure B.1 - Lognormal plot of Table B.2

**Step 4**

Using the *reduced* Eyring equation, carry out a least squares fit to the log *median* failure times for each stress condition across all specimens and stress conditions.

**Table B.3 - Log mean for each stress condition**

| Group | Log <i>median</i> | Temp. | 1/T(Kelvin) | Humidity |
|-------|-------------------|-------|-------------|----------|
| 1a    | 6,4960            | 85    | 0.00279213  | 85       |
| 2a    | 6,9470            | 85    | 0.00279213  | 70       |
| 3a    | 7,6577            | 65    | 0.00295727  | 85       |
| 4a    | 8,0659            | 70    | 0.00291418  | 75       |

**Table B.4 - Coefficients of reduced Eyring equation**

| B       | $\Delta H/k$ | $\ln(A)$ |
|---------|--------------|----------|
| -0,0437 | 8 355,7529   | -13,1982 |

**Step 5**

Employ bootstrapping (see reference [3]), use the residuals in Table B.5 from the fit in step 4 to generate a simulation sample of 1 000 predicted times-to-failure at ambient condition (see Table B.6).

Table B.5 - Data for bootstrap method

| Disc # | Stress condition |            |            |            |
|--------|------------------|------------|------------|------------|
|        | 85°C/85%RH       | 85°C/70%RH | 65°C/85%RH | 70°C/75%RH |
| 1      | 788              | 1 117      | 2 057      | 3 240      |
| 2      | 743              | 1 118      | 1 948      | 2 596      |
| 3      | 685              | 880        | 2 078      | 2 615      |
| 4      | 647              | 999        | 2 106      | 2 920      |
| 5      | 762              | 1 126      | 2 167      | 2 496      |
| 6      | 607              | 870        | 2 031      | 2 644      |
| 7      | 588              | 1 035      | 2 151      | 2 851      |
| 8      | 654              | 1 043      | 2 128      | 3 318      |
| 9      | 578              | 994        | 2 799      | 2 847      |
| 10     | 669              | 911        | 2 297      | 3 129      |
| 11     | 671              | 1 065      | 2 075      | 3 249      |
| 12     | 614              | 1 059      | 2 236      | 3 343      |
| 13     | 626              | 880        | 2 352      | 3 435      |
| 14     | 778              | 1 037      | 2 486      | 2 456      |
| 15     | 704              | 959        | 1 972      | 2 582      |
| 16     | 807              | 1 149      | 2 189      | 3 649      |
| 17     | 723              | 999        | 2 845      | 2 761      |
| 18     | 645              | 1 058      | 2 308      | 3 316      |
| 19     | 649              | 1 078      | 2 001      | 3 051      |
| 20     | 656              | 1 046      | 2 207      | 2 550      |
| 21     |                  |            |            | 3 500      |
| 22     |                  |            |            | 3 593      |
| 23     |                  |            |            | 3 275      |
| 24     |                  |            |            | 4 034      |
| 25     |                  |            |            | 3 488      |
| 26     |                  |            |            | 3 707      |
| 27     |                  |            |            | 3 304      |
| 28     |                  |            |            | 2 787      |
| 29     |                  |            |            | 3 453      |
| 30     |                  |            |            | 2 841      |

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Table B.6 - Predicted times-to-failure at ambient condition by bootstrapping

