15 mai 2003
Mémo sur la réunion de la Joint Technical Commission ISO I3A WG 5 TG5 Digital Care and Handling of Optical Discs, Washington DC 7 et 8 mai 2003.

Introduction sur la signification du libellé de la Joint Technical Commission

Joint, parce que la commission est conjointe avec l'AES représentée par Ted Sheldon. L'AES publie ses recommandations qui diffèrent parfois en terminologie et présentations.

L' ISO (International Standard Organisation) est l'institution de normalisation, situé à Genève, mondialement reconnue dans le domaine de la permanence des images et de l'information. Les normes sont préparées par divers comités techniques, le comité technique sur la permanence des images est le TC 42. Les membres du TC 42 sont les organisations nationales des différents pays. En France, c'est l'AFNOR. et aux USA l'ANSI. Onze pays sont représentés. Tous les documents sur la permanence dépendent du groupe de travail (working group) WG5 qui est aussi en charge des méthodes de tests sur les propriétés physiques.

A l'origine le comité technique TC 42 avait pour seule responsabilité les normes photographiques, et ce pendant plus de 40 années. Les images ne sont plus obtenues par des procédés photochimiques mais aussi par des moyens électroniques. C'est pourquoi, en 1996, le champ d'action du TC 42 a été étendu aux images électroniques et le WG 5 a entrepris la préparation de standards sur les bandes magnétiques et les disques optiques.

En 1999 une autre décision essentielle a été prise aux USA quant à la promulgation des normes sur la permanence des images. Les groupes de travail concernés ANSI et ISO ont été combinés et les normes ont été alors publiées en tant que documents ISO. Ceci a permis de supprimer le processus interminable de publication ANSI avant de passer en publication ISO, valable pour le Monde entier. Pour faciliter l'identification des documents toutes les normes ISO ont la nouvelle désignation ISO 189xx, les deux derniers chiffres étant identiques à l'équivalent ANSI. 29 publications ANSI ont ainsi été converties en numérotation ISO dont 18 appartiennent au domaine de la permanence. Ce processus a demandé plusieurs années pour être achevé.

I3A : International Imaging Industry Association qui assure le secretariat du TC 42.

Rappel historique :

Ma participation à la Joint Technical Commission a commencée au cours de la Conférence AMIA (Association of Moving Image Archivists) les **12 et 13 novembre 2000 à Los Angeles, CA**

Travail sur le document en cours d'établissement "Care and handling of magnetic tapes".
Etaient présents :
Peter Adelstein (meeting chair), Richard Billeaud, David Boden, Peter Brothers, Gilbert Comeault, Ian Gilmour, Allan Goodrich, Jean-Pierre Lachapelle, Mike Newnham, Ted Sheldon, Heather Weaver, Jim Wheeler et Ed Zwaneveld

Deuxième participation : **31 mai et 1er juin 2001 à Library of Congress, Washington, DC**
Etaient présents :
Peter Adelstein, Richard Billeaud, Peter Brothers, Gerd Cyrener (EMTEC), Gerald Gibson, Allan Goodrich, Peter Roth, Ted Sheldon, Xiao Tang (NIST), Jim Wheeler, and Ed Zwaneveld
Voir la liste des membres en annexe 1
Travail sur :
- Care and Handling of Magnetic Tape
- Rank Rating of Magnetic Tape for Longevity : travail proposé par Jim Wheeler (à partir des tests Ampex sur la stabilité des images fixes, et Ian Gilmour, à partir de tests faits par SSA).
- projet sur les disques optiques

Troisième participation : **4 et 5 novembre 2001, Portland, Oregon**
Présents :
Peter Adelstein, Richard Billeaud, Peter Brothers, Ian Gilmour, Allan Goodrich, Jim Lindner, Mick Newnham, Ted Sheldon, Ollie Slattery, Jim Wheeler, and Ed Zwaneveld.
Sous groupe sur disques optiques (Ed Zwaneveld) : des documents seront transmis au groupe par Peter Adelstein pour commentaires. Mais la question reste posée de savoir si ce document pourra être utilisé et produit par le JTC. (voir **annexe 2**)

Quatrième participation : **17 et 18 novembre 2002, à Boston, MA**
Présents : Peter Adelstein, Richard Billeaud, Peter Brothers, Fred Byers, Ian Gilmour, Alan Goodrich, Mick Newnham, Ted Sheldon and Jim Wheeler
Changement de nom : cette commission ne dépend plus de IT9-5, le Comité Directeur de I3A ayant décidé que les sous comités IT9 deviennent des task groups de ISO WG-5.
Travaux futurs :
- document sur les disques magnétiques : Handling of optical and magnetic discs
- autre travail : répertorier par ordre de qualité les bandes magnétiques indépendamment du format
Il s'agit là de mettre en place des procédures de tests.

Ian Gilmour travaille, lui, sur "test method for comparing life expectancy of magnetic tapes".
Il semble beaucoup s'inspirer des travaux de Léopold Kranner décrits dans le JTS.

NIST (National Institute for Science and Technology) est en cours de réalisation de tests sur les disques optiques – à suivre.

Cinquième participation : **7 et 8 mai 2003, à National Archives of America Records (NARA), Washington DC**
Présents : Peter Adelstein, Richard Billeaud, Peter Brothers, Fred Byers (NIST), Alan Goodrich, Vivek Navale (NARA), Ted Sheldon, Don Weiss et Jim Wheeler

Etude du projet de rédaction : Care and Handling of Optical Discs. Voir **annexe 3**. Et le projet NIST de Fred Byers sur diskette jointe. **NOTA BENE : tous les documents joints sont confidentiels et doivent être limités à un usage interne.**

En conclusion : conformément à la demande de Pierre-William Glenn j'ai fait part de l'intérêt manifesté par la CST à participer aux travaux de la commission.
Résumé des travaux en cours ou en projets :
- document préparatoire sur l'effet de la lumière sur les CD-Rs
- normalisation des disques durs externes (magnetic disk drives), notamment en ce qui concerne la pression des têtes et la démagnétisation sur les disques haute densité.
- document préparatoire sur des recommandations de détermination de la qualité respective des bandes magnétiques (notamment quant à la stabilité du liant)
- rapport sur les recherches concernant l'effet de la congélation sur les bandes magnétiques
- document préparatoire sur "Care and Handling of Optical Discs

Certains tests et travaux de recherche et vérification pourraient être menés par la CST en liaison avec Jean-Marc Fontaine (CNRS-LAM) et le NIST. Notamment sur la définition de méthodes pour vérifier la stabilité des disques optiques et sur la sensibilité des disques optiques à la lumière, et éventuellement, sous forme de propositions, des procédures de tests pour déterminer la qualité des bandes magnétiques.

En dehors de cette participation à la commission ISO, la CST pourrait collaborer aux travaux menés par le NIST sur le cinéma numérique pour l'établissement de recommandations dans ce domaine (les informations en provenance de Hollywood étant loin d'être satisfaisantes !
La prochaine réunion de travail de la Joint Technical Commission est prévue mi-novembre à Vancouver.

Il convient donc d'étudier et discuter de ce que la CST, à la fois par ses services permanents et par la participation de ses membres et groupes de travail, peut et est prête à faire avant cette date afin que des propositions concrètes soient envoyées pour être jointes à l'ordre du jour.

En ce qui concerne NIST, les contacts peuvent être pris directement avec Xiao Tang et Charles Fenimore.

Richard Billeaud – Mai 2003.

Annexe 1
Liste du JTCAES SC-03/ANSI-PIMA IT9-5 June 2001

Dr. Peter Adelstein
Image Permanence Institute
Rochester Institute of Technology
70 Lomb Memorial Dr.
Rochester, NY 14623-5604
(tel) 716-475-2303
(fax) 716-475-7230
pzapph@rit.edu

Kevin Bradley
Sound Preservation & Technical Services
National Library of Australia
Canberra ACT 2600
AUSTRALIA
(tel))06) 262-1655
(fax) (06) 257-1703
kbradley@nla.gov.au

Peter Brothers
Specs Bros
P.O. Box 5
Ridgefield Park, NJ 07660
(tel) 201-440-6589
(fax) 201-440-6588
peter@specsbros.com

Katherine Cochrane
7960B Soquel Dr.
Ste 296
Aptos, CA 95003
(tel) 831-818-0826
(fax) 831-401-2361
katherine@cd-info.com

Gilbert L. Comeault
Provincial Archives of Manitoba
200 Vaughan St.
Winnipeg, MB
R3L 1J1 Canada
(tel) 204-945-1269
(fax) 204-942-2672
gcomeault@ga.mb.ca

Michael Cunningham
Eastman Kodak Company
460 Buffalo Rd.
Rochester, NY 14652-3836
(tel) 716-477-6171
(fax) 716-588-2624
michael.cunningham@kodak.com

Gerd Cyrener
Emtec Magnetics GmbH
Application Engineering MA
Kaiser-Wilhelm - Str. 52
D-67059 Ludwigshafen
Germany
(tel) 49-(0)621-5920-383
(fax) 49-(0)621-5920-375
Gerd.Cyrener@Emtec-Magnetics.com

Del Eilers
daeilers@aol.com

Jean-Marc Fontaine
Biblioteque nationale de France
Universite Paris 6 - CNRS
Laboratoire d’Acoustique Musicale
4, place Jussieu
75252 Paris Cedex 05 - France
(tel) 33-1-44 27 75 95
(fax) 33-1-44 27 75 29
jmfontai@ccr.jussieu.fr

Lars Gaustad
National Library of Norway - Rana
Head of FilmSoundVideo Lab
mail Postbox 278
8600 MO
NORWAY
(tel) (47.751) 21154
(fax) (47.751) 21222
business Langueset 29
8600 MO NORWAY
lars.gaustad@nb.no

Gerald Gibson
118 Monroe St. #410
Rockville, MD 20850
(tel) 301-762-7234
ggib@msn.com

John Gignac
Photographic & Imaging Manufacturers Association
550 Mamaronock Ave.
Harrison, NY 10528
natlstds@pima.net

(fax) 310-392-2188
Cheryl@grammy.com

Ian Gilmour
National Film and Sound Archives
G.P.O. Box 2002
Camberra, A.C.T. 2601
Australia
(tel) 61-6-267-1711
(fax) 61-6-247-4651
ian_gilmour@screensound.gov.au

