INTERNATIONAL STANDARD

ISO/IEC 10995

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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.

This second edition cancels and replaces the first edition (ISO/IEC 10995:2008), which has been technically revised.

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 document 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 Technical Committee 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 document.

ECMA-379 1st Edition was fast-tracked to ISO/IEC JTC 1 in August 2007 and during this process its editorial content was slightly modified. The approved International Standard was published as ISO/IEC 10995:2008 in April 2008. ECMA-379 2nd Edition is technically identical with ISO/IEC 10995:2008. ECMA-379 3rd Edition is an editorial amendment including corrections of some calculations, and the Bootstrap method has been deleted. Although the Bootstrap method poses no problem in itself, miscalculation might be caused depending on the data set conditions.

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 can be applied to additional optical disk formats with the appropriate specification substitutions and can be updated in the future as required.

This International Standard includes

- stress conditions,
- assumptions,
- ambient conditions,
  - controlled storage conditions, e.g. 25 °C and 50 % RH, using the Eyring model,
  - uncontrolled storage conditions, e.g. 30 °C and 80 % RH, using the Arrhenius model,
- evaluation system description,
- specimen preparation,
- data acquisition procedure, and
- 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 12862:2009, *Information technology — 120 mm (8,54 Gbytes per side) and 80 mm (2,66 Gbytes per side) DVD recordable disk for dual layer (DVD-R for DL)* (ECMA-382)

ISO/IEC 13170:2009, *Information technology — 120 mm (8,54 Gbytes per side) and 80 mm (2,66 Gbytes per side) DVD re-recordable disk for dual layer (DVD-RW for DL)* (ECMA-384)

ISO/IEC 16448:2002, *Information technology — 120 mm DVD — Read-only disk* (ECMA-267)

ISO/IEC 16449:2002, *Information technology — 80 mm DVD — Read-only disk* (ECMA-268)

ISO/IEC 17341:2009, *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)* (ECMA-337)

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)* (ECMA-338)

ISO/IEC 17344:2009, *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)* (ECMA-349)

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)* (ECMA-330)

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)* (ECMA-359)

ISO/IEC 25434:2008, *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 16X)* (ECMA-364)

ISO/IEC 26925:2009, *Information technology — 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)* (ECMA-371)

ISO/IEC 29642:2009, *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)* (ECMA-374)

4 Terms and definitions

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

4.1
archival (lifetime)
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
Eyring method
accelerated aging model based on the effects of temperature and relative humidity

4.5
error rate
rate of errors on the sample disk measured before error correction is applied

4.6
incubation
process of enclosing and maintaining controlled test sample environments

4.7
life expectancy
LE
estimation of the length of time that information is predicted to be retrievable in a system while in a specified environmental condition

4.8
maximum error rate
maximum of the error rate measured anywhere in one of the relevant areas on the disk.

NOTE For DVD-R/RW and +R/+RW, this is the Maximum PI Sum 8; for DVD-RAM, this is the Maximum BER.

4.9
retrievability
ability to recover physical information as recorded

4.10
stress
temperature and relative humidity variables to which the sample is exposed for the duration of test incubation intervals

4.11
system
combination of hardware, software, storage medium and documentation used to record, retrieve and reproduce information

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 Abbreviated terms

BER byte error rate

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 its error rate after each stress condition incubation time interval. The control disk will also be measured following each incubation time interval.

7.1.2 Assumptions

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

— specimen life distribution is appropriately modeled by a statistical distribution,

— the Eyring model can be used to model acceleration with both 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 the 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 7.5. For each sample the Maximum error rate shall be determined.

Each DVD-R/RW, +R/+RW disk will have its maximum PI Sum 8 (Max PI Sum 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 in 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 7.5 shall not exceed 10^{-3} (See Annex E).

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 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 are entered into accelerated aging tests, they shall be recorded as optimally as is practicable, according to the descriptions given in the format standards identified in Clause 3. OPC (optimum power control) during the 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 be cleaned according to the instructions of the manufacturer of the disk.

7.3.2 Recording method

Specimen disks shall be recorded in 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 format standards identified in Clause 3 or equivalent, 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 should be calibrated as prescribed by its manufacturer using calibration disks approved by said manufacturer and as needed before disk testing.

A control disk should 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 the 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 capacity. Each of the three test bands shall have more than 750 ECC Blocks for 80 mm disks, and 2 400 ECC Blocks for 120 mm disks.