| Sampling number | Sampling data from each stress condition |            |            |            | Time-to Failure at 25°C/50% |
|-----------------|--|------------|------------|------------|-----------------------------|
|                 | 85°C/85%RH                               | 85°C/70%RH | 65°C/85%RH | 70°C/75%RH |                             |
| 1               | 607                                      | 1 035      | 2 207      | 3 488      | 576 977,5                   |
| 2               | 654                                      | 999        | 2 031      | 3 318      | 337 248,5                   |
| 3               | 704                                      | 1 078      | 2 001      | 3 240      | 246 008,5                   |
| 4               | 645                                      | 1 046      | 2 236      | 3 593      | 514 837,2                   |
| 5               | 723                                      | 1 046      | 2 128      | 2 582      | 127 316,4                   |
| 6               | 762                                      | 1 065      | 2 486      | 3 318      | 263 109,5                   |
| 7               | 778                                      | 1 058      | 2 151      | 3 453      | 223 679,1                   |
| 8               | 645                                      | 1 078      | 2 799      | 2 615      | 292 286,6                   |
| 9               | 704                                      | 1 046      | 2 308      | 2 841      | 203 964,6                   |
| 10              | 654                                      | 1 118      | 2 057      | 2 496      | 164 119,1                   |
| 11              | 807                                      | 880        | 1 948      | 2 851      | 92 163,5                    |
| 12              | 685                                      | 1 035      | 2 106      | 4 034      | 524 689,5                   |
| 13              | 743                                      | 1 078      | 2 128      | 2 582      | 117 060,7                   |
| 14              | 762                                      | 1 059      | 2 078      | 3 318      | 206 072,8                   |
| 15              | 685                                      | 911        | 2 236      | 3 240      | 290 891,6                   |
| 984             | 607                                      | 1 037      | 2 075      | 3 051      | 366 307,9                   |
| 985             | 647                                      | 911        | 2 207      | 2 847      | 245 130,1                   |
| 986             | 647                                      | 1 126      | 2 189      | 2 851      | 269 443,1                   |
| 987             | 685                                      | 1 059      | 2 297      | 2 550      | 166 622,3                   |
| 988             | 723                                      | 1 046      | 2 106      | 3 488      | 289 685,3                   |
| 989             | 762                                      | 1 078      | 2 128      | 3 343      | 219 133,3                   |
| 990             | 762                                      | 870        | 2 352      | 3 249      | 209 012,2                   |
| 991             | 743                                      | 994        | 2 352      | 4 034      | 445 445,1                   |
| 992             | 649                                      | 1 043      | 2 106      | 2 787      | 228 892,0                   |
| 993             | 588                                      | 1 035      | 2 189      | 3 304      | 550 507,4                   |
| 994             | 647                                      | 1 126      | 2 001      | 2 496      | 164 949,0                   |
| 995             | 588                                      | 1 046      | 2 128      | 2 761      | 323 337,4                   |
| 996             | 626                                      | 1 043      | 2 057      | 2 615      | 211 581,1                   |
| 997             | 704                                      | 1 126      | 2 799      | 3 707      | 574 192,4                   |
| 998             | 626                                      | 1 058      | 2 352      | 2 847      | 323 242,9                   |
| 999             | 588                                      | 959        | 2 352      | 3 318      | 591 577,5                   |
| 1 000           | 614                                      | 1 117      | 2 128      | 2 615      | 245 446,7                   |

**Step 6**

For the ambient condition, plot a histogram of these 1 000 predicted times-to-failure.