Allan Goodrich
JFK Library
Columbia Pt.
Boston, MA 02125
allan.goodrich@kennedy.nara.gov

James Hoagland
Tech. Dir. Shambhala Archives
1084 Tower Rd.
Halifax Nova Scotia
Canada B3H 2Y5
(tel) 902-425-4275 ext. 22
(fax) 902-423-2750
jhoagland@shambhala.org

Fredrick Kolb, Jr.
211 Oakridge Dr.
Rochester, NY 14617
Fred Layn
954 Hawthrone Dr.
Walnut Creek, CA 94596-6115
(tel) 925-945-8072
(fax) 925-930-7668
fredlayn@pacbell.net

Jim Lindner
Vidipax Inc.
450 W. 31st Street, 4th Floor
New York, NY 10001
(tel) 212-563-1999 x102
(fax) 212-563-1994
Vidipax@Panix.com

Cheryl Mollicone
National Academy of Recording Arts & Sciences
3402 Pico Boulevard
Santa Monica, CA 90405
(tel) 310-392- 3777

Bill Murray
507 Marnie St.
Maplewood, MN 55119
(tel) 612-514-1905
wpmurray@worldnet.att.net

Daniel Queen
Daniel Queen Associates
239 W. 23rd St.
New York, NY 10011
(fax) 212-645-5436
standards@aes.org

Dietrich Schuller
Phonographarchiv, IASA TC
Liebiggaße 5
A-1010 Wien (Vienna)
Osterreich (Austria)
(tel) 43.1 40103-2734
(fax) (43.1) 4030465
pha@oeaw.ac.at

Ted Sheldon
University of Missouri - Kansas City
Miller Nichols Library
5100 Rockhill Road
Kansas City, MO 64110-2499
(tel) 816-235-1531
(fax) 816-333-5584
sheldont@umkc.edu

Susan Stinson
Belfer Audio Archive
Syracuse University
222 Waverly Ave.
Syracuse, NY 13244-2010
(tel) 315-443-3477
(fax) 315-443-9510
ststinso@library.syr.edu

Carl Talkington
IBM - Boulder CO
Dept. EBG
6300 Diagonal Hwy.
Boulder, CO 80301
(tel) 303-924-6144
(fax) 303-924-7438
Carlt@us.ibm.com

Xiao Tang
NIST
100 Bureau Drive, Stop 8951
Gaithersburg, MD 20899-8951
(tel) 301-975-2503
(fax) 301-869-7429
xiao.tang@nist.gov

Bob Waelbroeck
Digital Audio Disc Corporation
1800 N. Fruitridge Avenue
Terre Haute, IN 47804
(tel) 812-462-8107
(fax) 812-462-8760
rwaelbro@disc.sony.com

Johanna Wellheiser
Metropolitan Toronto Reference Library
789 Yonge St.
Toronto, Ontario
M4W 2G8, CANADA
(tel) 416-393-7000
(fax) 416-393-7229
jwellheiser@tpl.toronto.on.ca

Jim Wheeler
Tape Archival and Restoration Service
1732 Tierra Nueva
Oceana, CA 93445
(tel) 805-489-8737
(fax) 805-489-8747
jimwheeler@aol.com

Mark Worthington
Optical Disc Technologies
13841 Tustin East, Suite 183
Tustin, CA 92780
(tel) 714-319-7339
flurpo@ix.netcom.com

Joe Wrobel
Eastman Kodak Company
460 Buffalo Road
Rochester, NY 14652-3836
(tel) 716-477-3320
(fax) 716-588-2624
joseph.wrobel@kodak.com

Ed Zwaneveld
National Film Board of Canada
3155, cote de Liesse Rd.
Saint Laurent, Quebec
H4N 2N4, Canada
(tel) 514-283-9143
(fax) 514-283-0278
e.ha.zwaneveld@nfb.ca

ANNEXE 2

ISO TC 171/SC 1N 120
Date: 2002-01-14 Vsn. 9

ISO/WD

Electronic imaging – Verification of information stored on CD media

Contents

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.

International Standard ISO was prepared by Technical Committee ISO/TC 171, *Document imaging applications*, Subcommittee SC 1, *Quality*.

Annex A, B, and C are for information only.

Introduction

Many organizations now use compact disks (CDs) for long-term storage of information. It is assumed that a disk selected for recording, has already been qualified for that purpose. It is therefore important to be able to verify that data has been recorded correctly and remains readable for the required amount of time. Previous ISO Standards clearly defined requirements for interchange, but did not contain requirements for longevity.

Longevity is limited both by media degradation and by technology obsolescence. Interchange must be regularly verified to assure that information on existing recorded media will continue to be recoverable. Users may have a maintenance policy that protects disks against unanticipated failure or use, such as by making one archival copy, another to function as a backup or master, and another for routine access. Hardware support life cycles typically vary between 5 to 10 years and technology lifecycles usually end after 20 years. Consequently, recordings that require a longer lifecycle may have to be transferred to upgraded platforms every 10-20 years.

Disks for long-term storage should be evaluated. Significant longevity differences may exist for disks from different manufacturers and also between disks from the same manufacturer. Degradation may be more severe for disks of very poor initial quality than for high quality recordings. This means that a disk of high initial recorded quality is expected to have superior longevity.

Powerful CIRC error correction systems (see Annex B) that are embedded in the disk and utilized by the drive can mask degradation. In the absence of drive standards, functionality does not allow the user to verify, in a simple manner, the quality of information recorded on a particular compact disk. Methods described in this standard define a quality control policy that can non-destructively identify degradation, and thereby support timely and effective corrective action.

Electronic imaging – Verification of information stored on CD media

1 Scope

This international standard provides specifications which allow users of storage systems that use compact disks for information storage to establish and verify longevity levels for individual compact disks.

This international standard is not applicable to CD-RW disks, to DVD disks, or to disks with analogue recorded information, such as CD-video disks.

2 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this International Standard. At the time of the publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on the International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO 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).
ISO 9660:1988, Information processing – Volume and file structure of CD-ROM for information interchange.
IEC 908:1987, Compact disc digital audio system.
ISO 12651:1999, Electronic imaging – Vocabulary.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 12651 and the following apply:

3.1 Block error rate (BLER): The rate of frames at the input of the C1-decoder after the 1-byte delay section, each containing, one or more erroneous bytes, representing the frame error rate multiplied by the frame rate (7 350 per second at a 1X test speed.) A BLER value of 220 at 1X test speed corresponds to a frame error rate of $3x\ 10^{-2}$.

3.2 BURST: One BURST error consists of seven or more successive frames at the input of the C1-decoder after the 1-byte delay section, each containing two or more successive erroneous bytes. Test equipment may additionally determine the actual burst error length, or BERL.

3.3 CD-R dye fading: Degradation by exposure to light irradiation of materials that contain strong
pigmenting power forming dyes in a CD-R disk recording layer. The dye provides a greater or lesser degree of light fastness and chemical stability, but when stressed allows fading as it degrades. It can be a factor when the entrance surface of a disk is exposed to direct light over a long period of time.

3.4 Compact disk (CD): An optical disk used for storage of digital information according to Standards referenced in 2.

3.5 Compact disk read-only memory (CD-ROM): A compact disk conforming to ISO/IEC 10149.

3.6 Compact disk recordable (CD-R): A Write once read many compact disk (WORM).

3.7 E22: Occurrence of one frame at the input of the C2 decoder containing two correctable erroneous bytes.

3.8 E32: Occurrence of one frame at the input of the C2 decoder containing more than two uncorrectable erroneous bytes.

3.9 End-of life (EOL): Loss of interchange whereby information cannot be reliably retrieved.

3.10 Erroneous byte: An 8-bit byte of unknown location containing one or more erroneous bits.

3.11 Frame error rate: Probability that a frame at the input of the C1-decoder after the 1-byte delay section contains one or more erroneous bytes.

3.12 Insulated records container*:* A storage box designed to withstand elevated or reduced temperatures. It provides an environmental buffer against temperature and humidity fluctuations and reduces stress on the CD disk structure.

3.13 Interchange and longevity: Disk content integrity is determined by 1) the ability to interchange the disk recording between different players; 2) longevity or robustness of the disk against media and signal deterioration, and the obsolescence of the technology required to decode and play it back; 3) the ability of the user to transfer disk content in time, before the error correction system no longer protects signal integrity.

3.14 Jitter: Encoded digital data is represented by nine different predetermined time intervals in the read signal. Jitter and effect length requirements assure that the tolerances relating to these time intervals are sufficient for interchange. Effect length measures statistical averages of eighteen different time interval distributions, nine for pits or marks and nine for lands, while jitter represents one standard deviation of each distribution.

4 Test methods

4.1 Calibration

Devices used for signal quality verification shall be calibrated to the Philips Test Signal Disc 5B, and shall consistently correlate with all tracks of Philips Multi-Point Calibration CD Discs RCD BH.1 (predefined BLER, HF measurement disc) and RCD JT.1 (predefined jitter and effect length disc.)

4.2 Test data

Devices used for signal quality verification shall, as a minimum, be able to provide the following data in a form that can be utilized to produce a permanent record:

a) Either frame error rate or BLER, utilizing one second averaging indicating the maximum level on the disk.

b) E22 errors indicating the total number on the disk.

c) E32 errors indicating the total number on the disk.

d) BURST errors indicating the total number on the disk.

e) Jitter indicating the maximum level on the disk.

4.3 Indicators of CD aging

There is no single end-of-life indicator common to all disk types. BLER or jitter may be poor indicators, showing acceptable results for disks that fail other important quality requirements. The reason is that BLER and jitter do not distinguish between easily correctable errors and severe, localized uncorrectable errors. The onset of E22, E32, or BURST errors clearly indicates end-of-life, and are essential quality indicators. Accompanying BLER and jitter data can usefully identify degradation before uncorrectable errors occur.

4.4 Procedure

Prior to conducting tests, visually examine the disk to determine whether it contains dust, finger prints, or other contaminants. If appropriate, remove such contaminants in accordance with the media manufacturer's recommendations. Certain options are contained in Annex A. Microscopic examination may reveal physical deterioration such as delamination.

