TECHNICAL REPORT

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Document management applications — Optical disk storage technology, management and standards

Applications de la gestion des documents — Technologie de stockage sur disque optique, gestion et normes

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Foreword

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

The main task of technical committees is to prepare International Standards. 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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 10255 was prepared by Technical Committee ISO/TC 171, *Document management applications*, Subcommittee SC 2, *Application issues*.

Introduction

This Technical Report specifies the recommendations and provides guidance for maintaining archival optical disk collections. The problem identified is one of systems becoming obsolete prior to the expiration of the useful life of the information. Additionally, technology is evolving so rapidly that the systems might be obsolete prior to the storage media reaching its life expectancy. These issues require a considerable amount of planning to occur in the initial stages of the development and implementation of imaging systems to provide a plan for migrating the information from a system utilizing obsolete technology to a system employing advanced technology. This planning is invaluable to the overall success of the system as the information itself might have a lifespan greater than the media and technology combined, resulting in inaccessibility.

The purpose of this Technical Report is to recommend methodologies by which optical disk users can understand various optical disk issues, such as implementation, retention, obsolescence, and basic data management. In addition, this report provides information describing the differences between various optical components as well as some basic concepts that should be used when determining which optical solution best fits the users' needs.

A list of related standards is given in Annex A.

Document management applications — Optical disk storage technology, management and standards

1 Scope

This Technical Report gives recommendations and provides guidance for maintaining archival optical disk collections. It describes the various services that would be necessary for the management of an optical media-based system to ensure a successful implementation of this technology.

This Technical Report also

- provides guidance in the maintenance of data residing on on-line, off-line, and near-line digital optical storage devices;
- establishes a plan to ensure the migration path of digital information from early and current technology and optical media to future technologies and media;
- provides guidance for the short- and long-term effect of the finite life of digital optical storage devices.

This Technical Report also describes all forms of optical disk media including write-once-read-many (WORM), magneto-optical (MO), compact disk (CD), digital versatile disk (DVD) and newer technologies.

2 Abbreviated terms

2.1
BD
Blu-ray Disc

2.2
CAV
constant angular velocity

2.3
CCS
continuous composite servo

2.4
CCW
continuous composite write-once

2.5
CD-DA
compact disk-digital audio

2.6
CD-R
compact disk-recordable

2.7
CD-ROM
compact disk-read only memory

2.8
CD-RW
compact disk-rewriteable

2.9
CD-I
compact disk-interactive

2.10
CLV
constant linear velocity

2.11
DBF
discrete block format

2.12
DIF
document interchange format

2.13
DVD
digital versatile disk

2.14
DVD-Audio
digital versatile disk-audio read only

2.15
DVD-R
digital versatile disk-recordable

NOTE One of three competing recordable DVD standards; the others are DVD+R(W) and DVD-RAM.

2.16
DVD+R
digital versatile disk+recordable

NOTE One of three competing recordable DVD standards; the others are DVD-R(W) and DVD-RAM.

2.17
DVD-RAM
digital versatile disk-random access memory

NOTE One of three competing recordable DVD standards; the others are DVD-R(W) and DVD+R(W).

2.18
DVD-RW
digital versatile disk-rewriteable

NOTE One of three competing recordable DVD standards; the others are DVD+R(W) and DVD-RAM.

2.19
DVD+RW
digital versatile disk+rewriteable

NOTE One of three competing recordable DVD standards; the others are DVD-R(W) and DVD-RAM.

2.20
DVD-ROM
digital versatile disk-recorded optical media or read only memory

2.21
DVD-Video
digital versatile disk-video

2.22
ECC
error correcting coding

2.23
FAT
file allocation table

NOTE Originally developed for the MS-DOS operating system.

2.24
GIF
graphics interchange format

2.25
HD-DVD
high definition-digital versatile disk

2.26
HFS
hierarchical file system

NOTE Developed for the Apple Macintosh operating system.

2.27
HPFS
high-performance file system

NOTE Developed for the OS/2 operating system.

2.28
INCITS
InterNational Committee for Information Technology Standards

2.29
ISO
International Organization for Standardization

2.30
IEC
International Electrotechnical Commission

NOTE Standards developed jointly between the IEC and the International Organization for Standardization are given the designation ISO/IEC.

2.31
JPEG
Joint Photographic Experts Group

NOTE Used to refer to both the International Standards Committee (ISO/IEC JTC 1/SC 29/WG 1) and the standard(s) they developed for coding and compression of still images.

2.32
JTC 1
Joint Technical Committee 1 on Information Technology

NOTE This is an International Standards development committee jointly operated by ISO and IEC.

2.33
LIMDOW
light intensity modulated direct overwrite

2.34
MPEG
Moving Picture Experts Group

NOTE Used to refer to both the International Standards Committee (ISO/IEC JTC 1/SC 29/WG 11) and the standard(s) they developed for video and audio encoding.

2.35
MO
magneto-optical

2.36
NFS
Network File System

2.37
NIST
National Institute of Standards and Technology

2.38
NSR
non-sequential recording for information interchange

2.39
ODC
optical disk cartridges

2.40
OSTA
Optical Storage Technology Association

2.41
PCX
PiCture eXchange

NOTE A graphics file format.