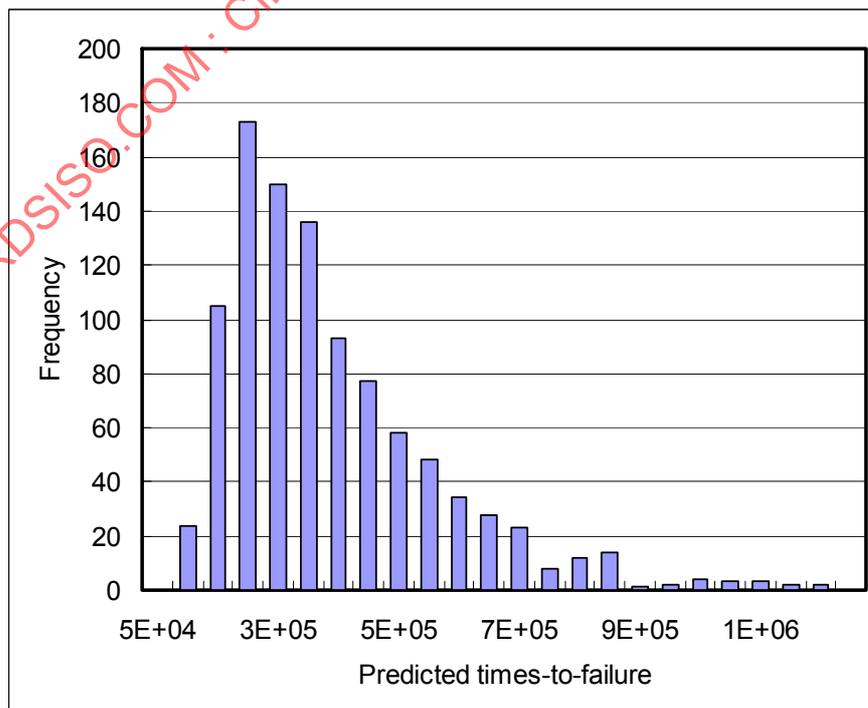


Figure B.2 - Histogram of predicted times-to-failure

**Step 7**

For the ambient condition, compute the estimated 5 % point and median value of the 1 000 predicted times-to-failure.

5% point of 1 000 predicted times-to-failure = 110 741,6 h (12,6 years)

Median value of 1 000 predicted times-to-failure = 272 077,23 h (31,0 years)

**Alternative steps 5-7, (without bootstrapping)**

**Step 5**

Calculate acceleration factors for each stress condition

$$\text{Life}_{\text{stress}} = \text{Exp} \{ \ln(A) + (\Delta H/k \times 1/\text{Temp}_{\text{stress}}) + (B \times \text{RH}_{\text{stress}}) \}$$

$$\text{Temp}_{\text{stress}} = \text{Temperature (in Kelvin)}$$

Calculating stress life using "best fit" B, ΔH/k, ln(A)

$$85^{\circ}\text{C}/85\%\text{RH} = \text{Exp} \{ (-13,1982) + (8\,355,7529 \times 1/358,15) + (-0,0437 \times 85) \} = 612,54 \text{ h}$$

$$85^{\circ}\text{C}/70\%\text{RH} = \text{Exp} \{ (-13,1982) + (8\,355,7529 \times 1/358,15) + (-0,0437 \times 70) \} = 1\,179,82 \text{ h}$$

$$65^{\circ}\text{C}/85\%\text{RH} = \text{Exp} \{ (-13,1982) + (8\,355,7529 \times 1/338,15) + (-0,0437 \times 85) \} = 2\,434,50 \text{ h}$$

$$70^{\circ}\text{C}/75\%\text{RH} = \text{Exp} \{ (-13,1982) + (8\,355,7529 \times 1/343,15) + (-0,0437 \times 75) \} = 2\,629,23 \text{ h}$$

$$25^{\circ}\text{C}/50\%\text{RH} = \text{Exp} \{ (-13,1982) + (8\,355,7529 \times 1/298,15) + (-0,0437 \times 50) \} = 309\,320,29 \text{ h}$$

Calculating acceleration factor for each stress condition

Acceleration factor = (Calculated ambient life) divided by (calculated stress life)

**Table B.7 - Acceleration factor for each stress condition**

| Stress     | Calculated life using "best fit" B, ΔH/k, ln(A) | Acceleration factor |
|------------|---|---------------------|
| 85°C/85%RH | 612,54 h  | 504,98              |
| 85°C/70%RH | 1 179,82 h                                      | 262,18              |
| 65°C/85%RH | 2 434,50 h                                      | 127,06              |
| 70°C/75%RH | 2 629,23 h                                      | 117,65              |
| 25°C/50%RH | 309 320,29 h                                    |                     |

**Step 6**

**Calculate normalized time-to-failure at 25 °C/50 % RH for each disk**

Use the acceleration factor to calculate the normalized time-to-failure.  
 Log the normalized time-to-failure values.  
 Calculate median and standard deviation for all disks.