Insert the CD into the test equipment, then obtain (with reference to the system's instruction manual) and permanently record the following information for the entire information area of the disk:

either maximum frame error rate or BLER utilizing one second averaging, total number of E22, E32, and BURST errors, and maximum jitter.

5 Error classification

CD disks shall be categorized into 5 classes as shown in table 1, dependent upon the results of the tests performed according to 4.

Table 1 — Error classification

CD Class	Frame error rate	E22 (total)	E32 (total)	BURST (total)	Jitter (ns)	Note
1	$< 7 \times 10^{-3}$	0	0	0	< 30	1
2	$< 7 \times 10^{-3}$	0	0	0	< 33	2
3	$< 3 \times 10^{-2}$	1-5	0	0	< 35	3
4	$> 3 \times 10^{-2}$	> 5	0	> 0	> 35	4
5			1			5

The following characteristics define the life expectancy of information recorded on CD media in decreasing order from class 1 to class 5.

Note 1: Class 1 is intended for long-term data storage (>3 years) of CD-ROM disks.

Note 2: Class 2 is intended for long-term data storage (>3 years) of CD–R disks and allows slightly higher jitter.

Note 3: Class 3 CDs are usable but present risks for long-term data storage (>3 years). They are characterized by the presence of one to five E22 errors, or by frame error rate values between 7×10^{-3} and 3×10^{-2}, or by Jitter values between 33 and 35 ns. It is therefore recommended to only use them for short or medium-term data storage (<3 years).

Note 4: Class 4 CDs should not be used for medium or long-term data storage applications. It is generally preferable to reject them. They are characterized by more than five E22 errors, or by violation of one or more of the BLER, Jitter, or BURST limits.

Note 5: Class 5 CD's shall be rejected. They are characterized by the presence of one or more E32 errors.

Disks that do not meet class 1 or class 2 requirements present potential risks for long term preservation of data stored on them. Information on class 3, class 4, or class 5 disks should be transferred to a replacement disk, either by copying or by the use of relevant back-up media. The replacement disc should be evaluated to assure conformance to class 1 or class 2 requirements.

6 Test frequency

Disk structure, initial quality, frequency and conditions of use, handling and storage conditions, and user confidence based upon experience all determine the testing frequency that is required to confirm longevity.

Disks having characteristics well with within those of class 1 or class 2 that are stored under conditions described in Annex A, are carefully handled, and are read infrequently may require testing only every few years. A history of satisfactory longevity with similar disks would encourage longer intervals between testing.

Disks that are frequently accessed and handled under marginal environmental conditions may require validation every few months. Disks containing information of critical importance, without backup, should be tested more frequently. The occurrence of readability problems or long read times indicate a need for immediate testing.

When tests indicate deterioration of one disk, additional tests should be performed on other CDs of the same type, age, or lot to ascertain their condition. Replacement of all similarly affected CDs should be considered if such additional tests indicate significant problems.

7 Prevention of deterioration

Necessary precautions shall be taken to reduce the possibility of deterioration, in order to assure the integrity of the disks during their use, storage, handling, or transportation. Causes of deterioration and their effects are noted in Annex C. For long-term storage, the recommendations in Annex A should be implemented.

Disks intended for long-term storage should not be left in readers, nor remain exposed to light, dust, or to extremes of temperature or humidity. Where required, CDs used for long-term preservation should have a proven long-term durability (longevity) or long life expectancy when purchased as well as when newly recorded.

Annex A

(informative)

Recommendations on handling, storage, and cleaning conditions

A.1 Handling

The fragile protective coating on the label surface is vulnerable to damage and must be protected together with the readout surface. Carefully handle the disk, touching only the outer edge and inner hole. Never touch either the label or readout surface.

Disks must be protected from dust and debris. This is especially important for CD-R disks during the recording process. The use of a deionizing environment is recommended to neutralize static charges on the disk that can attract and retain loose contaminants.

A.2 Storage

For long-term dark storage it is recommended to limit the storage environment to the ranges given in table A.2

Table. A.2 – Recommended dark storage ranges

Ambient Condition	Recommended Range
Temperature	+5º C to 20º C (+10º C optimum)
Relative humidity	30% to 50%
Wet bulb temperature	29ºC
Atmospheric pressure	75 kPa to 105 kPa
Temperature gradient	4ºC per hour maximum
Relative humidity gradient	10% per hour maximum

To maintain the desirable temperature and humidity fluctuation tolerance levels, and to protect against high intensity light and pollutants, archival storage of CD media in clean insulated records containers is suggested. Dust or debris in operational or storage locations should be minimized by appropriate maintenance and monitoring procedures, especially when recording CD-R disks.

A.3 Cleaning

Prior to performing cleaning operations of CDs containing useful data, tests should be carried out on CDs of the same type and from the same supplier that do not contain any useful data, in order to ensure that no adverse reaction will occur.

Loose contaminants may be removed by short, one second bursts of clean, dry air, avoiding expulsion of cold propellants. If the manufacturer has not supplied any cleaning information, organic polymer substrate CDs can be cleaned using a lint-free cloth of a non-woven fabric and either clean or soapy water. Do not use detergents or solvents such as alcohol. All wiping actions should be in a radial direction, taking care not to exert isolated pressure or to scratch the disks. Never use abrasives. Do not use acrylic liquids, waxes, or other coatings on either surface.

Annex B

(informative)

Error correction – Definitions

B.1 General

Read error detection and correction for all compact disks is carried out by a Cross Interleaved Reed-Solomon Code (CIRC) system consisting of three delay sections and two decoders (C1 and C2).

B.2 C1 error correction

After digitization of the read signal, removal of merging bits and frame sync, and EFM demodulation, read data is initially contained in an F3 frame. Subcode is removed, resulting in an F2 frame. All parity bytes are then inverted, and then alternate bytes are delayed by one frame time. The resulting C1 word forms the input to the C1 error correction decoder.

The C1 decoder utilizes four P parity bytes of a (32,28) Reed-Solomon code to detect and correct up to two erroneous bytes in each 32 byte C1 word.

B.3 C2 error correction

After removal of four P parity bytes, the 28 byte output of the C1 decoder enters another delay section consisting of a series of 28 different delays over 108 frames. Each byte is delayed by a different number of frames beginning with zero and increasing by an integer multiple of four for each successive byte. The resulting C2 word forms the input to the C2 error correction decoder.

The C2 decoder utilizes four Q parity bytes of a (28,24) Reed-Solomon code to detect and correct up to two erroneous bytes in each 28 byte C2 word.

After removal of four Q parity bytes, the 24 byte output of the C2 decoder undergoes additional delay and descrambling that is not related to read error detection and correction, and the output bytes are transferred to the host. Certain data sector structures may then apply additional Reed-Solomon Product Code (RSPC) error correction to this information.

B.4 Measures of quality

Although errors resulting from defects as large as 1 mm can be detected and corrected, a small probability of misdetection or miscorrection is present. Very low error rates provide confidence in data integrity by assuring that such a probability is very small. In addition, soft errors may occur when defects adversely affect the servomechanism of a read drive. In the absence of drive standards, the number and severity of soft errors may vary from drive to drive. Longevity can be achieved only by maintaining disk quality levels such that readability does not rely upon the full capabilities of the CIRC system. The following measures of quality are used for that purpose.

B.5 C1 measures

Block error rate (BLER) measures the probability that one frame at the input to the C1 decoder contains one or more erroneous bytes. BLER does not evaluate the level of correctability of such erroneous bytes.

E11 measures the probability that one frame at the input to the C1 decoder contains exactly one erroneous byte that can easily be corrected by the C1 decoder. Such errors introduce negligible risk to interchange and longevity.

E21 measures the probability that one frame at the input to the C1 decoder contains exactly two erroneous bytes that can be corrected by the C1 decoder. Such errors introduce minimal risk to interchange and longevity.

E31 measures the probability that one frame at the input to the C1 decoder contains more than two erroneous bytes which cannot be corrected by the C1 decoder. Very limited numbers of such errors are acceptable.

Burst error length measures the number of successive frames at the input to the C1 decoder, each containing two or more successive erroneous bytes. BURST measures the probability that burst error length exceeds six frames.

B.6 C2 measures

E12 measures the probability that one frame at the input to the C2 decoder contains exactly one erroneous byte which can easily be corrected by the C2 decoder. Limited numbers of such errors are acceptable.

E22 measures the probability that one frame at the input to the C2 decoder contains exactly two erroneous bytes which can be corrected by the C2 decoder. Such frames are of marginal quality, and may become E32 errors after additional degradation. If these are E22 soft errors, the associated flaw may result in E32 errors in a different read drive. E22 errors are not acceptable.

E32 measures the probability that one frame at the input to the C2 decoder contains more than two erroneous bytes which cannot be corrected by the C2 decoder. Uncorrectable errors are not allowed by CD standards.

B.7 Other measures

Certain advanced error correction decoding hardware may utilize a feedforward method that enhances the error correction capability of CIRC. This is accomplished by attaching an identifying flag to data bytes at the C1 level. Such bytes are defined as erasure bytes. The C1 decoder may flag corrected bytes, enabling the C2 decoder to confirm the absence of a misdetect or miscorrect. The C1 decoder may flag all bytes in one C1 word containing uncorrectable erroneous bytes, and the C2 decoder can then correct up to four erasure bytes in one C2 word since detection is not required. Alternatively, the C2 decoder can then detect and correct one erroneous byte in addition to correction of two erasure bytes in one C2 word.

Such hardware may or may not exist in commercial read drives. Users are normally unable to verify its presence, and measures of longevity should never assume the presence advanced error correction decoding hardware. Testers utilizing such hardware may report E42 errors in addition to those described above.

Annex C

(informative)

Causes of deterioration

C.1 Deterioration

Both unrecorded CD-R and recorded compact disks can deteriorate over the course of time. The level of deterioration depends upon such factors as disk design, inherent stability of the materials used for the disk structure, manufacturing quality assurance/control standards, initial quality, time in storage and conditions of storage, and maintenance and handling conditions.