Table 1 — Nominal radii of the three test bands (Unit; mm)

	DVD-R/RW, +R/+RW disk (Single Layer/Dual Layer)		**DVD-RAM disk**	
	80mm	120mm	80mm	120mm
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 (incubation)		Number of specimens	Incubation duration	Minimum Total time	Intermediate RH	Minimum equilibration duration
	Temp (°C)	%RH		hours	hours	%RH	hours
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 °C	Relative humidity %	Duration hours
Start	at T_{amb}	at RH_{amb}	—
T, RH ramp	to T_{inc}	to RH_{int}	1,5 ± 0,5
RH ramp	at T_{inc}	to RH_{inc}	1,5 ± 0,5
Incubation	at T_{inc}	at RH_{inc}	See Table 2
RH ramp	at T_{inc}	to RH_{int}	1,5 ± 0,5
Equilibration	at T_{inc}	at RH_{int}	See Table 2
T, RH ramp	to T_{amb}	to RH_{amb}	1,5 ± 0,5
end	at T_{amb}	at RH_{amb}	—

amb = room ambient T or RH (T_{amb} or RH_{amb})
inc = stress incubation T or RH (T_{inc} or RH_{inc})
int = intermediate relative humidity (RH_{int}) that at T_{inc} supports the same equilibrium moisture absorption in polycarbonate as that supported at T_{amb} and RH_{amb}

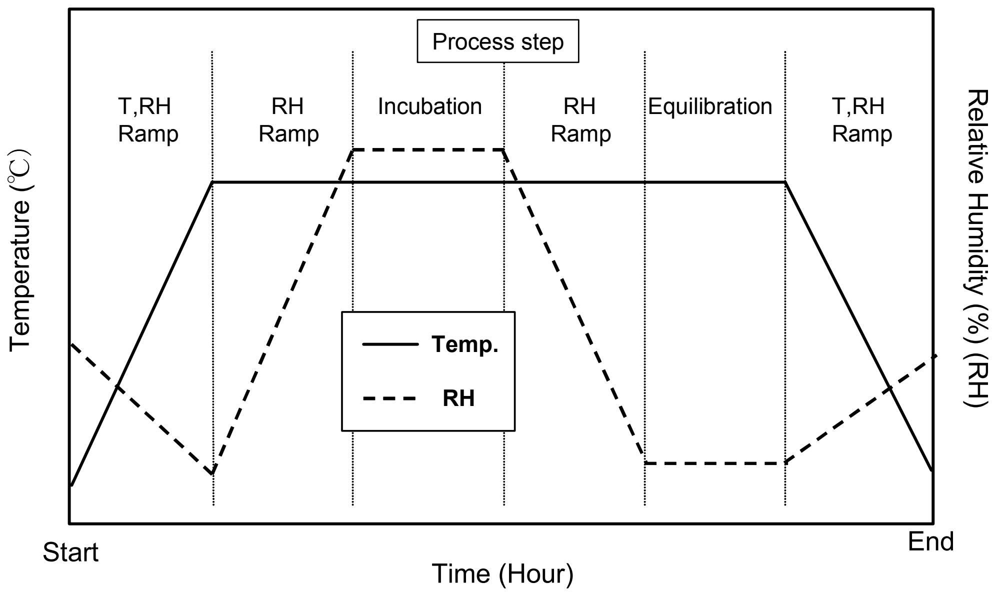

Figure 1 — Graph of typical transition (ramp) profile

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 dependent 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 ±2 °C of the target temperature; all relative humidities may deviate ±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:

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

where: T_{amb} and T_{inc} are 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;
ΔH is the activation energy per molecule;
k is the Boltzmann's constant (1,3807 × 10^{-23} J/molecule degree K);
T is the temperature (in Kelvin);
B, C are 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:

$$t = Ae^{\Delta H / kT} e^{B\times RH}$$, 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 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, 7.1.2 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. Calculate acceleration factors for each stress condition.
6. For the ambient condition, calculate normalized time-to-failure for each disk.

For the ambient condition, calculate 95 % survival probability with 95 % confidence for lifetime.

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 7.1.3:

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 BLER of 220, or 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					
Disk #	Hours					Hours to Failure
	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

Table B.1 (*continued*)

Group 2a	85°C/70%RH					
Disk #	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					
Disk #	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

Table B.1 (*concluded*)

Group 4a	70°C/75%RH					
Disk #	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 −0,3)/(n+0,4), 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	Disk #	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	0,034	-1,821
2	A7	26	121	274	589	781	588	6,3767	0,083	-1,383
3	A6	21	111	207	567	896	607	6,4085	0,132	-1,115
4	A12	24	136	267	444	719	614	6,4200	0,181	-0,910
5	A13	35	76	265	567	610	626	6,4394	0,230	-0,738
6	A18	26	109	238	421	641	645	6,4693	0,279	-0,585
7	A4	26	111	247	343	718	647	6,4723	0,328	-0,444
8	A19	26	111	253	378	638	649	6,4754	0,377	-0,312
9	A8	31	108	223	315	745	654	6,4831	0,426	-0,185
10	A20	31	91	206	367	728	656	6,4862	0,475	-0,061
11	A10	12	85	178	312	988	669	6,5058	0,525	0,061
12	A11	28	111	167	312	771	671	6,5088	0,574	0,185
13	A3	26	94	190	335	642	685	6,5294	0,623	0,312
14	A15	28	88	158	308	654	704	6,5568	0,672	0,444
15	A17	18	87	176	302	558	723	6,5834	0,721	0,585
16	A2	25	64	134	342	532	743	6,6107	0,770	0,738
17	A5	27	89	185	246	466	762	6,6359	0,819	0,910
18	A14	19	53	112	278	534	778	6,6567	0,868	1,115
19	A1	16	78	116	278	445	788	6,6695	0,917	1,383
20	A16	27	68	120	263	432	807	6,6933	0,966	1,821
						median	663	6,4960		

