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Imaging materials — Compact discs (CD-ROM) — Method for estimating the life expectancy based on the effects of temperature and relative humidity

Matériaux pour l'image — Disques compacts (CD-ROM) — Méthode d'estimation de l'espérance de vie basée sur les effets de la température et de l'humidité relative

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Contents

Page

1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 Purpose and assumptions 3
5 Measurements 3
6 Accelerated stress test plan 4
7 Data evaluation 8
8 Disclaimer 10

Annexes

A Numbering system for related International Standards 11
B Step analysis outline 13
C Example of a test plan and data analysis 14
Bibliography 21

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

International Standard ISO 18921 was prepared by Technical Committee ISO/TC 42, *Photography*.

This International Standard is one of a series of standards dealing with the physical properties and stability of imaging materials. To facilitate identification of these International Standards, they are assigned a number within the block from 18900 – 18999 (see annex A).

Annexes A, B and C of this International Standard are for information only.

Imaging materials — Compact discs (CD-ROM) — Method for estimating the life expectancy based on the effects of temperature and relative humidity

1 Scope

This International Standard specifies a test method for estimating the life expectancy (LE) of information stored on compact disc (CD-ROM) media, including CD audio, but excluding recordable media. Only the effects of temperature and relative humidity on the media are considered.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/IEC 10149:1995, *Information technology — Data interchange on read-only 120 mm optical data disks (CD-ROM)*

IEC 60908:1999, *Audio recording — Compact disc digital audio system*

3 Terms and definitions

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

3.1
$F(t)$
probability that a random unit drawn from the population fails by time t, or the fraction of all units in the population which fails by time t

3.2
$R(t)$
probability that a unit drawn from the population will survive at least time t, or the fraction of units in the population that will survive at least time t

NOTE $R(t) = 1 - F(t)$.

3.3
baseline
condition representing the disc at time of manufacture

NOTE This is customarily the initial parameter measurement taken prior to any application of stress. The designation is usually $t = 0$ for a stress time equal to zero hours.

3.4
block error rate
BLER
ratio of erroneous blocks to total blocks measured at the input of the first (C1) decoder (before any error correction is applied)

NOTE The more commonly reported value for BLER is the number of erroneous blocks per second measured at the input of the C1-decoder during playback at the standard (1×) data rate.

[IEC 60908:1999]

3.5
CD-ROM
compact disc-read only medium

3.6
end-of-life
occurrence of any loss of information

3.7
information
signal or image recorded using the system

3.8
life expectancy
LE
length of time that information is predicted to be retrievable in a system under extended-term storage conditions

3.8.1
standardized life expectancy
SLE
minimum life span, predicted with 95 % confidence, of 95 % of the product stored at a temperature not exceeding 25 °C and a relative humidity (RH) not exceeding 50 % RH

3.9
retrievability
ability to access information as recorded

3.10
stress
experimental variable to which the specimen is exposed for the duration of the test interval

NOTE In this International Standard, the stress variables are confined to temperature and relative humidity.

3.11
system
combination of recording medium, hardware, software and documentation necessary to retrieve information

3.12
test cell
device that controls the stress to which the specimen is exposed

3.13
test pattern
distribution of the characters l and 0 within a block and the block-to-block variation

4 Purpose and assumptions

4.1 Purpose

The purpose of this International Standard is to establish a methodology for estimating the life expectancy of information stored on CD-ROMs. This methodology provides a technically and statistically sound procedure for obtaining and evaluating accelerated test data.

4.2 Assumptions

The validity of the procedure defined by this International Standard relies on three assumptions:

— the dominant failure mechanism acting at the usage condition is the same as at the accelerated conditions;

— the dominant failure mechanism is appropriately modelled by an Eyring acceleration model;

— life expectancy is appropriately modelled by the two parameter Weibull distribution (see [1] in the Bibliography). The shape parameter of the Weibull distribution is assumed to be independent of the stress level.

