Longevity of Recordable CDs and DVDs

Introduction

The longevity of recordable compact discs (CD-Rs) and recordable digital versatile/video discs (DVD±Rs1) is uncertain, leading to a widespread lack of trust by libraries and archives. Research studies, anecdotal information, and manufacturers’ literature suggest that the lifetime of CDs and DVDs can range from a couple of years to more than 200 years. This Note explores several of the factors that affect whether a disc fails within a short period or continues to perform well for many years.

Manufacturing Quality

Poorly manufactured discs (i.e. discs that do not meet standard specifications for proper function) will probably fail sooner than good-quality ones due to rapid chemical degradation or physical damage. This was a significant problem when discs were introduced (CD-Rs first appeared in the marketplace in 1991, DVD-Rs in 1997, and DVD+Rs in 2002) and for at least 2–3 years afterwards. Poor manufacturing is still a problem to some extent, either because of cost-cutting to meet competitive pricing or speedy production runs to meet high demand.

Determining if a disc is poorly manufactured is an impossible task without thorough testing, which likely would include accelerated aging. This is not feasible for most archives, libraries, and museums. In the absence of testing, discs with a recognized brand name can generally be assumed to be of good quality. Even though some large manufacturers label discs produced elsewhere with their own brand name, most have no desire to be associated with an inferior product. Information on where the disc was actually produced may be available by consulting the manufacturer and/or examining disc coding.

Materials Used in Disc Manufacturing

CD-R

CD-Rs are composed of several layers (see Figure 1):
- base layer
- dye layer
- metal reflective layer
- top protective layer
- label layer (optional)

The base layer of a CD-R is always composed of polycarbonate. However, the dye and metal reflective layers can be composed of various materials, each with its own inherent stability. The quality of the top protective layer is also important.

Figure 1. Cross section of a CD-R.

1. Recordable DVDs are available in two formats, the –R version and the +R version, which are supported by two different groups of manufacturers. The –R format was released to the marketplace 5 years prior to the +R format and, therefore, is more commonly found and used. There are some technical differences between the two formats. For example, the +R format uses a different system of tracking and speed control than the –R format, one that is supposed to allow for better high-speed recording quality. In addition, the +R version has a more robust error management system, which could translate into better-quality recordings regardless of the disc brand or type being used. For the most part, these differences have not been a huge benefit for the average user. Where this Note refers to both formats, the term DVD±R is used.
The CD-R specification was designed around cyanine dye (shades of blue) and, therefore, most of the early discs used it. Azo dye (deeper blue) was introduced in 1996. However, neither of these dyes matches the stability of light-green phthalocyanine, which is very stable to light, high temperature, and high relative humidity (RH). Phthalocyanine was available in the early days of CD-R manufacture, but it was not widely used until around 2002.

The type of dye in a CD-R can sometimes be determined by transmitting light through the disc and viewing the colour (see Table 1). However, the presence of a thick, dark label may make identification impossible with transmitted light. In these cases, reflective light can be used although the colour of the metal reflective layer may alter the appearance of the dye colour. Note also that some discs have pigmented bases, such as black or one of a variety of fluorescent colours; these colours do not indicate a different dye or metal layer than indicated in Table 1. The type of dye in a disc can also be determined by consulting the manufacturer or their literature.

A CD-player reads a disc by directing a laser light through the base and dye layers to the metal layer, which reflects it back to the player’s signal detector. If the reflective layer is altered in any way, it will not perform as expected and the disc cannot be read. The metal reflective layer in CD-Rs has generally been gold, silver, or silver alloy. Gold is very stable, so discs with a gold reflective layer are not at risk for “laser rot” (a term used to describe the corrosion of the metal layer) and hence have excellent longevity. However, silver and silver alloys are susceptible to corrosion, so CD-Rs with these kinds of reflective layers are more likely to fail, especially if they are exposed to pollutants.

The top protective layer should have good chemical resistance and be rugged enough to protect the sensitive metal layer from handling damage. If this layer is of poor quality or has not been applied evenly and completely on the disc, then early disc failure is likely. Many manufacturers specifically mention that their discs contain rugged topcoats.

**DVD±Rs**

A recordable DVD provides much more capacity than a recordable CD and, therefore, is often the desired format for storing information. Recordable DVDs are composed of two individual discs, half the thickness of a CD-R, manufactured separately and then glued together (see Figure 2). DVD±Rs can also have two information layers.