$$\text{Median Exp (12,63)} = 305\,590,1 \text{ h (34,9 years)}$$

Table B.8 - Data for composite lognormal plot

| Hours to Failure | Group# | normalized to 25C/50%RH (A) | Ln of (A) | Group# | Ascending (A) | order | media rank | critical value |  |
|------------------|--------|-----------------------------|-----------|--------|---------------|-------|------------|----------------|--|
| 788              | 1      | 397 924,04                  | 12,89     | 2      | 228 036,86    | 1     | 0,0106     | -2,3060        |  |
| 743              | 1      | 375 199,95                  | 12,84     | 2      | 230 657,98    | 2     | 0,0217     | -2,0205        |  |
| 685              | 1      | 345 911,12                  | 12,75     | 2      | 230 657,98    | 3     | 0,0328     | -1,8414        |  |
| 647              | 1      | 326 721,89                  | 12,70     | 2      | 238 783,43    | 4     | 0,0439     | -1,7072        |  |
| 762              | 1      | 384 794,56                  | 12,86     | 3      | 247 400,36    | 5     | 0,0550     | -1,5982        |  |
| 607              | 1      | 306 522,70                  | 12,63     | 3      | 250 448,42    | 6     | 0,0661     | -1,5054        |  |
| 588              | 1      | 296 928,09                  | 12,60     | 2      | 251 364,77    | 7     | 0,0772     | -1,4240        |  |
| 654              | 1      | 330 256,75                  | 12,71     | 3      | 254 131,48    | 8     | 0,0883     | -1,3511        |  |
| 578              | 1      | 291 878,29                  | 12,58     | 3      | 257 941,55    | 9     | 0,0994     | -1,2847        |  |
| 669              | 1      | 337 831,45                  | 12,73     | 2      | 260 538,67    | 10    | 0,1106     | -1,2236        |  |
| 671              | 1      | 338 841,41                  | 12,73     | 3      | 261 243,61    | 11    | 0,1217     | -1,1667        |  |
| 614              | 1      | 310 057,56                  | 12,64     | 2      | 261 849,22    | 12    | 0,1328     | -1,1134        |  |
| 626              | 1      | 316 117,32                  | 12,66     | 2      | 261 849,22    | 13    | 0,1439     | -1,0630        |  |
| 778              | 1      | 392 874,24                  | 12,88     | 3      | 263 529,65    | 14    | 0,1550     | -1,0152        |  |
| 704              | 1      | 355 505,74                  | 12,78     | 3      | 263 910,65    | 15    | 0,1661     | -0,9696        |  |
| 807              | 1      | 407 518,65                  | 12,92     | 3      | 267 466,72    | 16    | 0,1772     | -0,9260        |  |
| 723              | 1      | 365 100,35                  | 12,81     | 3      | 270 260,76    | 17    | 0,1883     | -0,8841        |  |
| 645              | 1      | 325 711,93                  | 12,69     | 2      | 271 285,23    | 18    | 0,1994     | -0,8436        |  |
| 649              | 1      | 327 731,85                  | 12,70     | 2      | 271 809,46    | 19    | 0,2106     | -0,8045        |  |
| 656              | 1      | 331 266,71                  | 12,71     | 3      | 273 181,82    | 20    | 0,2217     | -0,7666        |  |
| 1 117            | 2      | 292 850,40                  | 12,59     | 2      | 273 382,12    | 21    | 0,2328     | -0,7297        |  |
| 1 118            | 2      | 293 112,58                  | 12,59     | 2      | 274 168,46    | 22    | 0,2439     | -0,6938        |  |
| 880              | 2      | 230 714,73                  | 12,35     | 3      | 275 213,85    | 23    | 0,2550     | -0,6588        |  |
| 999              | 2      | 261 913,66                  | 12,48     | 2      | 277 313,79    | 24    | 0,2661     | -0,6246        |  |
| 1 126            | 2      | 295 209,99                  | 12,60     | 2      | 277 575,91    | 25    | 0,2772     | -0,5911        |  |
| 870              | 2      | 228 092,97                  | 12,34     | 3      | 278 007,90    | 26    | 0,2883     | -0,5583        |  |
| 1 035            | 2      | 271 351,99                  | 12,51     | 2      | 279 148,57    | 27    | 0,2994     | -0,5260        |  |
| 1 043            | 2      | 273 449,39                  | 12,52     | 3      | 280 293,94    | 28    | 0,3106     | -0,4943        |  |
| 994              | 2      | 260 602,78                  | 12,47     | 2      | 282 556,02    | 29    | 0,3217     | -0,4630        |  |