Group 2a		85°C/70%RH								
order number	Disk #	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	0,034	-1,821
2	B3	12	26	72	185	421	880	6,7799	0,083	-1,383
3	B13	10	27	89	175	385	880	6,7799	0,132	-1,115
4	B10	17	38	67	179	378	911	6,8145	0,181	-0,910
5	B15	28	39	125	172	278	959	6,8659	0,230	-0,738
6	B9	25	46	124	182	224	994	6,9017	0,279	-0,585
7	B4	20	43	120	166	219	999	6,9068	0,328	-0,444
8	B17	20	43	75	166	256	999	6,9068	0,377	-0,312
9	B7	21	30	89	155	221	1 035	6,9422	0,426	-0,185
10	B14	23	54	111	148	221	1 037	6,9441	0,475	-0,061
11	B8	22	26	72	125	267	1 043	6,9499	0,525	0,061
12	B20	10	19	28	121	268	1 046	6,9527	0,574	0,185
13	B18	22	26	50	172	229	1 058	6,9641	0,623	0,312
14	B12	8	15	36	144	189	1 059	6,9651	0,672	0,444
15	B11	28	58	88	120	268	1 065	6,9707	0,721	0,585
16	B19	13	38	78	124	189	1 078	6,9829	0,770	0,738
17	B1	10	20	67	112	156	1 117	7,0184	0,819	0,910
18	B2	8	20	47	84	188	1 118	7,0193	0,868	1,115
19	B5	32	45	76	103	267	1 126	7,0264	0,917	1,383
20	B16	25	53	88	130	188	1 149	7,0466	0,966	1,821
						median	1 040	6,9470		

Table B.2 — Median rank and the critical value for estimated time to failure (*continued*)

Group 3a		65°C/85%RH								
order number	Disk #	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	0,034	-1,821
2	C15	25	65	89	184	256	1 972	7,5868	0,083	-1,383
3	C19	28	56	108	176	243	2 001	7,6014	0,132	-1,115
4	C6	10	14	45	154	231	2 031	7,6163	0,181	-0,910
5	C1	14	23	58	112	278	2 057	7,6290	0,230	-0,738
6	C11	21	38	89	148	227	2 075	7,6377	0,279	-0,585
7	C3	11	56	88	138	189	2 078	7,6392	0,328	-0,444
8	C4	18	28	78	117	243	2 106	7,6525	0,377	-0,312
9	C8	29	54	106	154	218	2 128	7,6629	0,426	-0,185
10	C7	31	53	111	156	211	2 151	7,6737	0,475	-0,061
11	C5	17	45	78	143	189	2 167	7,6811	0,525	0,061
12	C16	10	18	57	113	178	2 189	7,6912	0,574	0,185
13	C20	29	36	57	143	238	2 207	7,6994	0,623	0,312
14	C12	24	45	68	134	211	2 236	7,7124	0,672	0,444
15	C10	29	36	78	145	188	2 297	7,7394	0,721	0,585
16	C18	12	20	34	112	176	2 308	7,7441	0,770	0,738
17	C13	28	57	78	132	190	2 352	7,7630	0,819	0,910
18	C14	19	47	61	117	150	2 486	7,8184	0,868	1,115
19	C9	22	32	65	89	126	2 799	7,9370	0,917	1,383
20	C17	21	34	45	98	121	2 845	7,9533	0,966	1,821
					median		2 159	7,6774		

Table B.2 — Median rank and the critical value for estimated time to failure (*concluded*)