C.2 Disk structure

Recorded data is contained in an information layer utilizing physical data spacings and track dimensions that are comparable to one wavelength of light. A label surface is proximate to the delicate information layer. Information is optically accessed through an entrance, or readout, surface that is separated from the information layer by 1,2 mm of organic polymer substrate.

CD-ROM disks utilize a molded organic polymer substrate containing the information layer, over which a reflective metal layer is applied, over which a thin organic protective layer is coated to form the label surface.

CD-R disks utilize a molded organic polymer substrate containing a pregroove, over which an organic dye layer is coated into which information can be recorded, over which a reflective metal layer is applied, over which a thin organic protective layer is coated to form the label surface.

C.3 Causes of deterioration

External agents can modify one or more of the disk layers, or can affect bonds between layers. Primary causes of deterioration are often improper handling that results in scratches or contamination of either surface. Degradation can be induced by environmental agents such as exposure to corrosive atmospheres, extremes of temperature or humidity, excessive ultraviolet-, visible-, infrared light, or nuclear radiation, organic solvents, oils from fingerprints, and liquid water. Mechanical stresses, either internal stress generated during manufacture or from external applied forces, including rapid changes in temperature or humidity, can degrade disks. Label adhesives or inks can adversely affect disks.

Deterioration can also involve internal flaws, including impurities or defects in the various layers of the disk. Incomplete or weak bonding of the layers can also limit longevity.

C.4 Nature of deterioration

Internal chemical reactions can induce defects or can cause the growth of existing defects. Molecular breakdown or crystallization of one or more organic components may occur. The reflective metal layer can corrode. Mechanical stress can result in increased birefringence, warp, tilt, or delamination. Dyes are subject to fading and should be protected from direct light exposure during storage.

C.5 Effects of deterioration

Loss of disk interchange can result from either hard errors or soft errors. Hard errors result from unreadable portions of the information layer and are reproducible. Soft errors result from disturbances to the read drive servo mechanisms that indirectly cause read errors. Soft errors may not be reproducible, and are often dependent upon the particular read drive. Both hard and soft errors can result from timing, amplitude, and dimensional effects.

Timing errors in the analogue read signal directly result in bit errors in the digitized data stream.

Low amplitude analogue read signals, and the resulting poor HF signal-to-noise ratios, cause an increase in bit errors in the digitized data stream. Errors also result from loss of amplitude of the low frequency servomechanism signals, resulting in improper radial tracking, focus, or spindle speed, indirectly causing errors both during the period of low amplitude and also during the servomechanism recovery time following restoration of the normal analogue read signal.

Dimensional changes caused by mechanical deformation may exceed the dynamic range of drive servomechanisms, or may degrade spot geometries with accompanying high crosstalk or intersymbol interference.

ANNEXE 3
Care and Handling of Optical Discs
Version 4: April 24, 2003
General Editor: T. Sheldon

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1 Introduction: Use, advantages, disadvantages (Alt.: Nature and design of discs)

Probably no form of data storage has been accepted and adopted as rapidly as the optical disc. It has become the media of choice for numerous applications with ever increasing use for the recording and storage of information. The advantages are many. Information is recorded in digital format which not only provides high storage density but allows duplication without information loss, ease of data manipulation and facilitates transmission. It is of tremendous benefit for audio usage since it permits uninterrupted playback for long periods of time and is more resistant to surface imperfections than vinyl records. Records in a disc format can be accessed very quickly, unlike those in a roll format such as magnetic tape which requires rewind time.

While the advantages are many, as with other media, there are nevertheless concerns about the life expectancy of recorded information on optical discs. This depends upon three independent components, namely the permanence of the disc itself, the disc drive and the software. Obsolescence of the disc drive and software, lack of playback device or inoperability of the playback device are all serious uncertainties. Their finite life is well recognized and one approach to this problem is periodic transferring or reformatting the information. The ability to play back a disc in the future depends on the existence of functional playback equipment. As new formats become popular, equipment manufacturers discontinue the production and support of older, superseded equipment. Eventually, usable equipment to play older obsolete optical disc formats becomes impossible to find. Before this occurs a migration plan should be in place. However, these issues are outside the scope of this standard. This document is only concerned with the stability of the optical disc itself. A primary objective of those involved with the preservation of information on this media is that the disc should not be the weak link among the necessary components. To eliminate this factor, the optical disc should be more stable than either the hardware or the software.

As with paper records, photographic film and magnetic tape, optical discs are subject to both damage and decay. They have a finite life. Predictions of the life expectancy of optical discs have involved extrapolations of property retention after high temperature and humidity incubations to practical conditions. These extrapolations follow mathematical treatments that were developed for simpler chemical reactions and therefore the results must be interpreted with some caution. These predictions cover a very wide range, from 25 to over 250 years and vary with the disc type and the manufacturer. Their effective life can be increased or decreased significantly depending upon the conditions under which they are stored. Storage recommendations for optical discs are given in ISO 18925. Followings these recommendations promotes the physical integrity of the media and increases their effective life.

In addition to the storage conditions, proper care and handling of optical discs are also vital to prolong disc life. This is becoming increasingly more important as optical discs are becoming the media of choice for the recording and storage of information. This standard gives guidelines for their recommended care and handling and will be beneficial for all optical discs, regardless of their inherent stability.

2 Scope (Alt.: same)

This standard concerns the care and handling of optical discs during use. It addresses the issues of physical integrity of the medium necessary to preserve access to the recorded data (information). Included are recommendations for handling procedures to maximize the effective life of optical discs. Faulty handling, packing and transporting techniques and methods often cause physical damage to the discs and to the content recorded thereon. Extending the longevity of optical discs requires the identification of appropriate handling methods and well-developed training programs.

While some of the recommendations in this standard, such as staff training, apply specifically to large-scale or archival usage, the basics of all recommendations in this document can and should be applied in circumstances where the desired result is long-term usage of the medium whether archival, commercial or personal. This standard is not aimed at casual home users of CD or DVD discs.

This standard addresses the following subjects:

a) use and handling environments, including pollutants, temperature and humidity, light exposure and magnetic fields;
b) contamination concerns;
c) inspection;
d) cleaning and maintenance, including cleaning methods and frequency;

e) transportation;
f) disasters, including water, fire, construction and post-disaster procedures;
g) staff training.

3 Normative references

The following standard contains provisions that, through reference in this text, constitute provisions of this document. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the indicated standards.

ISO 18925:2002, *Imaging materials – Optical disc media – Storage practices.*

ISO 14644-1:1999, *Cleanrooms and associated controlled environments – Part I: Classification of air cleanliness.*

ISO 14644-2:2000, *Cleanrooms and associated controlled environments – Part 2: Specifications for testing and monitoring to improve continued compliance with ISO 14644-1.*

4 Terms and definitions (Adelstein)

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

4.1 acclimatization

NOTE Sometimes called "staging"

4.2 blister

localized delamination that looks like a bubble

4.3 carton

box

outer container that can hold one or more individual units and may be a fabrication of paper, card stock or plastic

4.4 compact disc

CD

optical disc in which the information layer is located at one surface of a substrate and the data can be read by an optical beam

NOTE Described in IEC 60908

4.5 compact disc – read only medium

CD-ROM

optical disc to which information is transferred during manufacture to certain areas in the compact disc format and can be read multiple times by an optical beam

NOTE Described in ISO/IEC 10149

4.6 compact disc – recordable

CD-R

4.7 compact disc – rewritable

CD-RW

recordable optical disc in which information can be recorded to certain areas in the compact disc format and can be erased, rerecorded many times and read many times

4.8 conditioning

4.9 container

box, can, or carton used for storage and shipping of recording materials

EXAMPLE The box into which a reel, cassette, cartridge, or shell is placed is a container

4.10 delamination

separation of a laminate into its constituent layers

4.11 digital versatile disc

DVD

NOTE Formerly called digital video disc

4.12 DVD-RAM, DVD+RW, DVD-RW

NOTE Described in ISO/IEC 16824

4.13 DVD-ROM

NOTE Described in ISO/IEC 16448 and ISO/IEC 16449

4.14 enclosure

4.15 end-of-life

loss of information which cannot be reliably retrieved

4.16 extended-term storage conditions

4.17 information

data recorded using the system

4.18 insulated record container

4.19 macroenvironment

4.20 magnetic field intensity

magnitude of the magnetic field, in amperes per meter, at a point in space

4.21 medium

media, pl.

material on which information is recorded

4.22 microenvironment

4.23 MO disc

NOTE Information can be recorded, read many times and overwritten many times

4.24 optical disc

4.25 optical disc cartridge

ODC

case containing an optical disc

4.26 recording layer

4.27 relative humidity

RH

ratio, defined as a percentage, of the existing partial vapour pressure of water to the vapour pressure at saturation

NOTE It is usually, but not always, equal to the percentage of the amount of moisture in the air to that at saturation

4.28 retrievability

ability to access information as recorded

4.29 staging

acclimatization

process of conditioning material from one set of temperature/moisture conditions to another

4.30 storage environment

4.31 storage housing

physical structure supporting materials and their enclosures

NOTE It may consist of drawers, racks, shelves, or cabinets

4.32 substrate

4.33 system

combination of material, hardware, software, and documentation necessary for recording and/or retrieving information

4.34 WORM disc

optical disc in which the data in specified areas can be written only once and read multiple times by an optical beam

5 Composition of optical discs

5.1 Disc Structure

CDs and DVDs employ the same basic materials and layers but are manufactured differently. A DVD is actually like two thin CDs glued together. A CD is read and written to (by laser) from one side only. A DVD can be read or written to from one side only or both sides, depending on how the disc was manufactured. Recordable ®, RW, RAM) DVDs can be manufactured with one recording layer on both sides. Pre-recorded (ROM) DVDs can be manufactured with one or two recorded layers on both sides.