2.42
PDD
Professional Disk for DATA

2.43
RTF
rich text format

2.44
TC
Technical Committee

NOTE A committee designated by ISO to develop International Standards in a particular area.

2.45
TIFF
tagged image file format

2.46
UDO
ultra density optical

2.47
UDF
universal disc format

2.48
UNIX
trademark used for a computer operating system

2.49
VTP
variable track pitch

2.50
WAV
waveform audio format

2.51
WORM
write-once-read-many

2.52
WORM/MO
write-once-read-many/magneto-optical

3 Optical storage concepts

3.1 General

Optical storage has been used for data storage for over 20 years. Data is recorded on reflective media using a laser-powered head. The preciseness of the laser and the properties of the media combine to allow data to be stored at very high densities. For example, the current generation of optical storage technology can store up to 8,5 GB of data on a 120 mm disk and up to 50 GB of data on a 130 mm disk. The steady increase of storage capacity on removable optical media enables organizations to consider long-term storage of information for archival use taking into account reliability and technology trustworthiness.

3.2 On-line versus off-line storage

The storage components within any computer system directly affect the overall system operation. There are several different types of storage components that can be attached to any of these systems. Before discussing each of these components, let us consider the various storage groupings, including on-line storage, near-line storage, and off-line storage.

— **On-line storage** is considered to be any storage device that is always available to a system user. An example of this type of storage is a fixed hard disk either attached directly to a computer or available across a local area network. Removable storage media, including removable hard disks and optical media, are considered to be on-line storage devices when they are mounted, or in other words, can be accessed by a user without any system intervention other than reading or writing the requested data.

- **Off-line storage** defines any storage media that is removed from the system and typically stored in a separate area for archival purposes. Removable optical devices and magnetic tapes that are not mounted fall into this category.
- **Near-line storage** devices are stored in a mechanical library, which can be defined as a hardware component consisting of media drives, such as optical or tape, and numerous storage slots or bays to store the media. These libraries are often referred to as jukeboxes for their mechanical similarities to musical jukeboxes. These systems typically contain a robotics arm, which is used to store and retrieve the optical media. In addition, most optical libraries also provide a mailbox slot which is used to insert and/or remove optical media from the system for offsite storage or simple removal from the system.

  The most important aspect of the optical library is its ability to store numerous platters or other types of media as well as multiple drives in a single storage cabinet. Libraries typically only support one form of media and often only one particular class, such as CD or DVD.

3.3 Data layout formats

There are three different data formats used in the manufacturing process of 130 mm optical disks. These formats are not compatible, and media can only be read by optical disk drives supporting that particular format. Two of these formats, Format A and Format B, are described in ISO/IEC 9171.

In the list of currently available industry International Standards (see Annex A), some of these International Standards refer to continuous composite write-once capability (CCW) while others refer to WORM. The CCW media uses MO disks to emulate a WORM-like function. The recording technology used for this emulation is the same as that used for rewritable media. The references to WORM refer to ablative or permanent change write-once media (see section 3.5.2).

See Annex A for a detailed list of relevant International Standards.

3.4 Rotational models

There are two basic rotational modes used by optical disk drives. The first mode is the Constant Angular Velocity (CAV). Within this mode, the media is spun at a constant rate so the angular velocity of the optical media does not change. This simple implementation means that the outer edge of the optical disk rotates faster than the inner edge, storing data further apart toward the outer edge. Since the amount of data stored in each track is constant, the data density is greater on the innermost tracks. With this approach, the amount of data stored is limited by the data rate achieved on the inner tracks.

The second mode is the Constant Linear Velocity (CLV) mode. This mode requires that the disk speed change as the laser head moves from the innermost portion of the optical media to the outermost. The most significant aspect of this mode, in contrast to the CAV, is that the data density does not change throughout the disk. The result of the greater data density towards the outermost edge of the optical device is greater storage capabilities. In addition, since the rotation speeds are slower as the laser head is positioned over the outermost tracks, the data transfer rates are higher than they would be with CAV. Seek times are slightly longer than for CAV because the angular velocity is required to change at the same time as the head moves.

3.5 Physically writing to the disk surface

3.5.1 General

Optical media may be written using several different mechanisms. Some of these mechanisms are write once; that is, the changes made to the surface of the media are irreversible and controlled by the media recording layer, which actually identifies the media type to the optical drive.

3.5.2 Ablative

Originally, data was written onto optical media by physically etching pits into the surface. These techniques have largely been replaced by dye-layer and phase-change recording.

3.5.3 Dye-laser recording

This technique is primarily used for CD-R recording. The media contains a thin layer of light-sensitive dye. During the recording process, a laser hits the dye and causes it to change colour to denote bits. Once the recording is complete, a lower-powered laser is used to read the resulting differences between lighter and darker bits.

3.5.4 Phase change

Phase change technologies are used in many rewritable operations. The media contains a crystalline recording layer that is highly reflective. A higher-intensity laser strikes the media, causing the recording layer to change from the crystalline state to an amorphous state which does not reflect as well. A lower-intensity laser is then used to read the bits. When the information is to be overwritten, a moderate-intensity pulse is used to restore the crystalline state.