Group 4a		70°C/75%RH								
order number	Disk #	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	0,023	-1,995
2	D5	5	20	78	132	187	2 496	7,8224	0,056	-1,590
3	D20	12	56	66	124	249	2 550	7,8438	0,089	-1,348
4	D15	22	26	73	145	252	2 582	7,8563	0,122	-1,166
5	D2	25	93	134	154	211	2 596	7,8617	0,155	-1,017
6	D3	7	23	97	103	178	2 615	7,8690	0,188	-0,887
7	D6	5	15	52	112	167	2 644	7,8800	0,220	-0,771
8	D17	22	26	93	145	178	2 761	7,9233	0,253	-0,664
9	D28	20	28	45	111	243	2 787	7,9327	0,286	-0,565
10	D30	10	34	54	96	176	2 841	7,9519	0,319	-0,470
11	D9	22	34	67	132	189	2 847	7,9540	0,352	-0,380
12	D7	22	34	67	132	188	2 851	7,9554	0,385	-0,293
13	D4	10	20	56	89	155	2 920	7,9793	0,418	-0,208
14	D19	11	32	44	97	143	3 051	8,0232	0,451	-0,124
15	D10	23	27	54	121	152	3 129	8,0485	0,484	-0,041
16	D1	25	34	64	92	167	3 240	8,0833	0,516	0,041
17	D11	11	20	41	87	115	3 249	8,0861	0,549	0,124
18	D23	11	16	27	54	160	3 275	8,0941	0,582	0,208
19	D27	21	39	63	78	163	3 304	8,1029	0,615	0,293
20	D18	18	27	56	88	134	3 316	8,1065	0,648	0,380
21	D8	12	17	56	78	108	3 318	8,1071	0,681	0,470
22	D12	15	18	43	88	118	3 343	8,1146	0,714	0,565
23	D13	19	21	38	82	135	3 435	8,1418	0,747	0,664
24	D29	15	21	38	65	134	3 453	8,1470	0,780	0,771
25	D25	11	25	22	62	130	3 488	8,1571	0,813	0,887
26	D21	14	34	54	77	112	3 500	8,1605	0,845	1,017
27	D22	20	23	25	50	181	3 593	8,1867	0,878	1,166
28	D16	18	18	29	66	127	3 649	8,2022	0,911	1,348
29	D26	17	24	25	70	123	3 707	8,2180	0,944	1,590
30	D24	17	24	25	58	108	4 034	8,3025	0,977	1,995
				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 σ 1is then calculated from the equation:

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

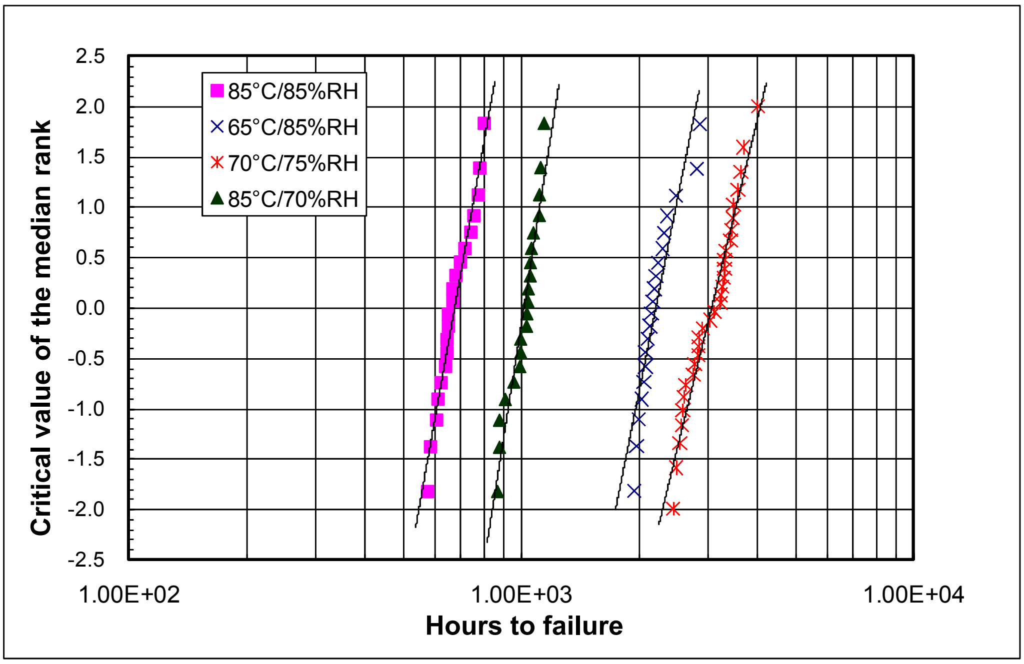

Figure B.1 — Lognormal plot of Table B.2

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 *median*	Temp.	1/T(Kelvin)	Humidity
1a	6,4960	85	0.00279213	85
2a	6,9470	85	0.00279213	70
3a	7,6774	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)
-0,0432	8 427,9450	-13,4380

Step 5

Calculate acceleration factors for each stress condition

$Life_{\text{stress}}$ = Exp {ln(A) + ($\Delta H/k$ × 1/$Temp_{\text{stress}}$) + (B × RH_{stress}) }

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

Calculating stress life using "best fit" B, $\Delta H/k$, ln(A)