5 Measurements

5.1 Block error rate (BLER)

The objective of measuring the block error rate (BLER) is to establish a practical estimation of the system's ability to read the pre-recorded bits using a standard drive. This International Standard considers BLER to be a high level estimate of the performance of the system. A change in BLER in response to the time at an elevated temperature and humidity is the principal quality parameter.

The true end-of-life is loss of information. Ideally, each specimen is tested until actual time of failure occurs. Realistically, this is impractical. For the purposes of this International Standard, the maximum ten-second average of the BLER, as specified in ISO/IEC 10149, shall be 220. This is very dependent on the system and its use here is an arbitrary level chosen as a conservative prediction of the onset of unacceptable errors and thereby the end of disc life.

5.2 Test equipment

5.2.1 Compact disc test system

Any compact disc test system (tester) that is in accordance with ISO/IEC 10149 may be used. The make, model and version of the test equipment (including software) shall be reported with the test results.

5.2.2 Calibration and repeatability

Calibration according to the tester manufacturer's procedure shall be performed prior to any measurement data being collected. A calibration disc shall be available from the tester manufacturer.

In addition to the calibration disc, one control disc shall be maintained at ambient conditions and its maximum BLER measured before and after each data collection interval. A control chart shall be maintained for this control disc with $\pm 3\sigma$ action limits. The mean and standard deviation of the control disc shall be established by collecting at least five measurements. Should any individual maximum BLER reading exceed the action limit, the problem shall be corrected and all data collected since the last valid control point shall be remeasured.

If it becomes necessary to replace the tester, a method shall be followed for correlating tester outputs (see [2] in the Bibliography).

5.3 Test specimen

A test specimen is any disc that meets ISO/IEC 10149 specifications and contains representative data extending to within 2 mm of the maximum recording diameter.

6 Accelerated stress test plan

6.1 General

A CD-ROM of good manufacture should last several years or even decades. Consequently, it is necessary to conduct accelerated ageing studies in order to develop a life expectancy estimate. The key is conducting and evaluating a test plan that will provide the information necessary to satisfactorily evaluate the particular product.

Many accelerated life test plans follow a rather traditional approach in sampling, experimentation and data evaluation. These “traditional plans” share the following characteristics:

— the total number of specimens is evenly divided amongst all the accelerated stresses;

— each stress is evaluated at the same time increments;

— the Arrhenius relationship is used as the acceleration model;

— the Least Squares method is used for all regressions;

— the calculated life expectancy is for the mean or median life rather than for the first few failure percentiles.

On the other hand, “optimum test plans” have been proposed which differ in significant aspects from traditional plans. These plans have the following characteristics:

— two and only two acceleration levels for each stress;

— a large number of specimens distributed mostly in the lowest stress levels;

— the need to know the failure distribution, a priori, in order to develop the plan.

The maximum effectiveness of a plan can either be estimated before the test starts or determined after the results have been obtained. As each CD-ROM system has different characteristics, a specific, detailed optimum plan is impossible to forecast.

This test plan borrows from the optimum plan, the traditional plan, previous experience with the systems, test equipment and accelerated test stresses to put together a “compromise test plan”. Modifications of this plan will be required to design the best plan for other applications. The methodology shall be applicable to all CD-ROM media assessments.

6.2 Stress conditions

6.2.1 Levels

As mentioned in 6.1, an optimum test plan utilizes only two stress levels for each parameter evaluated, since in an ideal case the relationship between changes in the parameter investigated and changes in stress is known. The compromise test plan documented in this International Standard does not make such an assumption; therefore, three different stress levels per parameter shall be used so that the linearity of the parameter function versus the stress level may be demonstrated.

The test plan shall have the majority of test specimens placed at the lowest stress condition. This minimizes the estimation error at this condition and results in the best estimate of the degradation rate at a level close to the usage condition. The greater number of specimens at the lower stress also tends to equalize the number of failures observed by test completion.