| 911              | 2      | 238 842,18                  | 12,38     | 3      | 283 977,01    | 30    | 0,3328     | -0,4323        |  |
| 1 065            | 2      | 279 217,26                  | 12,54     | 4      | 288 851,15    | 31    | 0,3439     | -0,4019        |  |
| 1 059            | 2      | 277 644,21                  | 12,53     | 3      | 291 724,14    | 32    | 0,3550     | -0,3719        |  |
| 880              | 2      | 230 714,73                  | 12,35     | 1      | 291 751,68    | 33    | 0,3661     | -0,3422        |  |
| 1 037            | 2      | 271 876,34                  | 12,51     | 2      | 292 778,36    | 34    | 0,3772     | -0,3128        |  |
| 959              | 2      | 251 426,62                  | 12,43     | 2      | 293 040,47    | 35    | 0,3883     | -0,2837        |  |
| 1 149            | 2      | 301 240,03                  | 12,62     | 3      | 293 121,17    | 36    | 0,3994     | -0,2548        |  |
| 999              | 2      | 261 913,66                  | 12,48     | 4      | 293 555,56    | 37    | 0,4106     | -0,2261        |  |
| 1 058            | 2      | 277 382,03                  | 12,53     | 2      | 295 137,36    | 38    | 0,4217     | -0,1976        |  |
| 1 078            | 2      | 282 625,55                  | 12,55     | 1      | 296 799,29    | 39    | 0,4328     | -0,1693        |  |
| 1 046            | 2      | 274 235,92                  | 12,52     | 3      | 298 709,27    | 40    | 0,4439     | -0,1411        |  |
| 2 057            | 3      | 261 356,27                  | 12,47     | 4      | 299 906,52    | 41    | 0,4550     | -0,1130        |  |
| 1 948            | 3      | 247 507,05                  | 12,42     | 2      | 301 165,93    | 42    | 0,4661     | -0,0850        |  |
| 2 078            | 3      | 264 024,47                  | 12,48     | 4      | 303 670,06    | 43    | 0,4772     | -0,0571        |  |
| 2 106            | 3      | 267 582,06                  | 12,50     | 4      | 305 316,60    | 44    | 0,4883     | -0,0292        |  |
| 2 167            | 3      | 275 332,54                  | 12,53     | 1      | 306 389,74    | 45    | 0,4994     | -0,0014        |  |
| 2 031            | 3      | 258 052,79                  | 12,46     | 4      | 307 551,20    | 46    | 0,5106     | 0,0265         |  |
| 2 151            | 3      | 273 299,63                  | 12,52     | 1      | 309 923,07    | 47    | 0,5217     | 0,0543         |  |
| 2 128            | 3      | 270 377,32                  | 12,51     | 4      | 310 961,90    | 48    | 0,5328     | 0,0823         |  |
| 2 799            | 3      | 355 632,57                  | 12,78     | 3      | 315 727,57    | 49    | 0,5439     | 0,1102         |  |
| 2 297            | 3      | 291 849,95                  | 12,58     | 1      | 315 980,20    | 50    | 0,5550     | 0,1383         |  |
| 2 075            | 3      | 265 643,30                  | 12,48     | 4      | 324 722,32    | 51    | 0,5661     | 0,1665         |  |
| 2 236            | 3      | 284 099,47                  | 12,56     | 1      | 325 570,65    | 52    | 0,5772     | 0,1948         |  |
| 2 352            | 3      | 298 838,09                  | 12,61     | 1      | 326 580,17    | 53    | 0,5883     | 0,2233         |  |
| 2 486            | 3      | 315 863,73                  | 12,66     | 1      | 327 589,69    | 54    | 0,5994     | 0,2519         |  |
| 1 972            | 3      | 250 556,42                  | 12,43     | 4      | 327 780,19    | 55    | 0,6106     | 0,2808         |  |
| 2 189            | 3      | 278 127,79                  | 12,54     | 1      | 330 113,50    | 56    | 0,6217     | 0,3099         |  |
| 2 845            | 3      | 361 477,19                  | 12,80     | 1      | 331 123,02    | 57    | 0,6328     | 0,3392         |  |
| 2 308            | 3      | 293 247,58                  | 12,59     | 4      | 334 131,15    | 58    | 0,6439     | 0,3689         |  |
| 2 001            | 3      | 254 241,08                  | 12,45     | 4      | 334 836,81    | 59    | 0,6550     | 0,3989         |  |
| 2 207            | 3      | 280 414,82                  | 12,54     | 4      | 335 307,25    | 60    | 0,6661     | 0,4292         |  |
| 3 240            | 4      | 381 175,38                  | 12,85     | 1      | 337 684,91    | 61    | 0,6772     | 0,4599         |  |