3.5.5 Magneto-optical

This technology uses a combination of magnetic and optical techniques to store large quantities of information. A laser is used to heat the surface of the media to a specific temperature which changes the magnetic properties of the media to allow polarity changes. The magnetic head is activated and changes the polarity of the bit. When the spot cools, the information is stored and accessed using a lower-powered laser. There is both a WORM and Rewritable format as discussed below.

3.5.6 WORM

WORM (Write-Once Read Many) allows a user to write data one time but read the data as many times as necessary. This technology does not allow users to easily delete or modify previously stored data. Data is always read and written to optical devices in blocks of information, or sectors. Sectors are marked when they are written on. When a request to write data is made, the drive first checks to ensure a sector is not already used. If it has been, the optical drive will not allow that sector to be rewritten, regardless of how full or empty it is; and the new data, regardless of whether it is 10 or 511 bytes in size, will be written to the next unmarked sector. The important point to remember is that data cannot be written to the previously written sector even though the sector is not full.

WORM systems are typically not inter-compatible because they use different methods to write data to the media. Originally, WORM employed ablative methods to permanently write grooves into the recording substrate. Today, most WORM drives rely on continuous composite write, or CCW – a firmware-based technique to prevent recorded areas from being rewritten or erased – or as phase change technology to permanently change the reflectance of the recording layer.

3.5.7 Rewritable

Rewritable optical data storage allows users to write over previously used sectors multiple times. This technology has been gathering popularity throughout the industry and consists of three basic approaches. The more common of these is the Magneto-optical (MO) technology, which combines features from the magnetic and optical technologies. The MO technology uses a laser to heat the surface of the media to the point at which its magnetic properties change allowing polarity changes. The magnetic head then writes the data onto the heated surface. The magnetic head reads the data without heating.

Erasure is performed by heating and re-magnetising the surface. This process requires two or three steps, depending on the recording head, to process a block of data on a sector previously written. The first pass is needed to erase existing data, the second pass to write the new data, and the third pass to verify the accuracy of the data. The second approach to rewritable media is the phase change process, which requires only one overwrite pass as compared to the MO process. The existing data is erased and the new data is written in the same pass. A third technology incorporates the new light intensity modulation-direct overwrite (LIMDOW) technology. LIMDOW technology allows magneto/optic (MO) disks to be rerecorded without using a two- or three-pass technique to change the content of the disk. At a minimum, this technology doubles the data recording performance of optical drives.

Rewritable storage technologies enable organizations to erase data from the optical device whenever required and allowed by the overall storage solution security features and/or configuration(s). For applications that require the ability to delete or modify data, rewritable optical systems offer the best solution, even though they reduce data security. Some multifunction optical drives can be modified to not allow updates to data previously written. This feature is similar to a write-protect function. It is a fairly simple matter for a user to insert the optical media in a non-modified drive (the majority of the market) thereby bypassing the so-called non-updateable feature. Caution should be exercised when using this type of WORM. Before selecting this type of optical storage, users should determine whether they truly need the level of data security provided with the WORM technology.

4 Optical media

4.1 General

Optical media are available in several form factors ranging from a diameter of 63,5 mm to 355,6 mm, and capacities of 140 MB to 60 GB. A library is required to include drives and robotics to handle the appropriate form factor. The earliest optical libraries in the late 1980's tended to incorporate large form factor cartridges. As densities have increased, the smaller form factors have become more prevalent— currently the most common disk formats are 120 mm, used by CD, DVD, and BD; and 130 mm, used by WORM/MO and UDO.

4.2 DVD technologies

DVDs originated in the consumer market but have become the preferred optical media for many applications due to the increased storage capacity per disk and the compatibility between systems.

DVDs are based on a 120 mm form factor which can support writing to one or two layers, and theoretically on both sides, with a top storage capacity of 17 GB. DVDs can be written in session-at-once, track-at-once, and packet writing modes. Both DVD+R and DVD-R support multi-session disks and can write them in track-at-once mode.

DVDs come in write-once and rewritable versions. However, there are competing standards for DVD and not all older readers/writers support all formats. The DVD Forum has released the DVD Multi-specification, which provides that compliant devices are required to be able to read and write DVD-R, DVD-RW, and DVD-RAM disks, as well as the read-only DVD-Audio, DVD-Video, and DVD-ROM formats. The DVD+RW Alliance maintains the DVD+RW and DVD+R specifications. Most DVD readers/writers available today will read both the DVD- and DVD+ formats. DVD-RAM is a unique technology from the DVD Forum that uses a dual-sided, single-layer disk and protective cartridge form factor. This provides up to 9,4 GB storage capacity and the ability to rewrite the disk more than 100 000 times.

DVD drives originally provided a data transfer rate of 1,25 MB/s, referred to today as 1×. Subsequent generations have increased the data transfer rate from 2,4×, or 3 MB/s, to 16×, or 20 MB/s.