6.2.2 Conditions

For implementing the test plan documented in this International Standard, five stress conditions shall be used. The minimum distribution of specimens among the stress points that shall be used is shown in Table 1. For improved precision, additional specimens and conditions may be used if desired.

Table 1 — Summary of stress conditions

Test cell number	Test stress T_{inc}/RH_{inc}	Number of specimens	Incubation duration h	Minimum total time h	Intermediate RH RH_{int}	Minimum equilibrium duration h
1	80 °C/85 % RH	10	500	2 000	31 %	6
2	80 °C/70 % RH	10	500	2 000	31 %	8
3	80 °C/55 % RH	15	500	2 000	31 %	4
4	70 °C/85 % RH	15	750	3 000	33 %	8
5	60 °C/85 % RH	30	1 000	4 000	36 %	11

6.2.3 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 level shall not be so high that plastic deformation occurs.

The typical substrate material for CD-ROMs is polycarbonate (glass transition temperature ∼ 150 °C). The glass transition temperature of other layers may be lower. Experience with high temperature testing of CD-ROMs indicates that an upper limit of 80 °C is practical for most applications.

6.2.4 Relative humidity (RH)

Practical experience shows that 85 % RH is the upper limit within most accelerated test cells. This is due to the tendency for condensation to occur on cool sections of the chamber, e.g., observation windows, cable ports, wiper handles, etc. Droplets may become dislodged and entrained in the circulating air within the chamber. If these droplets fall on the test specimen, false error signals could be produced.

6.2.5 Rate of stress change

The process described in this International Standard requires that discs be ramped from the test conditions to stress conditions and back again a number of times during the course of testing. The ramp duration and conditions shall be chosen to allow sufficient equilibration of absorbed substrate moisture.

Large departures from equilibrium conditions may result in the formation of liquid water droplets inside the substrate or at its interface with the reflecting layer. Gradients in the water concentration through the thickness of the substrate shall also be limited. These gradients drive expansion gradients which can cause significant disc deflection.

In order to minimize moisture concentration gradients, the ramp profile specified in Table 2 shall be used. The objects of the profile are:

— to avoid any situation that may cause moisture condensation within the substrate;

— to minimize the time during which substantial moisture gradients exist in the substrate;

— to produce, at the end of the specified profile, a disc that is sufficiently equilibrated to proceed directly to testing without delay.

The profile accomplishes this by varying the moisture content of the disc only at the stress incubation temperature, and allowing sufficient time for equilibration during ramp-down based on the diffusion coefficient of water in polycarbonate.

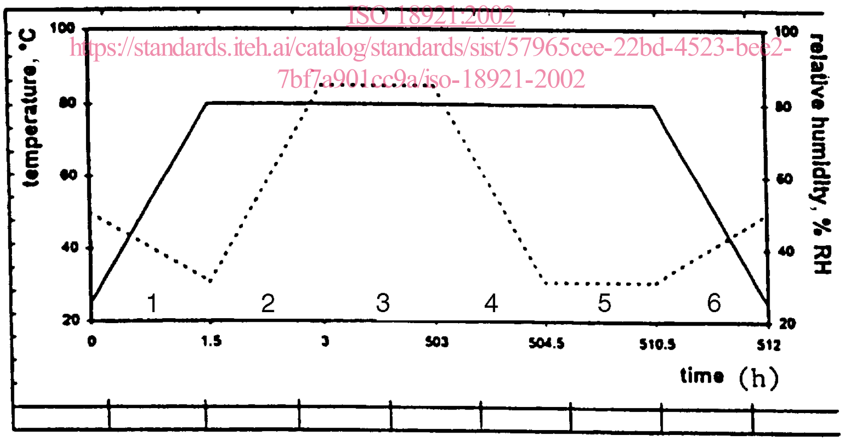
Table 2 — Temperature and relative humidity transition (ramp) profile