85°C/85%RH = Exp { (-13,4380) + (8 427,9450 × 1/358,15) + (-0,0432 × 85) } = 615,16 hours

85°C/70%RH = Exp { (-13,4380) + (8 427,9450 × 1/358,15) + (-0,0432 × 70) } = 1 176,01 hours

65°C/85%RH = Exp { (-13,4380) + (8 427,9450 × 1/338,15) + (-0,0432 × 85) } = 2 474,24 hours

70°C/75%RH = Exp { (-13,4380) + (8 427,9450 × 1/343,15) + (-0,0432 × 75) } = 2 650,56 hours

25°C/50%RH = Exp { (-13,4380) + (8 427,9450 × 1/298,15) + (-0,0432 × 50) } = 31 7891,70 hours

Calculating acceleration factor for each stress condition

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

Table B.5 — Acceleration factor for each stress condition

Stress	Calculated life using "best fit" B, $\Delta H/k$, ln(A)	Acceleration factor
85°C/85%RH	615,16 hours	516,76
85°C/70%RH	1 176,01 hours	270,31
65°C/85%RH	2 474,24 hours	128,48
70°C/75%RH	2 650,56 hours	119,93
25°C/50%RH	317 891,70 hours	

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.

Median Exp (12,66) = 314 896,7 hours (35,9 years)