4.3 Blue-indigo laser technologies

Technologies that use blue-indigo lasers to increase data density and throughput are commercially available. The current implementations include 130 mm media that use protective cartridges, and 120 mm DVD without protective cartridges

Current examples of blue laser-based technologies offer dramatically increased data density through several mechanisms. The blue laser operates at a much shorter wavelength than red laser. In addition, the lens used to focus the beam is more precise, resulting in storage capacities today between 20 and 60 GB per disk. The leading vendors' roadmaps describe data storage in excess of 100 GB in the next two years through improvement in optics technologies and multi-substrate disks.

4.4 Blu-ray Disc

Blu-ray disc (BD) is an optical disc storage media format. Its main uses are high-definition video and data storage. The disc has the same dimensions as a standard DVD or CD.

BD uses a “blue” (technically violet) laser operating at a wavelength of 405 nm to read and write data. Conventional DVDs and CDs use red and near infrared lasers at 650 nm and 780 nm respectively.

The blue-violet laser's shorter wavelength makes it possible to store more information on a 120 mm CD/DVD sized disc. Currently, BD media comes in 25 GB for single layer recording and 50 GB for dual layer recording. BD features improvements in data encoding that further increase capacity.

4.5 Ultra Density Optical (UDO)

An Ultra Density Optical disc or UDO is a 133,35 mm ISO/IEC 17345 cartridge optical disc which can store up to 60 GB of data. Utilizing a design based on a Magneto-optical disc, but using phase change technology combined with a blue violet laser, a UDO disc can store substantially more data than a magneto-optical disc or MO, because of the shorter wavelength (405 nm) of the blue-violet laser employed. MOs use a 650 nm-wavelength red laser. Because its beam width is shorter when burning to a disc than a red-laser for MO, a blue-violet laser allows more information to be stored digitally in the same amount of space.

Current generations of UDO store up to 60 GB (30 GB per side), and a 120 GB version of UDO is in development.

It should be noted that these technologies use different lens optics and mechanisms that result in different densities of data and different read/write times. Some blue laser technologies use 120 mm media, while others use 130 mm. These differences result in all current blue laser-based products being incompatible. Some initiatives have been proposed to develop an industry standard for recording with blue laser technologies, but little progress has been made to date in this area.

Note also that the technology is sufficiently advanced to render it incompatible with prior generations of optical media, e.g. CD and DVD. In other words, blue-laser media readers are unable to read red-laser media and vice versa. Manufacturers have recently announced plans to make devices capable of reading both red- and blue-laser media, but these have not been put into production as yet. Moreover, there are still questions about which versions of red- and blue-laser-based technologies will be supported by particular manufacturers.

5 Optical device characteristics

5.1 General

The fundamental component in optical storage is the optical drive. This device contains the laser, actuator, and loading mechanism to allow data to be stored on the reflective optical media. A drive can be attached directly to a computer, and if the appropriate device drivers are in place, the computer can access the device for data storage and retrieval.

5.2 Readers / writers

As optical technologies have been introduced, the pattern has typically been to introduce a reader followed by a writer. These devices typically hold one media at a time and require intervention to physically unload and reload other media.

Historically these have been specific to particular optical technologies and media. For media that required cartridges, this distinction is even more pronounced.

Later generations of technology often offer increased compatibility with earlier formats.

5.3 Multi-function drives

There are three basic approaches to the development and use of multi-function drives. The first approach is the combination of WORM and phase change media. This approach provides the combined functionality of write-once capability and rewritable functionality using the phase change technology. The second approach is similar to the first but uses MO technology in place of phase change technology. The third approach is to use a single-function drive and through modification to the media provide both write-once and rewritable capabilities.

Multi-function drives provide the ability to read both WORM disks and rewritable disks using a mode which can be changed through the software drivers accessing the optical drive. This functionality was an important step forward in the optical drive industry. Most system integrators recognize the importance of using rewritable disks for those customers who need the ability to change the data on the disk. Before rewritable systems became available, users were sometimes told that even though WORM disks were write-once devices, the software provided the ability to update the data by redirecting pointers away from the old data and toward new data. In this case, the old data remains, but security features would prevent unauthorized access to any but the appropriate version. There are two significant problems with this approach. First, as the data is updated, more and more space is used. Perhaps more importantly, the data is never truly overwritten. The advantage to the approach of never erasing the older data is that the software system can be designed to store several pointers, which supports an audit trail of document changes.

Some vendors have developed a different approach to providing multi-function drives to their customers. This approach utilizes special encoding of the media when manufactured.

5.4 Jukeboxes/libraries

5.4.1 General

Commonly, optical drives are incorporated in a library configuration with an autochanger and a number of storage slots for media. This configuration is often referred to as a jukebox, since it resembles the jukeboxes of the fifties. Attaching a jukebox to a computer or, network of computers gives potential access to a very large amount of data.

Jukeboxes can be very slow in production environments where requests are made to different media constantly, because of the requirement for the robotics to unload and reload media frequently. There are strategies available to mitigate this issue, including prefetching, disk optimization, and copying the data to attached magnetic disk.

The following should be noted.

— Information stored in jukeboxes is typically used for archival purposes and access is required by the user community and usually configured along with a transient or temporary magnetic cache that is used for frequent and/or “in-process” work activities. This enables users to utilize optical storage technology for archival purposes while having rapid access to the information as required by the organization.