Disc structure tables:

Table 4: Basic Layers of CD-ROM and DVD-ROM

(Commercially available pre-recorded discs with audio, video, computer use, or interactive games)

CD-ROM (Single-sided)	**DVD-ROM (Single-sided)**	**DVD-ROM (Single-sided)**	**DVD-ROM (Double-sided)**	**DVD-ROM (Double-sided)**
(All CD-ROMs are one-sided) **One** recorded layer	(One side) **One** recorded layer	(One side) **Two** recorded layers	(Both sides) **One** recorded layer per side	(Both sides) **Two** recorded layers per side
Label, optional	Label, optional	Label, optional	Label, optional (hub area only)	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate	Polycarbonate	Polycarbonate
Metal	Center Adhesive	Metal (fully-reflective)	Metal	Metal (semi-reflective)

Polycarbonate	Metal	Center Adhesive	Center Adhesive	Adhesive
	Polycarbonate	Metal (semi-reflective)	Metal	Metal (fully-reflective)
		Polycarbonate	Polycarbonate	Center Adhesive
			Label, optional (hub area only)	Metal (fully-reflective)
				Adhesive
				Metal (semi-reflective)
				Polycarbonate

				Label, optional (hub area only)

Table 5: Basic Layers of CD -R/-RW and DVD -R/-RW/+R/+RW/RAM

(Blank recordable discs for all applications as ROM discs listed above)

CD-R, CD-RW **(Single sided)**	**DVD-R, DVD-RW,** **DVD+R, DVD+RW, DVD-RAM** **(Single sided)**	**DVD-R, DVD-RW,** **DVD+R, DVD+RW, DVD-RAM** **(Double sided)**
CD-R/RW are one-sided, **One** recordable layer only	(One side) **One** recordable layer only	(Both sides) **One** recordable layer per side only
Label, optional	Label, optional	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate
Metal	Center Adhesive	Recording/writing layer
Recording/writing layer	Metal	Metal
Polycarbonate	Recording/writing layer	Center Adhesive
	Polycarbonate	Metal
		Recording/writing layer
		Polycarbonate
		Label, optional (hub area only)

5.2 Polycarbonate substrate (plastic) layer

The polycarbonate substrate comprises most of the disc including the surface of the disc that is read by the laser (opposite the label side on CDs). It is on both sides of a DVD even if the DVD is a “single sided” disc with a label on one side. The polycarbonate (plastic) substrate layer provides the proper disc depth to maintain laser focus on the metal and data layers. It also provides the disc enough strength to remain flat. Anything in or on the polycarbonate layer that interferes with the ability of the laser to focus on the data layer will result in missing data as it is being read. Polycarbonate is a relatively soft plastic that will allow moisture (water or other liquids) to be absorbed. Fingerprints, smudges, scratches, dirt, dust, solvents, excessive moisture, and any other foreign material can interfere with the ability of the laser to read the data. Contact with any of aforementioned should be avoided with the polycarbonate substrate (plastic) layer.

5.3 Data Layer

The data layer holds data as marks or conditions within the layer that either absorb or transmit the laser light as it is reflected back to the laser photosensor. The data layer and the metal layer in a CD are very close to the top of the disc (label side). DVDs also have metal and data layers as CDs do, but these are located in the middle of the disc (Figures 1 & 2). The type of layers used depends on whether it is a read-only (ROM) disc, write-once ®), or rewritable (RW, RAM) disc. Table 5 below shows the relationship between the data and metal layers and the disc type.

Table 6: Disc type, Read/Record Type, Data layer, and Metal layer

Source	Media	Temperature	Maximum Temp. Gradient	Relative Humidity	Maximum RH Gradient
ISO TC 171/SC Jan. 2002	CD-R CD-ROM	+5EC to 20EC (41EF to 68EF)	4EC /hr	30% to 50%	10% /hr
IT9.25 and ISO 18925 February, 2002	CDs DVDs	-10EC to 23EC (14EF to 73EF)		20% to 50%	∀10%
NARA, FAQ About Optical Media, April, 2001	CDs DVDs	68EF (20EF)	+/- 1EF /day	40%	5% /day
National Archives of Australia, April, 1999	CDs	18EC to 20EC (64EF to 68EF)		45% to 50%	10% /24 hrs
Library Technical Report Nov.-Dec. 1997	CDs	-10EC to 50EC (16EF to 122EF)		10% to 90%	
DVD Demystified, Second Edition, Jim Taylor, 2001	DVD-R DVD-ROM	-20EC to 50EC (-4EF to 122EF)	15EC /hr(59EF /hr)	5% to 90%	10% /hr
	DVD-RAM	-10EC to 50EC (16EF to 122EF)	10EC /hr(50EF /hr)	3% to 85%	10% /hr
	DVD+RW	-10EC to 55EC(14EF to 131EF)	15EC /hr(59EF /hr)	3% to 90%	10% /hr
National Library of Canada, 1996	CDs	15EC to 20EC(59EF to 68EF)	2EC /24 hrs	25% to 45%	5% /24 hrs
Media Services, Inc. Jerome L. Hartke July 2001	CD-R	10EC to 15EC (50EF to 59EF)		20% to 50%	
Kodak, Storage Conditions for CDs, Sept. 2001	CDs	10EC to 25EC (50EF to 77EF)	15EC /hr (27EF /hr)	20% to 50%	10% /hr

6 Common disc problems (Alt.: Failure mechanisms)

(Alt.: Methods to extend life)

(Alt.: Preserving signal quality)

(Alt.: Preserving the media)

(Alt.: System obsolescence)

The requirements for proper care and handling of optical discs can be best understood if the potential problems first are reviewed. Various types of defects can be encountered because of the complex structure of these materials. CDs and DVDs are laminates of very dissimilar layers and each layer can cause malfunctions. The primary layers are as follows:

Polycarbonate substrate. CDs have a single substrate and DVDs consist of two. Warping or lack of flatness creates tracking and/or reading problems. This may be caused by physical abuse, exposure to high or rapidly changing temperature or humidity.

Data layer. In ROM discs, the data is molded into the substrate and this layer is not present. However in recordable and rewritable discs, the recording layer can be sensitized by light, heat or magnetic fields. The recorded signal can therefore be degraded by unwanted exposure to these factors, by mold or by chemical degradation due to aging.

Metal layer. This reflects the modulated optical beam to the receiver. Any change in reflectivitiy caused by abrasion or corrosion due to moisture or pollutants is very detrimental.

Lacquer layer. This exists in CDs to protect the metal layer. Any removal or abrasion can destroy this function.

In addition to maintaining the integrity of each layer, it is essential that the disc not undergo any delamination. This may occur because of an inherent weakness of the disc, exposure to temperature and humidity extremes, mechanical stresses or the effect of external agents such as solvents, adhesives and oils from fingerprints.

6.2 Light

6.2.1 Light on ROM Discs

ROM discs generally are available commercially containing pre-recorded music, video, interactive games, or computer applications type of discs. The long-term effect of light on ROM discs is not known. The possible effect of long-term exposure to light (UV, sunlight, infrared, fluorescent, and other) under general intensity, like room lighting on ROM discs is generally thought to be so minimal that light is not considered a factor in the lifetime of the disc. Any effect of light on ROM discs would be to the degradation of the polycarbonate substrate (plastic) that comprises most of the ROM disc. It is very unlikely that discs will be exposed to light all the time, long-term. The effects from room or storage facility lighting would most likely take several decades or over a hundred years of daily exposure to the ROM disc before becoming noticeable. This should also be true for indirect sunlight through windows. The degradation effects may likely be in the form of “clouding” or “coloring” of the polycarbonate. To our knowledge, there is no report on the potential impact of this kind of material change on the playability of the disc. Light effects on ROM discs therefore are considered negligible.

6.2.2 Light on CD-R and DVD-R (recordable, or write-once) discs

“R” (recordable) discs are blank discs that can be recorded (written to) but cannot be erased or rewritten to over previously written areas. Prolonged exposure to sunlight or other sources of UV light can significantly increase the degradation rate of the recordable layer in these discs. Deterioration of the dye makes the pits and lands on the recording layer indistinguishable from each other to the laser sensor, resulting in errors during reading.

Actually, the most likely cause of sunlight damage to R discs is a result of the heat when left exposed to the sun. Much of the ultraviolet range of sunlight can be filtered (or absorbed) by glass if a disc is exposed to the sunlight, for example, through a glass window. The effects are in this case, likely to be more from the lower light frequency range (infra-red) that do more harm by simple heating. From our primary experimental observation, if a disc is left exposed to direct sunlight behind a glass window but kept cool in an air-conditioned room, the effects should be minimal. If left exposed to direct sunlight without protection (glass, plastic window), the disc dye will degrade more rapidly.

6.2.3 Light on CD-RW and DVD-RW/+RW/RAM (rewritable) discs

UV light should have minimal, if any effect on RW type discs. The phase-changing film that contains the data in these discs is affected by heating. The heat generated from the laser beam writes the data in the phase-changing film unlike the photochemical reaction in the writing of R (recordable) discs. The phase changing film used in RW (rewritable) discs is not light sensitive, but the heat effect from direct sunlight is similar to both discs. The heat build up in the disc as a result of direct sunlight will affect the disc by accelerating the phase-changing film degradation rate just as it does to the dye in R type discs. The phase-changing film in RW discs degrades naturally at a faster rate than the dye in R discs and will also degrade at a faster rate than R discs when exposed to heat build up from direct sunlight or other sources.

7 Contamination (Fontaine, Sheldon, edit)) (Alt.: Contaminants)

7.1 Fingerprints, Smudges, Dirt, Dust

Fingerprints, smudges, dirt or dust on the laser-reading side of the disc can interfere with the laser focusing on the data more that a scratch. Such contaminants will not only cross data lines but will cover wide areas of data along the data lines or tracks. They are more likely to cause the laser path to go out of focus and cause a more wide spread misreading of data along lines or tracks. Such obstructions are not only likely to cause the laser path to go out of focus but also to cause a more widespread misreading of data along data lines or tracks in amounts exceeding the error correction capacity of the disc drive. Fingerprints, smudges and dirt are easier to remove than scratches by appropriate cleaning. Dirt and dust on the disc can reduce the light level of the laser as the disc is being read resulting in misreading. Dust can also spin off into the drive and collect on the laser head or other internal components.

7.2 Water, Moisture

The polycarbonate substrate, or the "plastic" make-up of the disc, is a polymer material. Any prolonged exposure to moisture, liquid, humid air, or immersion in water, can become absorbed into the polycarbonate substrate and may react with any of the layers. Returning the disc to a "dry" condition will allow the absorbed moisture or water to dissipate out of the disc over time. If no permanent damage occurred to the disc while it had absorbed the liquid, the disc should play normally. We have totally submerged a CD into clean water for 24 hours and while the disc was unreadable initially (after removing the disc from the water and allowing the surface to dry), the disc played normally after 24 hours of "drying out" at approximately 70'F, 50%RH (normal room condition). A water- based liquid may leave behind contaminates such as dyes or other particles within the disc.