| 2 596            | 4      | 305 410,89                  | 12,63     | 1      | 338 694,43    | 62    | 0,6883     | 0,4911         |  |
| 2 615            | 4      | 307 646,18                  | 12,64     | 4      | 343 422,37    | 63    | 0,6994     | 0,5228         |  |
| 2 920            | 4      | 343 528,43                  | 12,75     | 1      | 345 761,08    | 64    | 0,7106     | 0,5550         |  |
| 2 496            | 4      | 293 646,22                  | 12,59     | 1      | 355 351,53    | 65    | 0,7217     | 0,5878         |  |
| 2 644            | 4      | 311 057,93                  | 12,65     | 3      | 355 479,27    | 66    | 0,7328     | 0,6212         |  |
| 2 851            | 4      | 335 410,80                  | 12,72     | 4      | 358 829,33    | 67    | 0,7439     | 0,6554         |  |
| 3 318            | 4      | 390 351,82                  | 12,87     | 3      | 361 321,37    | 68    | 0,7550     | 0,6903         |  |
| 2 847            | 4      | 334 940,22                  | 12,72     | 1      | 364 941,98    | 69    | 0,7661     | 0,7261         |  |
| 3 129            | 4      | 368 116,59                  | 12,82     | 4      | 368 002,95    | 70    | 0,7772     | 0,7628         |  |
| 3 249            | 4      | 382 234,20                  | 12,85     | 1      | 375 037,20    | 71    | 0,7883     | 0,8007         |  |
| 3 343            | 4      | 393 292,99                  | 12,88     | 4      | 381 057,70    | 72    | 0,7994     | 0,8396         |  |
| 3 435            | 4      | 404 116,49                  | 12,91     | 4      | 382 116,19    | 73    | 0,8106     | 0,8799         |  |
| 2 456            | 4      | 288 940,35                  | 12,57     | 1      | 384 627,65    | 74    | 0,8217     | 0,9217         |  |
| 2 582            | 4      | 303 763,84                  | 12,62     | 4      | 385 174,06    | 75    | 0,8328     | 0,9652         |  |
| 3 649            | 4      | 429 292,89                  | 12,97     | 4      | 388 584,77    | 76    | 0,8439     | 1,0106         |  |
| 2 761            | 4      | 324 822,60                  | 12,69     | 4      | 389 996,09    | 77    | 0,8550     | 1,0581         |  |
| 3 316            | 4      | 390 116,53                  | 12,87     | 4      | 390 231,31    | 78    | 0,8661     | 1,1082         |  |
| 3 051            | 4      | 358 940,15                  | 12,79     | 1      | 392 703,82    | 79    | 0,8772     | 1,1612         |  |
| 2 550            | 4      | 299 999,14                  | 12,61     | 4      | 393 171,57    | 80    | 0,8883     | 1,2177         |  |
| 3 500            | 4      | 411 763,53                  | 12,93     | 1      | 397 751,43    | 81    | 0,8994     | 1,2784         |  |
| 3 593            | 4      | 422 704,67                  | 12,95     | 4      | 403 991,73    | 82    | 0,9106     | 1,3442         |  |
| 3 275            | 4      | 385 293,01                  | 12,86     | 4      | 406 108,72    | 83    | 0,9217     | 1,4164         |  |
| 4 034            | 4      | 474 586,88                  | 13,07     | 1      | 407 341,88    | 84    | 0,9328     | 1,4968         |  |
| 3 488            | 4      | 410 351,77                  | 12,92     | 4      | 410 225,08    | 85    | 0,9439     | 1,5883         |  |
| 3 707            | 4      | 436 116,40                  | 12,99     | 4      | 411 636,41    | 86    | 0,9550     | 1,6954         |  |
| 3 304            | 4      | 388 704,77                  | 12,87     | 4      | 422 574,17    | 87    | 0,9661     | 1,8265         |  |
| 2 787            | 4      | 327 881,41                  | 12,70     | 4      | 429 160,35    | 88    | 0,9772     | 1,9995         |  |
| 3 453            | 4      | 406 234,13                  | 12,91     | 4      | 435 981,76    | 89    | 0,9883     | 2,2679         |  |
| 2 841            | 4      | 334 234,34                  | 12,72     | 4      | 474 440,36    | 90    | 0,9994     | 3,2608         |  |
| median           |        |                             | 12,63     | Total  |               |       | 90         |                |  |
| Deviation        |        |                             | 0,169     |        |               |       |            |                |  |
| 95% confidence   |        |                             | 0,0349    |        |               |       |            |                |  |