— Jukeboxes commonly have a standard capacity from 750 GB to 35 TB and can incorporate many different types of storage media in a secure environment.

— Access time when the media is not in a drive can average 5 s (this access time is important to understand as related to the concept of prefetching, disk optimization, copy to magnetic, etc.). In the case of data caching to hard disk, there is no latency for reading and writing of data if the information is in cache. If it is not, then the hardware latency applies, which can be on average 5 s before the media is ready for access.

5.4.2 Data cache

Data caching is the process of using a hard disk cache to manage the directory structure of the data and the reads and writes to and from the library, while in the background the cached data is archived to the optical media. This process is transparent to the user and provides significant performance benefits to the archive system. Another benefit is system longevity. Multiple requests for data may be retrieved from the cache rather than having to go and fetch the media for each request. This mitigates the unmounting and remounting media between requests. The cache is managed as part of the archive file system.

5.4.3 Prefetching

Prefetching assumes that a request for a particular piece of data will be followed by a subsequent request for nearby or related data. For example, a user who opts to retrieve a particular TIFF from a DVD may also want the next or previous TIFF, or may want all the TIFFs in a particular folder. The prefetching application retrieves those additional files automatically based on rules. Prefetching can also be based on analysis of work to be performed, so that data that may be required are cached to a high performance magnetic disk before the work is assigned.

5.4.4 Disk optimization

Disk optimization refers to storing similar documents together on the same physical media. There are two primary reasons for doing this. The first is performance related: servicing requests from a single media reduces the need to unmount and remount media between requests, dramatically speeding response times. The second relates to the need to manage documents through their lifecycle and then destroy them once that lifecycle has expired. It is simple to destroy an entire media and all the documents on it that expire at the same time, compared to managing documents with different retention periods. This is discussed in further detail in 6.8.

5.4.5 Copy to magnetic

Some optical libraries include magnetic storage as well. This magnetic storage can be used to hold the contents of several media or even all the media mounted in the library, thereby providing access to the information stored on the library at much higher speeds. This is often used when there is a regulatory requirement to store information on non-rewritable media; the data is stored on WORM-type optical media, but a higher volume of requests can be serviced faster through the local magnetic copies.

5.5 Software support for optical libraries

In attaching an optical library (jukebox) to a computer system, there are three functions that the system should be able to perform. First of all, the robotic function of the jukebox should be controlled. This is generally accomplished via device drivers, which are very low-level software programs that send commands to the jukebox to do operations like retrieve a cartridge and load it in a drive. The next function needed is the ability to format data for storage on the media. This layer of software is typically referred to as a file system. Finally, in a comprehensive system, there may be a requirement for jukebox management. This could include ejecting an infrequently used cartridge to make room for media which stores more active data.

The device driver layer of software is usually customized to the individual jukebox, but there are two approaches which can be taken to the file system and library management software.

One approach to reading and/or writing data to optical media is to implement a proprietary system, not only to read and write the actual data but also to interface with the computer. The advantage to this approach is that the system is usually streamlined to provide maximum throughput and performance without affecting the local or wide-area network. The disadvantage of this approach lies in the fact that it is a proprietary system thereby limiting future changes or modifications.

Another approach typically implemented by organizations choosing to use optical storage media eliminates the potentially very significant issue of using a proprietary methodology and utilizes ISO/IEC 13346 also referred to as “UDF”. This is a technology International Standard supported by almost all optical storage vendors/solutions used to read/write data to/from the optical media. ISO/IEC 13346 describes in great detail the methodologies to be used when reading or writing optical media, thereby ensuring the data can be retrieved at a later date by any software package supporting the industry standard.

6 Implementation strategies

6.1 General

The implementation of an optical-disk-based system can be difficult if not approached in a careful manner. Since a one-size-fits-all approach is not prudent or practical, a complete and detailed analysis of the process that is to be image-enabled should be performed. This analysis should provide information that will be used in the selection of the type of optical media, the capacity per disk, the total system capacity, and required system response. Together with the initial selection of optical storage capabilities, the imaging analysis should provide information enabling the design of an upwardly scaleable system. For example, if the current and near-future retrieval and storage requirements are small, a stand-alone optical system could provide sufficient capacity. As the need for additional data storage increases, that initial stand-alone drive could be inserted into a jukebox that would provide greater storage and retrieval capabilities. However, if the initial and near-future storage and retrieval capabilities are large, as it is in most cases, the user can purchase multiple optical drives and mount them into a jukebox that will handle the greater capacity. In any event, the buyer should estimate future growth and storage requirements and address the question of hardware compatibility and interoperability in light of future needs.

The first step in the analytical process is reviewing the existing flow of data throughout the organization that is being image-enabled. This information provides several key perspectives which are used throughout the remaining analysis, including

— the number of users currently accessing the information,

— the overall volume of information being accessed,

— access frequency,

— information's useful lifespan, and

— whether data changes over the lifespan.

The second phase of the analysis provides detailed information allowing for a tight integration between the selected imaging application and the management of the data stored on the optical media.

Note that a vendor's product could be an excellent fit for the imaging system, but if the company is planning to drop support for the product in the near-term or if the company is on shaky financial footing, the product selection will not be valid. This is especially of concern when comparing older technologies with current ones, and when evaluating newer, not as mature technologies such as blue-indigo laser-based optical storage.