![Figure 2. Cross section of a DVD±R.](image)

DVD±Rs are produced with an azo or cyanine type dye, giving the discs a blue, bluish-purple, or purple appearance. It is difficult to provide specific details about the dyes, as there is significantly less information available on dyes in recordable DVDs than in CD-Rs.

The metal layer in DVD±Rs is generally similar to that in CD-Rs, i.e. it is usually composed of silver, silver alloy, or gold. However, dual-layer discs use a semi-reflective metal so that some laser light can pass through to the second information layer.

<table>
<thead>
<tr>
<th>Dye and dye colour</th>
<th>Reflective layer</th>
<th>Appearance from the non-labelled side of the disc with reflected light</th>
<th>Appearance from the non-labelled side of the disc with light transmitted through the disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>cyanine (blue)</td>
<td>gold</td>
<td>green</td>
<td>blue</td>
</tr>
<tr>
<td>phthalocyanine (light green)</td>
<td>gold</td>
<td>gold</td>
<td>light green</td>
</tr>
<tr>
<td>cyanine (blue)</td>
<td>silver alloy</td>
<td>blue</td>
<td>blue</td>
</tr>
<tr>
<td>phthalocyanine (light green)</td>
<td>light green</td>
<td>light green</td>
<td>light green*</td>
</tr>
<tr>
<td>azo (dark blue)</td>
<td>silver alloy</td>
<td>dark blue</td>
<td>dark blue</td>
</tr>
</tbody>
</table>

* Because the phthalocyanine dye is very light green, the label on the top of the disc may change the appearance of the dye. In this case, the colour of the disc with reflected light is generally a better indication of the dye type than the colour of the disc with transmitted light.
DVD±Rs do not require a top protective layer, as the metal and dye layers are situated in the middle of the disc structure, sandwiched between two layers of polycarbonate (see Figure 2).

One additional concern about DVD±Rs is the bonding adhesive. There are some anecdotal reports that DVD±Rs have separated due to adhesive failure, or the metal layers have corroded due to chemical reactivity of the adhesive. However, no extensive research or studies have yet been performed to confirm these observations.

**Disc Recorder/Reader Compatibility**

The original specification for CD-Rs accommodated discs with a maximum capacity of 650MB of data (74 minutes of audio recording). When CD-Rs with a capacity of 700MB of data (80 minutes of audio recording) were introduced around 1998, they caused numerous compatibility problems. However, once a new generation of equipment was introduced, incompatibility became less significant. Nonetheless, early high-capacity discs (produced from 1998 to 2000) may not perform well, no more so than new high-capacity discs played in older equipment.

DVD-Rs generally have better disc/reader compatibility than DVD+Rs, especially when using older readers/drives. To ensure that incompatibility is not mistaken for disc failure or disc degradation, it is important to know which format the equipment was designed to read (not all drives can read both).

Overall, single-layer recordable DVDs have better disc recorder/player compatibility than dual-layer formats.

**Recording Techniques**

One of the primary reasons for premature failure of CD-Rs and DVD±Rs is improper recording, i.e. the initial error rate was too high or the recording software created other problems.

All recorded discs have inherent error rates, which are the number of errors per second when the disc is played. These are measured by BLER (Block Error Rate) for CD-Rs and PI (Parity Inner Error Rate) for DVD±Rs. Players/readers can correct errors up to a certain point (and some are more efficient than others); however, if there are too many errors or they are too severe, the disc will not play properly. Specifications state that the maximum allowable BLER for CD-Rs is 220 and the maximum PI for DVD±Rs is 280, but it is preferable that the initial error rate be less than 50. This will ensure that the disc is playable in a wide variety of players, even those with poor correction capability — a factor that becomes increasingly important as technology obsolescence reduces the number of available players. A low error rate also leaves more room for additional errors before disc failure occurs. For example, a disc with a low error rate can tolerate the additional errors from a scratch or other damage without problems, whereas a disc with an error rate that is close to the limit will likely fail if more errors are introduced.

Low error rates can be achieved by following a few simple recommendations.

- Ensure the recorder is well maintained and the disc surfaces are clean. Dust on discs will interfere with the recording process and cause errors.
- Confirm that the disc is compatible with the recorder being used. (Check the recorder manufacturer’s literature to see if it recommends certain disc brands.) Fortunately, this seems to be less of a problem today than it was a few years ago.
- Use moderate recording speeds. CD-Rs were originally rated for speeds below 8×, but since 2000 these ratings have increased quickly all the way up to 52×. However, recording speeds between 4× and 12× will produce discs with the lowest error rates. Recordable DVDs currently have maximum recording speeds of 16× (2.4× for dual-layer discs), but the lowest error rates for single-layer DVD±Rs will be achieved at recording speeds between 4× and 8×.