Table B.6 — Data for composite lognormal plot

Hours to Failure	Group#	normalized to 25C/50%RH (A)	ln of (A)	Group#	Ascending (A)	Ascending ln (A)	order	media rank	critical value
788	1	407,206.88	12.92	2	235,169.70	12.37	1	0.0077	-2.4208
743	1	383,952.68	12.86	2	237,872.80	12.38	2	0.0188	-2.0791
685	1	353,980.60	12.78	2	237,872.80	12.38	3	0.0299	-1.8827
647	1	334,343.72	12.72	2	246,252.41	12.41	4	0.0409	-1.7400
762	1	393,771.12	12.88	3	250,279.04	12.43	5	0.0520	-1.6258
607	1	313,673.32	12.66	3	253,362.56	12.44	6	0.0631	-1.5296
588	1	303,854.88	12.62	3	257,088.48	12.46	7	0.0741	-1.4458
654	1	337,961.04	12.73	2	259,227.29	12.47	8	0.0852	-1.3711
578	1	298,687.28	12.61	3	260,942.88	12.47	9	0.0962	-1.3033
669	1	345,712.44	12.75	3	264,283.36	12.48	10	0.1073	-1.2410
671	1	346,745.96	12.76	3	266,596.00	12.49	11	0.1184	-1.1832
614	1	317,290.64	12.67	3	266,981.44	12.49	12	0.1294	-1.1291
626	1	323,491.76	12.69	2	268,688.14	12.50	13	0.1405	-1.0781
778	1	402,039.28	12.90	2	270,039.69	12.51	14	0.1515	-1.0298
704	1	363,799.04	12.80	2	270,039.69	12.51	15	0.1626	-0.9838
807	1	417,025.32	12.94	3	270,578.88	12.51	16	0.1737	-0.9398
723	1	373,617.48	12.83	3	273,405.44	12.52	17	0.1847	-0.8975
645	1	333,310.20	12.72	3	276,360.48	12.53	18	0.1958	-0.8567
649	1	335,377.24	12.72	3	278,416.16	12.54	19	0.2069	-0.8174
656	1	338,994.56	12.73	2	279,770.85	12.54	20	0.2179	-0.7792
1,117	2	301,936.27	12.62	2	280,311.47	12.54	21	0.2290	-0.7422
1,118	2	302,206.58	12.62	3	281,242.72	12.55	22	0.2400	-0.7062
880	2	237,872.80	12.38	2	281,933.33	12.55	23	0.2511	-0.6710
999	2	270,039.69	12.51	2	282,744.26	12.55	24	0.2622	-0.6367
1,126	2	304,369.06	12.63	3	283,555.36	12.56	25	0.2732	-0.6031
870	2	235,169.70	12.37	2	285,987.98	12.56	26	0.2843	-0.5701
1,035	2	279,770.85	12.54	2	286,258.29	12.56	27	0.2954	-0.5378
1,043	2	281,933.33	12.55	3	287,281.28	12.57	28	0.3064	-0.5060
994	2	268,688.14	12.50	2	287,880.15	12.57	29	0.3175	-0.4748
911	2	246,252.41	12.41	2	291,394.18	12.58	30	0.3285	-0.4439
1,065	2	287,880.15	12.57	4	294,548.08	12.59	31	0.3396	-0.4136
1,059	2	286,258.29	12.56	3	295,118.56	12.60	32	0.3507	-0.3835
880	2	237,872.80	12.38	3	296,531.84	12.60	33	0.3617	-0.3538
1,037	2	280,311.47	12.54	1	298,687.28	12.61	34	0.3728	-0.3245
959	2	259,227.29	12.47	4	299,345.28	12.61	35	0.3838	-0.2954
1,149	2	310,586.19	12.65	2	301,936.27	12.62	36	0.3949	-0.2665
999	2	270,039.69	12.51	3	302,184.96	12.62	37	0.4060	-0.2379
1,058	2	285,987.98	12.56	2	302,206.58	12.62	38	0.4170	-0.2095
1,078	2	291,394.18	12.58	1	303,854.88	12.62	39	0.4281	-0.1812
1,046	2	282,744.26	12.55	2	304,369.06	12.63	40	0.4392	-0.1531
2,057	3	264,283.36	12.48	4	305,821.50	12.63	41	0.4502	-0.1251
1,948	3	250,279.04	12.43	4	309,659.26	12.64	42	0.4613	-0.0972
2,078	3	266,981.44	12.49	2	310,586.19	12.65	43	0.4723	-0.0694
2,106	3	270,578.88	12.51	4	311,338.28	12.65	44	0.4834	-0.0416
2,167	3	278,416.16	12.54	4	313,616.95	12.66	45	0.4945	-0.0139
2,031	3	260,942.88	12.47	1	313,673.32	12.66	46	0.5055	0.0139
2,151	3	276,360.48	12.53	4	317,094.92	12.67	47	0.5166	0.0416
2,128	3	273,405.44	12.52	1	317,290.64	12.67	48	0.5277	0.0694
2,799	3	359,615.52	12.79	3	319,401.28	12.67	49	0.5387	0.0972
2,297	3	295,118.56	12.60	1	323,491.76	12.69	50	0.5498	0.1251
2,075	3	266,596.00	12.49	4	331,126.73	12.71	51	0.5608	0.1531
2,236	3	287,281.28	12.57	1	333,310.20	12.72	52	0.5719	0.1812
2,352	3	302,184.96	12.62	4	334,244.91	12.72	53	0.5830	0.2095
2,486	3	319,401.28	12.67	1	334,343.72	12.72	54	0.5940	0.2379
1,972	3	253,362.56	12.44	1	335,377.24	12.72	55	0.6051	0.2665
2,189	3	281,242.72	12.55	1	337,961.04	12.73	56	0.6162	0.2954
2,845	3	365,525.60	12.81	1	338,994.56	12.73	57	0.6272	0.3245
2,308	3	296,531.84	12.60	4	340,721.13	12.74	58	0.6383	0.3538
2,001	3	257,088.48	12.46	4	341,440.71	12.74	59	0.6493	0.3835
2,207	3	283,555.36	12.56	4	341,920.43	12.74	60	0.6604	0.4136
3,240	4	388,573.20	12.87	1	345,712.44	12.75	61	0.6715	0.4439
2,596	4	311,338.28	12.65	1	346,745.96	12.76	62	0.6825	0.4748
2,615	4	313,616.95	12.66	4	350,195.60	12.77	63	0.6936	0.5060
2,920	4	350,195.60	12.77	1	353,980.60	12.78	64	0.7046	0.5378
2,496	4	299,345.28	12.61	3	359,615.52	12.79	65	0.7157	0.5701
2,644	4	317,094.92	12.67	1	363,799.04	12.80	66	0.7268	0.6031
2,851	4	341,920.43	12.74	3	365,525.60	12.81	67	0.7378	0.6367
3,318	4	397,927.74	12.89	4	365,906.43	12.81	68	0.7489	0.6710
2,847	4	341,440.71	12.74	1	373,617.48	12.83	69	0.7600	0.7062
3,129	4	375,260.97	12.84	4	375,260.97	12.84	70	0.7710	0.7422
3,249	4	389,652.57	12.87	1	383,952.68	12.86	71	0.7821	0.7792
3,343	4	400,925.99	12.90	4	388,573.20	12.87	72	0.7931	0.8174
3,435	4	411,959.55	12.93	4	389,652.57	12.87	73	0.8042	0.8567
2,456	4	294,548.08	12.59	4	392,770.75	12.88	74	0.8153	0.8975
2,582	4	309,659.26	12.64	1	393,771.12	12.88	75	0.8263	0.9398
3,649	4	437,624.57	12.99	4	396,248.72	12.89	76	0.8374	0.9838
2,761	4	331,126.73	12.71	4	397,687.88	12.89	77	0.8485	1.0298
3,316	4	397,687.88	12.89	4	397,927.74	12.89	78	0.8595	1.0781
3,051	4	365,906.43	12.81	4	400,925.99	12.90	79	0.8706	1.1291
2,550	4	305,821.50	12.63	1	402,039.28	12.90	80	0.8816	1.1832
3,500	4	419,755.00	12.95	1	407,206.88	12.92	81	0.8927	1.2410
3,593	4	430,908.49	12.97	4	411,959.55	12.93	82	0.9038	1.3033
3,275	4	392,770.75	12.88	4	414,118.29	12.93	83	0.9148	1.3711
4,034	4	483,797.62	13.09	1	417,025.32	12.94	84	0.9259	1.4458
3,488	4	418,315.84	12.94	4	418,315.84	12.94	85	0.9369	1.5296
3,707	4	444,580.51	13.00	4	419,755.00	12.95	86	0.9480	1.6258
3,304	4	396,248.72	12.89	4	430,908.49	12.97	87	0.9591	1.7400
2,787	4	334,244.91	12.72	4	437,624.57	12.99	88	0.9701	1.8827
3,453	4	414,118.29	12.93	4	444,580.51	13.00	89	0.9812	2.0791
2,841	4	340,721.13	12.74	4	483,797.62	13.09	90	0.9923	2.4208
		median	**12.66**			Total	90		
		Deviation	**0.168**						
		95% confidence	0.0347						