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Step 7

Calculate 95 % survival probability for lifetime at 25 °C/50 % RH

Calculate 5 % lower limit of 12,63 median value with Standard deviation of 0,169

95 % confidence = 0,0349

Calculate 95 % survival probability with 95 % confidence.

223 489,5 h = 25,5 years

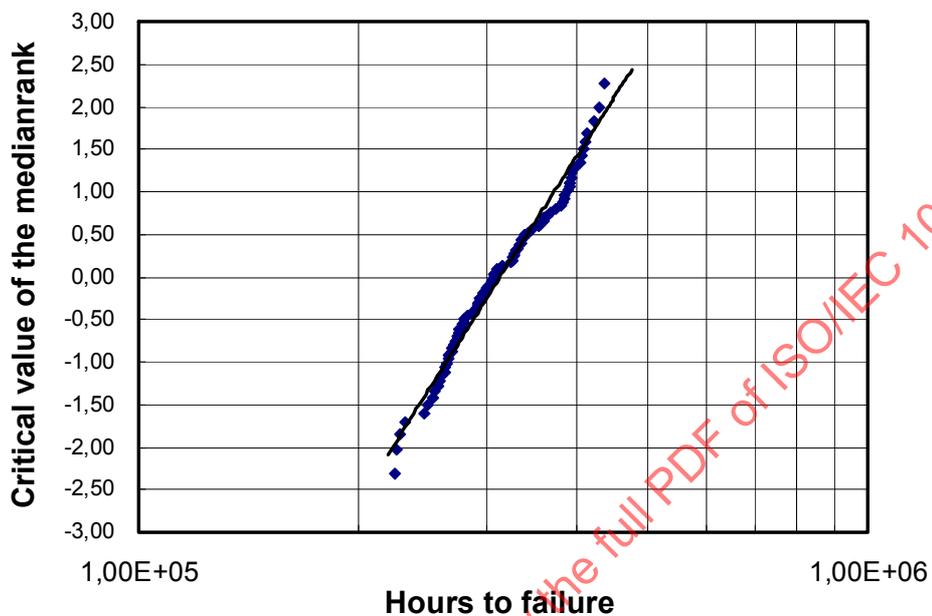


Figure B.3 - Plot of normalized data

## Annex C (normative)

### Uncontrolled Ambient Condition Media Life Calculation

A test method for a storage or usage condition of higher temperature and relative humidity than 25 °C and 50 % relative humidity.

This test method follows the scope in this document except for the ambient storage condition, which will be based on an environment of 30 °C and 80 % relative humidity. This test method will also use a different stress test design that makes possible the use of the Arrhenius equation.

This test demonstrates with a certainty of 95 % that information stored on a recordable or rewriteable optical disk will be viable for a predetermined minimum number of years when storage conditions do not exceed 30 °C and 80 % relative humidity.

The same method and assumptions apply except where the ambient condition, stress design, and Eyring equation is addressed. The controlled ambient condition of 25 °C and 50 % relative humidity will be replaced by an expected harsher user environment of 30 °C and 80 % relative humidity.

The *reduced* Eyring equation:  $t = Ae^{\Delta H / kT} e^{B \times RH}$  will be replaced by the Arrhenius equation:  $t = Ae^{\Delta H / kT}$ .