6.2 Relationships between applications and optical storage management

Typically, applications use optical storage to complement or extend other storage media such as hard disk subsystems or tape backup systems. The application will track when data (either a file or other unit of data) moves from the hard disk to optical media. In order to read or write data from/to optical, applications will normally interface to a data management system very similar to the physical data management systems for hard disk subsystems. Rewritable optical media behave just like hard disk media in the sense that the same issues about optimizing storage and reclaiming storage arise. WORM media are subject to different constraints if one is to avoid wasting space on the platter.

6.3 Optical media interchange across environments

Optical media provides high capacity removable storage with an extremely long life. The removability of the media provides the opportunity to easily transport and interchange large amounts of data. The goal of data interchange is to have the ability to store files on optical media using any type of computer and then be able to access these files using any other computer system. Removable media data interchange occurs at three different levels:

— sector;

— file;

— application.

The ability to interchange data at the sector level is sector interchange. This level of interchange is what defines the ability to universally move media among different optical drives. Sectors of data are being interchanged at this level. When it is stated that two different optical drives can interchange data at the sector level, it means that the drives can read and write sectors on media created by each other.

For example, assume that there are two optical drives, one manufactured by company A and the other drive by company B, and that it is necessary to write to sectors 100 to 200 on media in drive A. With sector-level interchange, it is possible to place the media in drive B and read sectors 100 to 200 that were written by drive A. It is then possible to write to sectors 300 to 400 on the media with drive B, and then move the media to drive A and read the sectors written by drive B. Therefore drives A and B support sector level interchange between each other. Sector-level interchange is a requirement of the next level of interchange which is file level interchange.

The file level interchange is sometimes referred to as the file system interchange. This level of interchange is what defines the ability to interchange files among different computers. Optical media supports a wide variety of native file systems such as FAT (DOS), HPFS (OS/2), HFS (Apple Macintosh), JFS (AIX), System V (UNIX), etc. With removable optical media and native file systems, files can be interchanged between computers running the same operating system. To be able to interchange files between computers running different operating systems, a file system format should be used that is supported by each operating system.

ISO 9660:1988 was developed for CD-ROM devices in order to support exchanging information among different operating systems. The CD-ROM market became successful as a result of this ability to exchange information. During the past several years a new file system standard has been under joint development through several standards organizations including ECMA. ISO/IEC 13346 (all parts), *Information technology — Volume and file structure of write-once and rewritable media using non-sequential recording for information interchange,* is commonly referred to as the NSR standard since it was designed for non-sequential recording media.

The ISO/IEC 13346 format is robust and contains many useful features which will be exploited for years to come. In a move to lower the costs of obtaining file interchange, several manufacturers and ISVs have begun the process of defining a simple subset of the ISO/IEC 13346 format. The trade association, Optical Storage Technology Association (OSTA), has published the UDF specification that provides this functionality. Current operating systems provide native UDF support for UDF 1.2 and 1.5, and the 2.5 version of the International Standard has been published. UDF version 2.6 is mandatory for Blu-Ray discs.

6.4 Rewritable and WORM support

The OSTA implementation plan supports both rewritable and WORM media. Native file systems such as FAT, HPFS, JFS, etc. were designed for magnetic hard drives. Native file systems always expect to have the ability to rewrite a sector on the media. WORM technology does not allow sector rewrites so a sector may only be written once. Until NSR was available, every WORM implementation used some form of a proprietary file system since this was the only way to support WORM media. With proprietary file systems, the ability to have file interchange is lost. The OSTA common file format, based on ISO/IEC 13346, provides true WORM support and true interchange.

6.5 Operating system independence

The OSTA common file format, like ISO/IEC 13346, is not tied to any particular operating system, but may be supported on multiple platforms. All files written on a given platform are readable and writeable by the implementations on the other platforms. For example, files written on a Windows platform may be updated on an AIX system, sent to a MAC system, and then sent back. Perhaps more important than its ability to support today's platforms, is that a common file format, like ISO/IEC 13346, can support the operating systems of tomorrow.

6.6 Vendor independence

The OSTA common file format is also not tied to any one vendor, and was developed with the assistance of mostly hardware vendors and a few software providers. A special panel within OSTA submitted their document and implementation plan to the various members of OSTA who have all agreed that supporting interchange amongst themselves is more important than having any competitive advantage over each other. The real winners are the end users, who can be sure that their data is written to optical in such a way that they will be able to read it on one or two generations of drives in the future, even if their current software vendor is no longer around in 30 years.

Note that all optical disks have a longer lifespan than their drives. With a new generation of drives being introduced every 18 to 24 months, a user should stay on top of the compatibility between the current drive generation and the media in use. Many vendors cannot guarantee that their drives will read back beyond two generations of media, and making an assumption contrary to this fact will lead to long term media in conflict with short term drives.