Step 7

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

Calculate 5 % lower limit of 12,66 median value with Standard deviation of 0,168

95 % confidence = 0,0347

Calculate 95 % survival probability with 95 % confidence

230 721,0 hours = 26,3 years

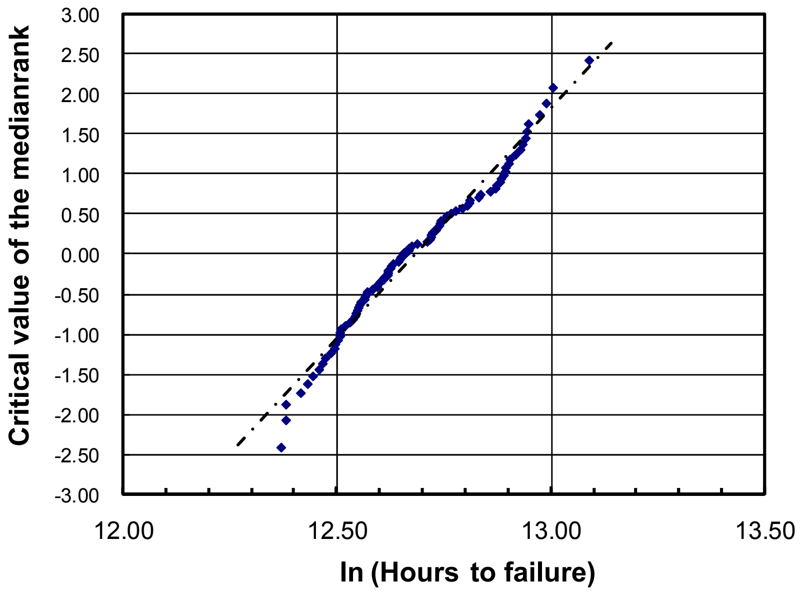

Figure B.2 — Plot of normalized data

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	Min total time	Intermediate RH	Min equilibration duration
	Temp	%RH		hours	hours	%RH	hours
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 ΔH (activation energy per molecule) of Eyring equation.

   Subtract two stress conditions with the same % RH.

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

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

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

$$\ln(Time_{85,85}) - \ln(Time_{65,85}) = [\ln A + \frac{\Delta H}{kT_{85}} + B \times RH_{85}] - [\ln A + \frac{\Delta H}{kT_{65}} + B \times RH_{85}]$$

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

   Solve for ΔH using these example times for the above stress conditions:

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

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

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

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

   Subtract two stress conditions with different Temperature and % RH

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

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

$$\ln(Time_{85,85}) - \ln(Time_{25,50}) = [\ln A + \frac{\Delta H}{kT_{85}} + B \times RH_{85}] - [\ln A + \frac{\Delta H}{kT_{25}} + B \times RH_{50}]$$

Using the example of 500 hours at 85 °C, 85 % RH and solving for 30 years lifetime:

85 °C, 85 % RH $Time_{85,85}$ = 500 h, 25 °C, 50 % RH $Time_{25,50}$ = 262 800 h (30 years = 30×8760)

Solve for *B*

$$\ln(500) - \ln(262{,}800) = [\frac{1{,}0948 \times 10^{-19}}{1{,}3807 \times 10^{-23}} \times (-5{,}6189 \times 10^{-4})] + B \times 35$$

$B = -5{,}169 \times 10^{-2}$

3. Solve for coefficient *A* (pre-exponential time constant) of Eyring equation.

   Solving for *A* after solving for ΔH and *B* ($\Delta H = 1{,}0948 \times 10^{-19}$, $B = -5{,}169 \times 10^{-2}$ using above)

   Eying equation logged:

   Example below using ambient condition of 25 °C, 50 % RH for 30 years

$$\ln(Time_{25,50}) = \ln A + \frac{\Delta H}{kT_{25}} + B \times RH_{50}$$

   Substitute ΔH and B with the calculated values and $Time$ with the selected archival time

   ΔH = $1{,}0948 \times 10^{-19}$

   B = $-5{,}169 \times 10^{-2}$

   $Time$ = 30 years (262 800 h)

   Solve for A, $A = 9{,}828 \times 10^{-6}$.