Before embarking on new recording projects, one or two discs should be recorded with the actual set-up (disc type, recorder, software, etc.) and then tested to ensure the error rate is sufficiently low. Specialized equipment is required for accurate error rate measurements. For large collections, it may be feasible to purchase the equipment and periodically test discs in the collection. For smaller collections, discs can be sent out for error rate testing (see Suppliers).

In the absence of specialized equipment, software such as “Nero CD-DVD Speed” can provide some information on disc quality. However, because the test results are specific to the drive being used, it is necessary to test the same disc in various drives. Also, because Nero CD-DVD Speed reports mainly the major uncorrectable errors, a disc with a high correctable error rate could still appear to be a good disc. Nevertheless, this software is free and can at least give a rough indication of disc quality.

Poor software or inadequate recording methods, such as not finalizing the recording session properly, can also lead to poorly recorded discs. These problems are not related to disc degradation, but still result in
unreadable discs. Information can sometimes be extracted from these types of discs with specialized software (see Suppliers).

Storage and Handling

As with all other information carriers, storage and handling of optical media are critical factors in determining how long they survive. The following recommendations will help maximize longevity.

Enclosures

• Store discs vertically in standard-sized jewel cases; paper or plastic sleeves are not recommended as they provide little physical protection, may interact chemically with the disc, and/or can scratch the disc surfaces.
• Use one-piece polypropylene cases for storage of discs that are handled frequently or when greater durability is desired.
• Remove liner notes or other materials from the jewel case when storing the disc (this is not essential if the disc is constructed with a gold metal layer and phthalocyanine dye).

Handling

• Hold discs by the centre hole and the outer edge between the forefinger and thumb.
• Avoid touching the disc surface with bare hands, as fingerprints will interfere with readability.
• Label discs with a water-based permanent marker on the clear inner hub; do not apply adhesive labels of any type.
• For more detailed handling information, see ISO Standard 18938:2008.

Cleaning

• Remove loose debris with a compressed air duster or a soft non-abrasive tissue or cloth, wiping from the centre of the disc outward in a radial direction. Never wipe in a circular direction.
• To remove fingerprints, apply a small amount of dishwashing liquid to the disc surface and gently wipe it with a wet soft cloth. Afterwards, rinse the disc in distilled water and carefully blot it dry to avoid the formation of water spots.
• Cleaning procedures can scratch the disc surfaces if not performed correctly.

Environmental storage conditions

• Limit exposure to pollutants and light as much as possible. Note that the negative effects of light (e.g. fading of the dye layer) are not a problem if discs are returned to their cases promptly after use.
• Suitable temperature and RH conditions are described in ISO Standard 18925:2008. The recommended RH range for extended storage is 20–50%, with RH never falling below 10% and never fluctuating more than ±10%. The recommended temperature range is from -10°C to 23°C, with the temperature never exceeding 32°C.
• Storage of discs in a cool and dry area will significantly increase media longevity.

Periodic testing

• If discs are stored under recommended conditions, test error rate and playability of representative samples every 5 years.
• If storage conditions are poor, test more frequently.

Disaster Preparedness and Recovery

To minimize the impact of a disaster such as a fire or flood, ensure that media are properly stored and that recovery procedures will be available if needed. Recovery procedures for optical disc media and other modern information carriers that have been subjected to various disasters are discussed in Technical Bulletin No. 25 Disaster Recovery of Modern Information Carriers: Compact Discs, Magnetic Tapes, and Magnetic Disks.

Remedies for Damaged Discs

Degradation and/or damage can sometimes render recordable CDs and DVDs unreadable. However, some damaged discs can be restored to normal playability. For example, there are treatments that can successfully restore scratched or warped discs. Also, a disc that can’t be played in one player/reader may play properly in another. Remedies for various degradation problems are discussed in Technical Bulletin No. 27 Remedies for Deteriorated or Damaged Modern Information Carriers.

Summary

The longevity of recordable CDs and DVDs can be maximized by adhering to the following guidelines.