7.3 Organic Solvents

Avoid disc contact with strong organic solvents. Harsher solvents such as Acetone or Benzene will dissolve the polycarbonate and ruin the disc beyond repair. Limited contact (cleaning) with mild solvents (Isopropyl alcohol, methanol) is okay. These are "weaker" forms of alcohol that evaporate quickly and will not dissolve the polycarbonate. They may however, dissolve or damage labels or optional coatings on the label side of the disc, depending on the material's reaction to alcohol.

7.4 Markers

Marking and labeling a CD or DVD is an essential process during their creation. Every CD or DVD is labeled in some form or fashion in order for them to be organized and distinguished. When labeling a CD, especially with markers, there are certain factors one must keep in mind. These factors are the contents of the ink in the marker and the style or design of the marker.

The ink in markers varies in terms of their chemical composition, their pigments or dyes and their solvents that form the ink solution. Markers are divided into three basic categories, water-based, alcohol-based and aromatic solvent-based. The distinction between these three types of markers is the liquid used to form the ink solution. Markers use water, alcohol and aromatic solvents respectively to dissolve the other ingredients used in ink to form a solution. Within these three main categories, markers are divided even further with regards to their permanence and their ability to write on different surfaces.

Along with the ink, markers also vary in terms of style and design. Markers come in different forms, such as, fine point, extra fine point, rolling ball, ball point, soft felt tip and chisel tip. All these styles of markers are used for different applications and naturally some are ideal for CD labeling, while others can potentially damage a CD.
When choosing a marker to label a CD or DVD one must note the surface they are writing on. The CD (CD-ROK CD-R, CD-RW) surface typically is a thin protective layer made of lacquer. Numerous CD vendors have noted that the lacquer coating has the potential to deteriorate when in contact with certain solvents in markers. For that reason it is suggested that one use water-based markers for CD labeling to virtually eliminate risk. Although alcohol is considered a solvent, it is generally less toxic than xylene and toluene, which are common in aromatic solvent based-makers. There are anecdotal reports of using alcohol-based markers to label CDs without resulting in performance problems, however there are no lab test results to show what affect solvents in markers have on different CD's and DVDs, particularly in the long-term.

The vulnerability of a CD is also a factor to consider when choosing a marker. A CD is composed of several layers. The most important of these layers is the recording layer. This is where the actual data of the CD is stored. On a CD the data layer is located nearest the label side. This location leaves the recording layer susceptible to damage from scratches or scrapes received on the label side. With this in mind, specialists advise using a felt tip marker, which minimizes the risk of scratching from the marker. One should never use a fine point or rolling ball marker because of their ability to scratch the surface of a CD and potentially damage the recording layer. Although CDs and DVDs look similar, their layer structures differ. As mentioned before, the recording layer of a CD is located just beneath the labeling side. On a DVD the recording layer is located in the center of the disc. In theory solvents from a solvent-based marker cannot penetrate the polycarbonate layer found on both sides of a DVD. Consequently, the data and metal layers located in the center, in theory, would not come in contact with any harmful solvents. However, in practice one is advised to take the same precautions needed for labeling CDs. The same marker used to label a CD Will work just as well on a DVD. This practice will save money in purchasing markers and create less confusion.

A safe investment would be to buy a CD safe marker sold buy numerous vendors. These markers are categorized as water/oil-based by manufacturers, for consumer use on their CDs. Rather then using dyes to give color, these CD safe markers generally contain pigments. The pigment in the ink gives the marker a permanent quality. An alternative is to simply use a water-based felt tip marker. Although these markers guarantee the integrity of one's CD, water-based markers are generally not as permanent as other solvent-based markers. Therefore, a permanent water/oil-based marker is recommended if it is necessary to mark the disc.

8 Handling techniques (Byers) (Alt.: same)

CDs and DVDs can be reliable for many decades with proper handling. Degradation is inevitable over a period of time, as with all other types of media, but steps can be taken to extend the life of discs. Especially important in this regard are proper handling techniques. (Byers, 5.0)

8.1 Surface Handling Effects (Byers, 5.3)

Anything on an optical disc surface that interferes with the ability of the laser to focus on the data layer can result in missing data and/or laser mis-tracking as the disc is being read. Fingerprints, smudges, scratches, dirt, dust, solvents, excessive moisture, and other foreign material can interfere with the ability of the laser to read the data. They can also interfere with the ability of the laser to follow the data track on the disc. Fingerprints and light scratches are very common, and although they both can interfere with laser reading, their affect on the disc is somewhat different.

8.2 Scratches

8.2.1 Scratches on the laser=reading side of CDs and DVDs

Scratches generally cross data lines or tracks on the disc, and depending how bad (width and depth) the scratch is, it may not interfere with the laser focusing on the data. Small or occasional scratches likely will have little or no effect on the ability of the laser to read the disc. The laser can still read the disc because the focus of the beam is far enough beyond the surface of the disc to read beyond the scratch. This is comparable to a light scratch on a pair of eyeglasses that is not very noticeable because the eye focuses beyond the scratch. If the scratch is deep or wide enough to effect the laser focus, the error detection and correction coding in the disc drive can recover the missing data. However, heavy, wide or multiple scratches close together can adversely affect the readability of the disc. These scratches can cause too numerous errors for the error correction coding to recover the lost data. Data errors generated from scratches running in the direction from the middle of the disc outward are more likely to be corrected by the error correction firmware in the disc drive. Scratches running in a circular direction around the disc are more likely to cause uncorrectable error.

8.2.2 Scratches on the label side of CDs

Scratches on the label side of CD discs can be a more serious problem. This type of damage cannot be repaired. Because the reflective metal layer and data layer is so close to the surface of the label side of the disc, it can be damaged very easily. A slight indentation or pinhole in the metal from a scratch, pen, pencil, ultra fine marker, or other object will destroy the reflectivity of the metal on the other side (laser reading side) and the readability of the data by the laser. Optical disc drives will be able to read through minor damage easily, especially scratches through the data that radiate from the center outward. Scratches to the data that follow the direction of the track will usually cause a problem. If the error detection and correction firmware in the drive cannot correct the data, it will not be recoverable. Scratches that do not reach through the thin protective lacquer coating should have no immediate affect but may allow moisture or other environmental influences, including pollutants in the air, to reach the metal. Adhesive labels (if applied) may add an extra layer of protection from scratches to the disc surface but may add other adverse conditions later as discussed in the "Labels" section below. Printable discs have an extra layer that can also add a level of protection from scratches.

8.2.3 Scratches on the label side of single sided DVDs

Scratches on the label side of single sided DVDs are not a problem unless any are extremely deep. The metal layer that is so prone to damage in CD discs is located in the middle of DVD discs. The metal layer has considerably more distance and protection from surface scratches and is unlikely to be affected unless the scratch is deep enough to reach the center of the disc where the metal and data is.

8.3 Labels

8.3.1 Adhesive Labels

For longer-term storage (more than five years), do not use adhesive labels on optical discs. The label may delaminate over time and interfere with disc drive operation. Any attempts to peel the label off can cause damage to the lacquer and metal layer in CDs. DVDs are different. Peeling a label off a DVD should not have the same adverse affect because the metal layer is not near the surface. Still, if a portion of the label is removed or left on the surface of any disc, it can cause an imbalance while spinning in the drive make the disc unreadable. Some earlier labels have been known to have the adhesive react with the lacquer surface. If you receive a disc with an adhesive label already applied to it, and you want to insure the availability of the information for the long-term, make a copy of the disc to store also (without an adhesive label).

Adhesive labels may be well suited for short-term disc usage (less than five years) and can add an additional level of protection from scratches and other potentially harmful contact. On the other hand, adhesive labels are subject to environmental conditions where they may dry out, absorb moisture, or be affected by heat or cold more so than the disc itself. Any of these factors may cause the label to delaminate. If you decide to use a label, use only labels manufactured for use on CDs or DVDs and use a disc label applicator tool to apply the label. The label applicator tool should position the label so that it is centered on the disc to insure a balanced spin while in the disc drive.

8.4 Printable CD-R and DVD-R disc surface

CD-R and DVD-R printer labeling requires discs that have a printable surface added to the disc at time of manufacturing. The following printing information relates to CD-R but would also apply to DVD-R.
Inkjet printing and thermal transfer printing are commonly used for customizing the surfaces of CD-R discs, however each uses different technology to place inks on the printing surface of the discs. Nearly all inkjet printable and thermal printable CD-Rs are not interchangeable.

The type of printing on a DVD disc depends partly on which format of DVD is being produced.
If it is a single-sided disc, a label may be printed on the top side. But because all DVDs are more susceptible to heat than are CDs, silk-screening, which uses ultraviolet heat, may not be the best choice. Ink also affects the flatness of the disc, and this is more critical for DVDs than for CDs.

To make a full-color label on a CD, some producers first silkscreen a base coat of white paint so the colors would not be affected by the metallic appearance of the disc. This “white coat” process cannot be applied to DVDs.
So-called “pit art” was developed to avoid some of these problems. Pit art is really a form of disc decoration in which the pits are produced only in some parts of a disc side, making a mirrored holograph-like pattern that gives the appearance of a design or a label. Because no ink is used, the flatness of the disc is not compromised.
If a DVD disc has data on both sides, neither silkscreening nor pit art may be used on the main surface. The “mirror band” in the center of the disc may be printed upon.

8.4.1 Thermal printable surface

Only specially designed thermal printers can print directly on the surface of thermal printable CD-R discs. You cannot use a thermal printer designed to print on paper. In thermal transfer printers, a print head that contains resistive elements in a linear array heats ink-coated films (ribbons). The head is in direct contact with the uncoated side of the ribbon and the ink-coated side of the ribbon is in direct contact with the disc's printable surface. The ink is heated, causing it to melt and adhere to the printing surface. Specially formulated materials are used for the printable surface of the disc to enhance high ink transfer efficiency and adhesion.