6.7 Massive volume support

The OSTA implementation plan has been specifically designed to accommodate large file sets, which facilitates the natural growth of the user's storage needs. File sets may be contained on a single surface or spread across multiple surfaces in an optical jukebox, for example. The OSTA implementation plan meets the mass storage needs of a global community well into the future. Once there is sector and file interchange, it is possible to move data among different optical drives on different computers with different operating systems. File interchange allows one to see the same directories and files on different computers. The next level of data interchange is application interchange which deals with the contents of the files on the optical media.

If sector and file interchange between a PC and a Mac is established, it is then possible to copy files to an optical cartridge on the Mac, bring that cartridge back to a PC and type in “DIR” to see the files copied to the cartridge on the Mac. Assume that a database application called ALPHA on the Mac has been used to create the files on the cartridge. Now assume that a database application BETA is to be used to read those files on the PC. Unless ALPHA and BETA use the same file format, it will not be possible to read the data written by the ALPHA program with the BETA program. Application interchange is the ability to do just this type of interchange. To achieve application interchange, the applications are required to use the same application standards and, in this case, the same file format.

There currently exist a wide variety of file format standards that allow application interchange. There are database file format standards such as DBF, DIF, and RTF. There are image file format standards such as TIFF, PCX, GIF, JPEG, and MPEG. There are audio file format standards such as WAV and VOC. Applications that support standard file formats will be able to interchange data at the application level.

6.8 Document/records management concerns

The methodology in which data is stored on optical media is an extremely important issue. Data storage should be determined after examining some basic factors. These factors include the following issues:

— How is the data currently organized or grouped?

— What is the expected lifetime for the data or the group?

— Are there expungement/deletion/archival requirements?

— What is the relationship between data groups?

The grouping of data on optical systems usually impacts the system performance directly when retrieving data from optical storage. When determining how the data should be grouped, several factors should be taken into consideration, such as the logical grouping of the documents. As there are logically related pages within a document, there are (in many cases) logically related documents within a specific topic or functional area. Groupings such as these can be increased or changed as necessary to fit the specific needs of the end user.

When these groupings are determined, the next factor which should be considered is the amount of performance degradation if a group resides on different platters.

Document/records management is concerned with the management of information throughout its lifecycle, from creation to use to archive to final disposition, such as transfer or destruction. Information that has passed its retention date should be reviewed for disposition, which may be non-recoverable destruction. Normally, deleting a file is insufficient because the deletion process typically only removes pointers to the file and marks it as available to be written to, while leaving the actual information present until overwritten. For magnetic and rewritable optical media the process is the same. For WORM-type media the information cannot be overwritten and is always susceptible to forensic recovery. The one exception is UDO. Through the use of a specially designed “shred” operation, individual records written to Compliant UDO Write Once media can be destroyed once their retention period expires for UDO compliance media.

This issue can also be addressed by copying documents that have not met their retention period from one media to another, leaving behind those documents that have expired. The media is then physically destroyed. This is a tedious and error-prone process insofar as expired documents might be retained or non-expired documents might be inadvertently destroyed.

Another mechanism is to use disk optimization techniques to store documents with similar retention requirements and dates on the same platter so that upon expiration of the retention period the platter can be destroyed without risk to other documents.

Work is ongoing to determine better mechanisms for managing expungement of information from WORM-type media, possibly using some type of encryption mechanism to permanently encrypt the documents on the media.

7 Information management

7.1 Retention

Data retention is defined as the shortest period of time that a record should be retained before it becomes eligible for destruction. The retention schedule sets minimum and maximum retention periods for various record types within an organization, with the objective of ensuring access to the record as long as necessary and no longer. This schedule should be developed as a result of research of the appropriate legal and regulatory recordkeeping requirements of each individual organization.

7.2 Archival support

Archival refers to the preservation of recorded information and their indices for periods that extend beyond generational change. This involves protecting each media used and the information system used to drive them from any damage, ensuring accurate long-term access to the information.

Perhaps a new definition of archival will be necessary for electronic document management; some organizations consider archival to mean long-term retention for recordkeeping purposes, while others consider archival as a tool to be used for backup and disaster recovery. A prudent organization will establish its own set of requirements to meet its archival needs. In addition, audit practices should also be established to guarantee that the archive management plan is being enforced.

Optical disks are also susceptible to technological obsolescence. Provided the user can retrieve documents at acceptable quality levels, it is likely that electronic media will at some time be considered archival. In the meantime, the responsibility will always remain with the user to make sure that the storage and retrieval methods used are satisfactory.

7.3 Deterioration

Various media can be described based upon its life expectancy, or the length of time that the information is expected to be retrievable in an information system under long term storage conditions. All storage media deteriorates as a result of environmental considerations. Optical media is not affected by strong magnetic fields in the same fashion as magnetic drives, and are not affected as much by dust particulates because they can be easily cleaned. Optical media are sensitive to high humidity, high light (i.e. sun), temperature (too high or too low) and to some airborne particles (and finally a combination of these causes), so the location of functional systems becomes a critical issue when considering potential image deterioration. Different media have different capabilities to correct errors on the surface of the media; those optical disks that use protective cartridges may also last longer than non-protected media.

A critical function of system design and implementation could include a media audit function. An ongoing statistical sampling to determine the physical condition of the media and its cause will be an important feature of this audit. There are different ways optical media can be tested including specific test drives and data monitoring software applications.