4. Solve for third stress condition

   Solving time for a third stress condition (example: 85 °C, 70 % RH) that equals 30 years life expectancy at 25 °C, 50 % RH.

   Eying equation logged:

   t = 358,15 Kelvin = 85 °C

   RH = 70 = 70 % Relative Humidity

$$\ln(Time_{85,70}) = -11{,}5303 + \frac{1{,}0948 \times 10^{-19}}{(1{,}3807 \times 10^{-23}) \times (85 + 273{,}15)} + (-5{,}169 \times 10^{-2} \times 70)$$

   Solve for $Time_{85,70}$, $Time_{85,70}$ = 1 086 h

Therefore,

If:

1. Archival time is selected to be 30 years,

2. Disks fail at 500 h at 85 °C, 85 % RH

3. And disks fail at 1 852 h at 65 °C, 85 % RH

Then:

According to the acceleration model, disks must not fail before 1 086 h (at 85 °C, 70 % RH) to have a minimum of 30 years life expectancy at 25 °C, 50 % RH.

The failure time for the third stress condition is dependent on the failure times at the first two stress conditions and the archival years target selected.

Table D.1 — Example using stress conditions of 85 °C, 85 % RH and 65 °C, 85 % RH

		ln(hrs)	Years	~	ln(Hours)	Hours	ln(Hours)	Hours	ln(Hours)	Hours	ln(Hours)	Hours	ln(Hours)	Hours	ln(Hours)	Hours
	100															
	90							actual								actual
	85						7,52	1 852							6,21	500
	80															
	75															target
%RH	70														6,99	1 086
	65															
	60															
	55															
	50	12,48	30,02													
	40															
	30															
		25	25	~	60	60	65	65	70	70	75	75	80	80	85	85

Temperature - Celsius

Annex E
(informative)

Relation between BER and PI Sum 8

The byte error rate BER is the number of erroneous symbols divided by the total number of symbols. Because the length of one code word of the inner code is 182, number of erroneous symbol in one inner code word N_{pi} can be expressed by binomial probability, and it is

$$N_{pi} = \sum_{i=1}^{182} {}_{182}C_i \times BER^i \times (1 - BER)^{182-i} \quad (1)$$

The number of PI errors in 8 ECC blocks N_{pis8} can be expressed by formula (2) because the length of the outer code word is 208.

$$N_{pis8} = 208 \times 8 \times N_{pi} \quad (2)$$

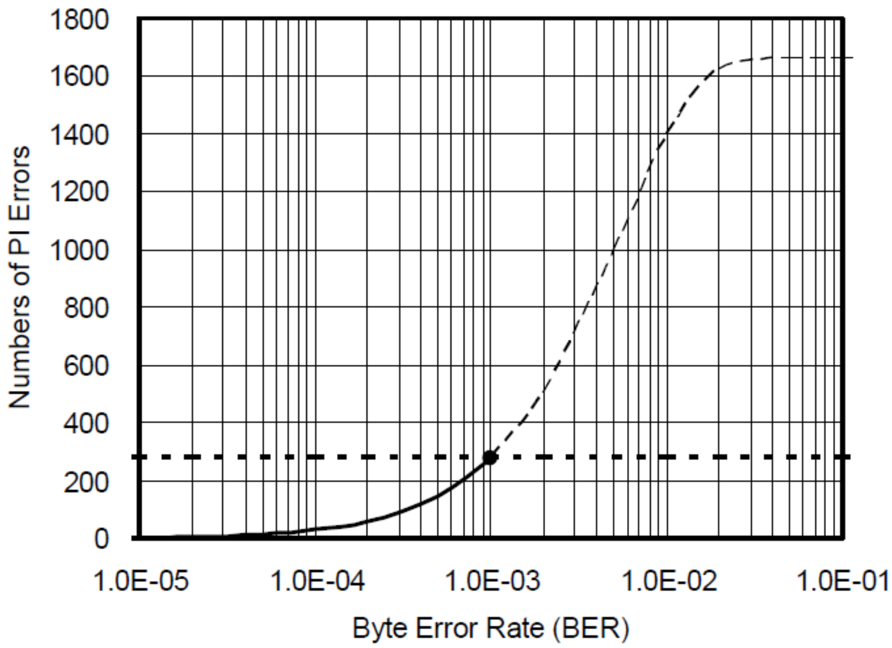

Figure E.1 — Relationship between BER and PI Sum 8

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