8.4.2 Inkjet printable surface

In inkjet printers, inks are sprayed, via droplets of an ink solution, onto a specially designed surface material on the disc. This special material, the inkjet receiver layer, is intended to hold the ink droplets in place while absorbing the liquid components of the ink.

8.4.3 Silkscreening

There are service bureaus that will silk screen your discs. A CD-R media distributors can provide this service as well. Also, you can buy equipment for silk screening the CD-Rs yourself. You need to use a UV-curable ink if you are going to silk screen, so that the ink colors will not run together. You also need to be sure that the UV curable inks do not contain any chemically active components that can affect the disc after the curing process. Likewise make sure there are no abrasive particles in the ink pigments that can damage the protective layer of the CD-R disc. [OSTA]

8.5 Flexing

Flexing (bending) the disk, as when removing it from a jewel case, sitting on it, or bending by any other manner, may be harmful to the disc. This may cause stresses and eventual separation between the disc layers. The disc should be stored in its case and placed on the shelf vertically like books. Long-term horizontal storage (particularly in a heated environment) can cause the disc to become permanently bowed. While the data may still be completely intact, the disc may not operate in the drive properly or allow the laser to follow the track. The maximum flex (bend) or number of times a disc can be flexed before it causes damage is not known. To minimize the risk of damage, avoid or minimize flexing of the disc as much as possible.

8.6 Magnetism, x-rays and microwaves

Magnetism and magnetometers have no effect on CDs or DVDs. X-ray exposure, for example from airport baggage screening machines, will not harm optical discs. Microwaves in a microwave oven will destroy a disc, and the metal layer in the disc may cause damage to the oven.

8.7 Wear

CDs and DVDs do not wear from friction as vinyl records or tapes do. There is no physical contact to the disc in the area that the laser uses.

Rewritable RW discs however, can "wear-out." CD-RWs and DVD-RWs should last for about 1000 rewrites before the rewriting capability is worn out, 100,000 times for DVD-RAMs, but the reading functionality of the disc should continue.

Actually, each time the laser reads a disc, the laser can have some minimal effect on the recording layer or polycarbonate. In theory, it may be possible for the disc to be read so many times that the cumulative effect of the laser light can eventually affect the disc. In reality, any effect should be so incredibly small as to be considered negligible. No cases are known where a disc has been played or read so many times as to exhibit damage from the laser light. The disc will fail from some other condition before it is played enough times to fail from the laser light in the disc drive.

9 Use environment (Talkington)

9.1 General

During use and handling, many environmental factors affect the functioning and life expectancy of optical discs. Among the most critical factors are temperature, humidity, cleanliness, and the presence of potential contaminants.

Optical disc life is affected by various forms of chemical deterioration. The rate at which this occurs varies depends on the chemical formulations used by the manufacturer, the manufacturing process and the environmental conditions to which the disc is exposed. For more information on disc life refer to the “Life Expectancy” section 1.3 of this standard.

The environmental conditions given in this section shall be followed for discs intended for extended life. They are also recommended for all handling environments to prolong the life of all discs.

9.2 Temperature and humidity

9.2.1. Environmental condition

Optical disc life is influenced directly by temperature and humidity. Optical discs should perform satisfactorily when used under the following conditions typical of non-air conditioned offices. The high end of the temperature range has been adjusted to include internal machine temperature rise so as to represent the temperature a disc will experience inside a machine inside a 40 ^{o}C office environment.

Temperature (Read/Write): -5 to + 55 ^{o}C.

Relative Humidity: 5 to 95% non-condensing

9.3 Life Expectancy

Life expectancy increases when optical discs are stored in a cool, dry environment characterized by stable temperatures and humidity. Time out of the recommended storage environment shall be minimized, as this will maximize disc life. For acceptable storage environments, see ISO 18925.

9.4 Water avoidance

A major cause of chemical degradation of optical discs is the interaction with water, called hydrolysis, either directly or through absorption of moisture by the polycarbonate substrate from the air. Precautions shall be taken to mitigate possible incursion of water due to condensation, floods, leaks, sprinklers, and to limit excess humidity. Walls and enclosures in use and handling areas shall be designed to prevent condensation of moisture on interior surfaces. All use and handling areas shall be above basement level where water damage is most prevalent. Floors shall be provided with drains or other means of water removal. Drains shall have systems to prevent liquids or sewage from backing-up into the facility. All work and handling surfaces shall be elevated off the floor.

9.5 Fungus

Extended exposure to humidity above 65 % RH will promote fungal growth.

9.6. Air Quality

9.6.1. General

Optical discs tend to develop an electrostatic charge, especially at low levels of humidity, and attract dust particles. For this reason it is recommended that recording and playback operations be performed in a clean dust-free environment (see “Clean room specifications” below).

9.6.2. Air flow

Positive air pressure in use and handling areas shall be maintained relative to adjacent hallways, rooms, and facility exteriors to minimize contamination from outside sources.

9.6.3 Clean room specifications

Record, playback and inspection usage of magnetic recording tape shall be performed in a clean room environment class 100,000 meeting the requirements of ISO 14644-1 or better. A class 100,000 environment represents a typical dust-free office.

9.7. Magnetic Fields

9.7.1 General

With the exception of MO discs, magnetic fields do not affect optical discs. External magnetic fields are observed most frequently near motors and transformers (e.g., elevators and lifts), but potentially damaging fields can be generated by some headphones, speakers, microphones, magnetic cabinet latches, and magnetized tools. Care shall be taken during the record process for MO discs to avoid placing the recording equipment in close proximity to potential sources of magnetic fields.

9. 7. 2 Levels

Within use and handling areas, the peak intensity of external steady state (DC) fields shall not exceed 4 kA/meter (50 Oersteds) and the peak intensity of external varying (AC) fields shall not exceed 800 A/meter (10 Oersteds).

9.7.3 Separation distance

Most sources of magnetic fields are localized and the field intensity falls off rapidly with separation (a few centimetres separation from the source will usually provide adequate protection).

9.8 Light exposure

Optical discs and their protective cases can be damaged by exposure to ultraviolet (UV) light. Optical discs and protective cases shall not be exposed to direct sunlight for prolonged periods of time. To reduce UV damage to protective cases and labels, lights shall be turned off in use and handling areas when the areas are not occupied.

9.9 Acclimatization

9.9.1 General

Environments may vary slightly from the general guidelines depending on the specific use, the duration of exposure during specific use, and the practical realities of use in environments where human control of the environment is severely limited. Cooler and drier environments are better for disc longevity; however, at the coldest and driest levels acceptable for long term storage, some discs cannot be used immediately in record or playback mode. Discs stored in such conditions must be acclimatized to a different set of environmental conditions prior to use. Acclimatization is the process of altering temperature and moisture content of the disc so that it can be used at a substantially different temperature and/or humidity level. A compromise between energy input, longevity, and comfort of handling, access time, and health requirements of operating staff must be achieved. In tropical climatic zones, a slightly higher temperature for the handling environment (25 ^{o}C) may be unavoidable, with the clear understanding that storage and handling environments must not differ substantially unless acclimatization is properly carried out.

9.9.2 Common problems

Failure to acclimatize discs can result in mis-tracking during playback, moisture condensation and high error rates. Discs exposed to temperatures above 25 ^{o}C or relative humidity above 50 % RH shall be acclimatized before use.

9.9.3 Moisture Absorption

Over time the substrate will absorb moisture and reach equilibrium with the surrounding environment. Sudden large deviations from these conditions can cause the formation of water droplets inside the disc substrate and result in significant warp age. These droplets may also form at the interface with the various disc layers resulting in significant performance degradation.

9.9.4 Condensation

Another reason to acclimatize discs is to avoid moisture condensation. Moisture condensation can occur when moving discs from cool conditions to warm, humid environments. This can be avoided by use of a staging room or an enclosure. The disc shall not be removed from the staging environment until it is above the dew point of the use environment.

9.10 Marginal environments

8.10.1 General

To mitigate negative environmental factors, optical discs shall not be removed from the buffering effect provided by their protective cases when in packing, shipping or receiving areas. To further buffer optical discs from exterior environmental factors, they shall be packed in additional, non-dusting, insulating material for shipment.

9.10.2 Shipping and receiving areas

Temporary fluctuations beyond the accepted temperature and humidity ranges are allowable as long as the environment is returned to recommended levels in less than one hour. Staging or holding areas for shipping and receiving shall not have direct access to the outdoors. Two sets of doors shall be used to minimize the impact of external temperatures and contaminants. Packing and unpacking shipments produces unavoidable debris substantially in excess of recommended levels. Areas where these activities are performed shall be cleaned on a regular basis to minimize the accumulation of debris.

9.10.3 Field environments

In the field, optical discs and protective cases shall be shielded from environmental extremes, including direct exposure to water, dust, and sunlight. Discs shall be kept in their protective cases unless they are being used. When possible, discs not needed for immediate use shall be kept in an air-conditioned space (e. g., hotel room, office, electronic news gathering (ENG) uplink van). As recording equipment is an integral part of the field use environment, these precautions shall be applied to the equipment as well as to the disc.

10 Inspection (Byers) (Alt.: same)

11 Cleaning and maintenance (Byer (Alt.: same)

11.1 General

Try to do as little cleaning as possible to CDs or DVDs! CDs and DVDs do not require a regular or routine maintenance cleaning. Only clean the disc when it is absolutely necessary. Discs shall be cleaned before storing when surface contamination is visible, before recording when surface contamination is visible, before playing when surface contamination may “fling off” while the disc is spinning, and when readability is impaired and surface contamination is visible.

The polycarbonate substrate is a relatively soft and transparent type of plastic. Each time the disc is wiped, rubbed, has a solution applied to it, or otherwise is treated, danger exists of scratching or contaminating the disc.

11.2 Solvents and cleaning compounds

In general, avoid using organic solvents. Harsher solvents (e.g., acetone, benzene) will dissolve the polycarbonate and ruin the disc beyond repair. Mild solvents (e.g., isopropyl alcohol, methanol), however, are okay to use. These are "weaker" forms of alcohol that evaporate quickly and will not dissolve the polycarbonate.