Process step	**Temperature** °C	**Relative humidity** % RH	**Duration** h
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 1
RH ramp	at T_{inc}	to RH_{int}	1,5 ± 0,5
Equilibration	at T_{inc}	at RH_{int}	See Table 1
T, RH ramp	to T_{amb}	to RH_{amb}	1,5 ± 0,5
End	at T_{amb}	at RH_{amb}	

NOTE 1 T_{amb} and RH_{amb} are room ambient temperature and relative humidity; T_{inc} and RH_{inc} are the stress incubation temperature and relative humidity; and RH_{int} is the intermediate relative humidity that at T_{inc} supports the same equilibrium moisture absorption in polycarbonate as that supported at T_{amb} and RH_{amb} (see Table 1).

NOTE 2 Transitions should not deviate from a linear change over the chosen duration by more than ± 2 °C and ± 3 % RH. Ramp transitions may be controlled automatically or manually.

Figure 1 graphically portrays the temperature and relative humidity changes that would occur during one cycle of incubation at 80 °C and 85 % RH, as per Tables 1 and 2.



Key

_____	Temperature (T)
....	Relative humidity (RH)
1	T, RH ramp
2	RH ramp
3	Incubation
4	RH ramp
5	Equilibration
6	T, RH ramp

Figure 1 — Graph of nominal 80 °C/85 % RH **transition (ramp) profile**

6.2.6 Independent verification of chamber conditions

A system independent of the chamber control system shall be used to monitor temperature and humidity conditions in the test chamber during the stress test.

6.2.7 Specimen placement

Disc specimens shall be placed uncovered, either vertically or horizontally, within the test chamber. Discs shall be aligned so that their surface is parallel to the chamber airflow, and a space of at least 2 mm shall be maintained between them.

6.2.8 Other influences

During the course of the test, the discs shall be shielded from excessive illumination and potentially corrosive fumes, gases and liquids.

6.3 Accelerated test cell specimen population

In order to estimate the shape and scale parameters of a Weibull distribution, at least ten failures shall be observed. Observing at least ten failures is generally not a problem for a realistic test time at 80 °C/85 % RH, but becomes more difficult at milder stress temperature and relative humidity combinations. Assigning a larger percentage of the specimens at the lower stresses increases the chance of observing the necessary number of failures within a practical time interval.

Specimens that have not failed at the end of the test duration shall be time censored. This is also known as Type I censoring (see [3] in the Bibliography).

To compute the estimated failure time for each disc, it is necessary to first determine a transformation of the maximum BLER, such as $\log_e$ (max. BLER), that results in a linear time dependence. Standard linear regression techniques shall be used to find the best fit to the transformed data. The failure time for each disc shall then be computed by interpolation using each disc's regression equation.

If ten failures are not observed by the end of the test duration, then failures may be estimated by extrapolation using the above technique.

6.4 Time intervals

For a test plan where the “exact time to failure” is to be the result of extrapolated rate data, five time intervals for data collection shall be used for each disc. The baseline measurement (at $t = 0$) is one of these data points. Within a stress condition, the intervals shall be constant.

As the milder stress conditions get lower, the intervals are longer. Longer time intervals provide the opportunity for more failures to occur at the milder stress conditions.

6.5 Test plan

Table 1 specifies the temperatures, relative humidities, number of specimens, time intervals, minimum total test time and specimen distributions for each stress condition. A separate group of specimens is used for each stress. This constitutes a “constant stress” test plan.

All temperatures have an allowed range of $\pm$ 2 °C; all relative humidities have an allowed range of $\pm$ 3 % RH.

The stress conditions tabulated in Table 1 offer sufficient combinations of temperature and relative humidity to satisfy the mathematical requirements of the Eyring model (see 7.1), to demonstrate linearity of either maximum BLER or the $\log_e$ (max. BLER) versus time and to produce a satisfactory confidence level to make meaningful conclusions.