Choose quality discs:

• well-known brand name/manufacturer
• recent date of manufacture (after 1995 for CD-Rs; after 1999 for DVD-Rs; after 2004 for DVD+Rs)
• phthalocyanine dye layer (not available for DVD±Rs)
• gold metal layer
• tough top protective layer (only for CD-Rs)
• no signs of damage to layers

Record the information properly:

• low error rate (<50 BLER for CD-Rs and <50 PI for DVD±Rs)
Handle the discs carefully:
• hold by the centre hole and outer edge between forefinger and thumb
• do not use adhesive labels or write on the top surface of the disc

Store the discs properly:
• a standard-size jewel case without additional materials in the case
• vertical orientation
• cool and dry environment

Ignoring these guidelines can lead to premature failure of discs, perhaps in as little as 2–10 years.

Table 2 compares the relative stability of the various optical disc formats. The most stable, and the one recommended for use when maximum longevity is desired, is a CD-R with phthalocyanine dye and a gold metal layer (Iraci 2000).

<table>
<thead>
<tr>
<th>Table 2. The relative stability* of optical disc formats</th>
</tr>
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<tbody>
<tr>
<td>CD-R (phthalocyanine dye, gold metal layer)</td>
</tr>
<tr>
<td>CD-R (phthalocyanine dye, silver alloy metal layer)</td>
</tr>
<tr>
<td>DVD-R (gold metal layer)</td>
</tr>
<tr>
<td>CD (read-only, e.g. audio CD)</td>
</tr>
<tr>
<td>DVD (read-only, e.g. movie DVD)</td>
</tr>
<tr>
<td>DVD-R (silver alloy metal layer)</td>
</tr>
<tr>
<td>CD-RW</td>
</tr>
<tr>
<td>CD-R (azo dye, silver alloy metal layer)</td>
</tr>
<tr>
<td>CD-R (cyanine dye, silver alloy metal layer)</td>
</tr>
<tr>
<td>DVD-RW</td>
</tr>
</tbody>
</table>

* These relative stability ratings are based on temperature and RH effects only. In the real world, where pollutants are also a factor, any discs without a gold metal layer (regardless of dye type) would likely rate very low on a stability scale. Therefore, although the CD-R with phthalocyanine dye and a silver alloy metal layer shows good relative stability here, it may not be an appropriate choice for practical applications where longevity is important.

**Important Note**

One key to preserving information on optical discs, magnetic tapes, and magnetic disks is to make a duplicate copy of the information on a different storage media than the original (or at least a different brand of the same storage media) and store it in a separate, off-site location.

**Suppliers**

Note: The following information is provided only to assist the reader. Inclusion of a company in this list does not in any way imply endorsement by the Canadian Conservation Institute.

**Polypropylene jewel cases:**
- Archival Products  
  http://www.archivalproducts.ca
- Brodart Company  
  http://www.brodart.ca
- Carr McLean  
  http://www.carrmclean.ca
- Dan’s Data  
  http://www.dansdata.com/discsavers.htm
- Metal Edge, Inc.  
  http://metaleedgeinc.com/Products.tpl?cart=11837484284332389&sid1=26&sid2=158&startat=1&--woSECTIONSdata=158&--SECTIONSword=ww&ran=659
- Stil Casing Solutions  
  http://www.stildesign.com/protection_numerique.html

**Phthalocyanine and gold metal layer CD-Rs and DVD-Rs:**
- MAM-A (Mitsui Advanced Media – Americas)  

**Rebranded MAM:**
- Delkin eFilm  
- HHB  
  http://www.hhb.co.uk/hhb/canada/hhbproducts/media/index.asp
- KMP (Kodak Media Products)  
  http://www.kmpmedia.com/business/product/kodak-cds
- Quantegy  
  http://www.quantegy.com/specsheets/PDF/CDR.pdf

**Others:**
- Apogee  

**Software for recovery of files from CDs/DVDs:**
- IsoBuster  
  http://www.isobuster.com
CD/DVD testing services:
AudioDev USA
http://www.audiodev.com
Canadian Conservation Institute
http://www.cci-icc.gc.ca
Media Sciences, Inc.
http://www.mscience.com

CD/DVD testing equipment:
AudioDev USA
http://www.audiodev.com
Clover Systems
http://www.cloversystems.com
DaTARIUS Technologies, Inc.
http://www.datarius.com

CD/DVD testing software:
Nero CD-DVD Speed
http://www.cdspeed2000.com

Bibliography