Other examples of solutions that are not harmful include water-based lens cleaners and water-based detergents (with mild soap) formulated for cleaning CDs or DVDs.

11.3 Cleaning methods

The polycarbonate substrate is a relatively soft and transparent type of plastic. Each time the disc is wiped, rubbed, has a solution applied to it, or otherwise "treated", the risk of scratching or contaminating the disc increases. The following cleaning practices shall be used.

a) Use a soft cotton cloth or chamois leather to wipe the disc.

b) Use a dry cloth only, first, before using any cleaning solutions. Do not wipe in a circular direction.

c) Wipe from the center of the disc towards the outer edge.

d) Avoid using paper products to wipe the disc, including lens paper. Avoid using anything abrasive on the surface of the disc.

e) If the disc has a heavy accumulation of dirt, try rinsing with water first.

12 Transfer of content (Alt.: Transfer in lossless manner)

13 Transportation (Alt.: Preparation and timing of transfer)

13.1 Enclosures

Optical discs shall always be in protective enclosures such as jewel cases and these enclosures packed in cartons or containers when shipped.

13.2 Cartons

Cartons and containers used for transporting optical discs shall be built solidly to protect the discs. The underside of each carton shall be inspected to ensure that it is intact and capable of bearing the load. If the quantity of optical disc enclosures is not sufficient to completely fil the container, the free space shall contain packaging material so that there is no movement of the discs during transport. It is recommended that optical discs by packed in cartons with shock protection packing such as bubble-pack or padding. When shipping discs in a high moisture climate, the discs shall be sealed in a plastic bag containing desiccant. Shipping containers shall be resistant to water and dust and shall be sealed to ensure that contaminants do not get into the package during transit.

13.3 Exposure

During shipping by public and commercial transit, the disc containers may be exposed to adverse environmental conditions. Common carriers will not guarantee against extremes or rapid changes in temperature and humidity. For example, the cargo bay of any aircraft can have rapid environmental extremes from a hot, damp environment on a tarmac to a cold, dry environment when airborne. These rapid extremes can be very detrimental to the physical integrity of the discs because of very different coefficients of humidity and temperature change between the various components of the disc laminate. To protect the discs from rapid environmental extremes, the shipping container shall be well insulated.

13.4 Security

Discs considered to have permanent value (e.g., master discs, unique, or original recordings) shall not be loaned or shipped without making sure that all criteria of this standard are met by both the shipper and the recipient. As a rule, duplicate or back-up copies should be shipped in the place of master discs. At no time shall the disc containers or the trucks in which they are being moved be left unattended in open areas. This minimizes disc deterioration and reduces the possibility of theft and damage.

13.5 External Fields

Magneto-optical discs shall not be exposed to external magnetic fields. A potential problem with airport and other conveyor belt systems is that the electric motor driving the belt may be located immediately under the belt. If this is the case, the magnetic field of the motor may affect any magneto-optical discs placed on the conveyor belt. These discs shall not be exposed to magnetometers such as hand-held security wands. The strong magnetic fields generated by these devices may damage the recording.

13.6 Biological irradiation

Optical discs shall not be exposed to high power biological decontamination scanners. High levels of radiation can produce sufficient heat to melt or deform the discs or their plastic containers.

13.7 X-rays

Discs and the recorded information are not damaged by properly functioning x-ray equipment.

14 Disasters

14.1 General

Optical discs are susceptible to damage in environmental disasters. The three most common problems are physical deformation, chemical decay and surface contamination. Short-term exposure to most disaster situations causes no detectable alteration of the recorded signal except in some situations for magneti-optical discs where there is direct or close proximity with electro-magnetic fields.

The majority of disaster losses are due to alterations in the physical characteristics of the discs such as distortions or delamination. These alterations result in an inability for the disc to track properly. Any small departure from flatness can cause the servo system, which keeps the laser on the recorded track, to lose control. Even imperceptible deformations may cause tracking problems. Any delamination of the component layers of the disc laminate is disastrous.

14.2 Water

The most common type of disaster is exposure to water. Discs are at risk from exposure to water due to the tremendous variety of sources from which the contamination can originate. Water exposure can result from many sources such as roof leaks, flooding, broken pipes, malfunctioning bathroom fixtures, municipal sewer problems, fire sprinkler systems, and spilled drinks. Exposure to water and various other liquids can seriously weaken or destroy the structural integrity of discs, resulting in permanent deformation or layer separation. Uneven drying of wet discs promotes disc distortions. Water or moisture can also cause removal of the identification label, increase hydrolytic breakdown of discs that have a data or recording layer, or cause fungus (mould and mildew) growth.

14.3 Fire

Another common disaster that affects optical discs involves fire. In fire scenarios, discs are exposed to heat, smoke, water, fire suppression chemicals, and debris. Each of these contaminants has a different effect. If exposed to sufficient heat, discs will melt or bum, but the most frequent damage during a fire is caused by smoke. Smoke will affect most discs in the general vicinity of a fire, and leaves an oily film on the surface that interferes with signal retrieval. Fire also produces particulate debris that may be deposited.

14.4 Dry debris

Unless a disaster results in fire or flooding, the primary concerns are impact from falling and exposure of the discs to dry particulate debris. Physical damage and the resulting distortions can be caused by falling or the impact of collapsed structure. Most dry debris will not interact chemically with optical discs. Debris that adheres to the disc may interfere with signal retrieval during playback.

14.5 Disaster response

Optical discs exposed to disasters may not be destroyed by the initial exposure. Damage may result from improper handling after a disaster or from delay in remedial work. While discs are fairly resistant to chemical decay over short periods of time, they may be contaminated with chemicals during extended exposure. If possible, both the handling and the decontamination shall be performed by specialists. As soon as a disaster site has been secured against possible injury to personnel, discs shall be removed from the site to avoid further contamination and damage. Where liquid is present, changes in orientation that spread contamination shall be avoided. Discs shall be cushioned against shock and insulated against sudden changes in temperature. They shall be decontaminated as soon as possible.

Discs shall not be returned to long-term storage before decontamination. Temporary storage shall be in a cool environment. Discs shall be acclimatized before cleaning. Dry particulate debris can become airborne and spread easily to its surrounding environment. Contaminated discs shall be isolated until decontamination is completed. Liquids shall not be used to remove dry particulate debris.

Wet discs are particularly vulnerable to damage. Biological and chemical deterioration can occur within twenty-four hours. Discs shall be decontaminated before they are allowed to dry. If water is used to rinse some chemical contaminants from the discs, only cold distilled water shall be used. All wet paper and cardboard, excluding labels, shall be removed from the vicinity of the discs as quickly as possibly to reduce water retention and potential fungal growth. If fungal growth is detected, discs shall be treated only by trained personnel.

15 Staff Training

15.1 Purpose

This section is intended for staff in archives in which the long-term storage of optical discs is paramount. The preservation and effective use of information contained on optical discs is enhanced by a regular staff training programme. This programme should achieve the following goals:

a) a high level of technical competence among staff,

b) familiarity with the functional characteristics of equipment;

c) awareness of required safety procedures including fire control, and chemical, biological and electrical hazard avoidance;

d) knowledge of policies and procedures governing work.

15.2 Training program

Each organization shall develop a program fitted to its individual circumstances and needs. The training program shall be updated regularly as equipment, procedures and needs change. Staff training programs shall be revised whenever major change occur (e.g. staff changes, major equipment changes, significant redirection of mission and services). New employees shall commence training starting shortly after the commencement of employment.

15.3 Content of training

Staff training programs shall include the following components:

a) Mission, goals, and objectives of the organization;

b) Position descriptions stating the roles and responsibilities of each staff member;

c) Published standards and bibliography of other information relevant to the work of the repository,

d) Guidelines governing access to the materials;

e) Maintenance schedules and procedures for equipment used in the facility;

f) Cataloguing, labeling, and shelf arrangement;

g) Physical facilities issues and concerns (e.g., location of fire alarms and emergency shut-off valves);

h) Occupational health and safety;

i) Instruction on the handling of optical discs; j) Actions to take if a disaster occurs.

16 Minimum Handling Requirements Checklist (“Do” and “do not” list)

16.1 General

This checklist is not a complete guideline or summary for optical disc care and handling. It contains only those items that experience and testing show will have an immediate or severe effect. Failure to adhere to the items on this list may cause premature loss or deterioration and should be considered misuse of the medium. These are minimum handling requirements that summarize good practices. Explanation and expansion of these and other items can be found elsewhere in the text of this standard.

16.2 Do

Familiarize yourself with proper techniques for the care and handling of optical discs:

a) Handle discs gently, touching only the outer edge and inner hole;

b) Keep discs in protective and unbroken jewel cases when not in use, after removing printed paper liner notes;

c) Protect both discs and machinery from dust and debris. The use of a deionizing environment is recommended to neutralize static charges;

d) Keep discs in a stable, cool and dry environment, see ISO 18925;

e) Use only new discs when recording for long-term storage;

f) Acclimatize discs before use if they are hot or cold;

g) Inspect discs for damage or contamination before use;

h) Clean discs before playback if they show any evidence of dirt or contamination;

i) Learn and use correct procedures for operating equipment;

j) Package discs adequately for protection before shipment or transport; k) Seek experienced help as soon as possible in the case of a disaster.

16.3 Do not

a) Do not expose discs to temperature extremes;

b) Do not store discs in an area subject to dampness or possible pipe leaks (e.g., basements);

c) Do not expose discs to UV radiation, including the sun, for extended periods;

d) Do not expose discs to food or beverages;

e) Do not drop or throw discs;

f) Do not stack or place objects on top of unprotected discs;

g) Do not touch disc surfaces with bare hands;

h) Do not leave discs intended for long-term preservation in readers;

i) Do not force discs into cases or machines;

j) Do not play discs that are dirty, contaminated, or wet;

k) Do not play discs on a dirty, misaligned, or malfunctioning machine;

l) Do not place magneto-optical discs on or near sources of magnetic fields;

m) Do not expose discs to high power biological decontamination scanners. High levels of radiation can produce sufficient heat to melt or deform discs or their plastic containers;

n) Do not attempt to clean discs contaminated with adhesives, fungus, or unknown substances unless you have the necessary experience or training. Do not use detergents, solvents or abrasives.

17 Bibliography