The ambient condition will be as stated above. The stress test design will be as follows:

**Table C.1 - Summary of Stress conditions for use with Arrhenius Method**

| Test cell number | Test stress condition (inc) |     | Number of specimens | Incubation duration<br>hours | Min total time<br>hours | Intermediate RH<br>%RH | Min equilibration duration<br>hours |
|------------------|-----------------------------|-----|---------------------|------------------------------|-------------------------|------------------------|-------------------------------------|
|                  | Temp (°C)                   | %RH |                     |                              |                         |                        |                                     |
| 1b               | 85                          | 80  | 20                  | 250                          | 1 000                   | 30                     | 5                                   |
| 2b               | 75                          | 80  | 25                  | 425                          | 1 700                   | 33                     | 7                                   |
| 3b               | 65                          | 80  | 30                  | 600                          | 2 400                   | 35                     | 10                                  |

Replace Step 4 in Annex A and B with:

#### Step 4

Using the Arrhenius equation, carry out a least squares fit to the log *median* failure times for each stress condition across all specimens and stress conditions.

## Annex D (informative)

### Truncated Test Method (Determination of Media Life Lower Bound)

This test method is to confirm the target minimum life expectancy and to calculate the minimum test time required to do so when media survives at a certain stress condition.

It eliminates the problem with "flat line" data where media continues to survive. Media is tested until failure (normally at the higher stress conditions). A desired minimum number of years lifetime is chosen and the number of hours at the minimum stress condition (without failure) is calculated. When this number is reached, the minimum life target is verified.

Example: See Table D.1 (media survives at high temperature and lower RH)

Using 30 years at 25 °C, 50 % RH as a constraint:

The following is an outline of steps to estimate the minimal life expectancy using the reduced Eyring equation, as a function of ambient temperature and relative humidity.

1. Solve for coefficient  $\Delta H$  (activation energy per molecule) of Eyring equation.

Subtract two stress conditions with the same % RH.

$$\ln(\text{Time}_{\text{Stress1}}) - \ln(\text{Time}_{\text{Stress2}}) = \left[ \ln A + \frac{\Delta H}{kT_{\text{Stress1}}} + B \times RH_{\text{Stress1}} \right] - \left[ \ln A + \frac{\Delta H}{kT_{\text{Stress2}}} + B \times RH_{\text{Stress2}} \right]$$

where  $\text{Time}_{\text{Stress1}}$  is time to failure at stress1 condition,  $\text{Time}_{\text{Stress2}}$  is time to failure at stress2 condition.

Example using stress conditions of 85 °C, 85 % RH and 65 °C, 85 % RH

$$\ln(\text{Time}_{85,85}) - \ln(\text{Time}_{65,85}) = \left[ \ln A + \frac{\Delta H}{kT_{85}} + B \times RH_{85} \right] - \left[ \ln A + \frac{\Delta H}{kT_{65}} + B \times RH_{85} \right]$$

$$\Delta H = \{ \ln(\text{Time}_{85,85}) - \ln(\text{Time}_{65,85}) \} \times (-8,3607 \times 10^{-20})$$

Solve for  $\Delta H$  using these example times for the above stress conditions:

At: 85 °C, 85 % RH  $\text{Time}_{85,85} = 500$  h at 65 °C, 85 % RH  $\text{Time}_{65,85} = 1\,852$  h

Solve for  $\Delta H$ ,  $\Delta H = 1,0948 \times 10^{-19}$

2. Solve for coefficient B (RH exponential constant) of Eyring equation.

Solving for B after solving for  $\Delta H$  ( $\Delta H = 1,0948 \times 10^{-19}$ , using the example above).

Subtract two stress conditions with different Temperature and % RH

$$\ln(\text{Time}_{\text{Stress1}}) - \ln(\text{Time}_{\text{Stress2}}) = \left[ \ln A + \frac{\Delta H}{kT_{\text{Stress1}}} + B \times RH_{\text{Stress1}} \right] - \left[ \ln A + \frac{\Delta H}{kT_{\text{Stress2}}} + B \times RH_{\text{Stress2}} \right]$$

Example using stress conditions at 85 °C, 85 % RH and 25 °C, 50 % RH.