7.4 Migration

As stated earlier, the incompatibility of generations of drives will be more of a factor in the lifecycle of media than the deterioration of the media. In order to address this, organizations required to retain information for extended periods should consider a migration plan. The same questions should be asked during migration planning as those asked during the initial system design:

— how the documents will be accessed and retrieved;

— the volumes required to be maintained; and

— how long the information should be kept.

Information should be migrated from older technology and media to newer while it is still readable. Once the migration is complete, the information should be verified using statistical sampling to ensure the migration was successful. It is common for organizations to implement the usage of various hash methods (i.e. SHA-1, MD5, etc.) to verify the integrity of data before and after the migration. Current best practice is to evaluate media 5 years after initial write and every 3 to 5 years thereafter; this has as much to do with maintaining hardware and software accessibility as with the actual condition of the media.

Verification is particularly important when considering migration across technologies, such as DVD to blue-indigo laser. The blue-laser readers are not backwards compatible with the older red-laser media, which can result in significant time and effort being required in order to migrate information. The migration will still be required, but should be planned for accordingly. Manufacturers have developed devices capable of reading both red and blue media.

7.5 Disposal

As documented in ISO 12037, disposal consists of the destruction of the electronic document or image and may include the elimination of its index information. This would only occur, according to the records retention schedule, when the information is no longer required. For WORM media, it may include reassigning the index pointers. For rewritable media, it will require erasing the data and inserting new data or leaving open tracks space. The destruction should follow industry accepted methods and be done upon receipt of proper authorization. In some cases, disposal requires the retention of original index information and/or specific metadata that indicates the date of disposal.

It is recommended that a periodic review of any information system be done to determine if the files and their indices have been properly identified and the retention schedule accurately reflects the current needs of the organization.

7.6 Legal admissibility concerns

Admissibility into evidence of records produced by information technology systems is an important consideration for any organization. ISO 15801 provides detailed information related to admissibility issues and should be carefully reviewed.

7.7 Evolving technology and vendor support

The technical life of the equipment and the software as well as the survival of the manufacturer/vendor is having a noticeable effect on emerging technologies. Also noticeable is the media evolution to higher performance levels and a lower cost.

Information system administrators should assess very carefully the long term relationship with the vendor when assessing an optical system.

8 Technical issues

8.1 Optical storage device file structures

8.1.1 An International Standard, ISO/IEC 13346, specifying a format and associated system requirements for volume and boot block recognition and volume structure has been approved by ISO. ISO/IEC 13346 provides an important step towards the standardization of optical media within the imaging industry. ISO/IEC 13346 applies to all media and is not restricted to being of one type, i.e. the type of medium may be either ROM, WORM, or rewritable, or a combination of these types. ISO/IEC 13346 specifies references, definitions, notation, and basic structures that apply to all of the other parts of this International Standard. ISO/IEC 13346 also specifies a format and associated system requirements for volume and boot block recognition by specifying:

— volume recognition;

— boot descriptors intended for use to bring a system to a known state;

— levels of media interchange;

— requirements for the processes which are provided within information processing systems to enable information to be interchanged between different systems; for this purpose, it specifies the functions to be provided within systems which are intended to originate or receive media which conform to the International Standard.

8.1.2 ISO/IEC 13346-2 specifies a format and associated system requirements for volume and boot block recognition by specifying:

— the attributes of a volume and the descriptors recorded on it;

— the relationship among volumes of a volume set;

— the attributes of a partition of a volume;

— the attributes of a logical volume and the descriptors recorded on it;

— levels of medium interchange;

— requirements for the processes which are provided within information processing systems to enable information to be interchanged between different systems; for this purpose, it specifies the functions to be provided within systems which are intended to originate or receive media which conform to ISO/IEC 13346.

8.1.3 Along with these items, ISO/IEC 13346 specifies a format and associated system requirements for file structure by specifying:

— the placement of files;

— the attributes of the files;

— the relationship among files of a logical volume;

— levels of medium interchange;

— requirements for the processes which are provided within information processing systems to enable information to be interchanged between different systems; for this purpose, it specifies the functions to be provided within systems which are intended to originate or receive media which conform to ISO/IEC 13346-4.

8.1.4 In addition to these file structure requirements, ISO/IEC 13346 specifies a format and associated system requirements for record structure by specifying:

— record structures intended for use when the information constituting a file is required to be interpreted as a set of records;

— the attributes of the records of a file;

— requirements for the processes which are provided within information processing systems to enable information to be interchanged between different systems; for this purpose it specifies the functions to be provided within systems which are intended to originate or receive media which conform to ISO/IEC 13346-5.

8.2 Periodic testing

Standard test methods for optical storage media characteristics are essential and allow for conformance verification to media interchange standards.

9 Optical disk standards

There are three primary areas of development for optical disk standards. Together these areas provide complete coverage of the appropriate optical components. These areas are covered in the multitude of International Standards which are listed in Annex A, and include:

— media interchange International Standards;

— test methodology International Standards;

— data and file system International Standards.

Annex A
(informative)

Related International Standards

A.1 General considerations

While ongoing efforts to enhance some of the following International Standards are in process, the list in this annex provides a good view of where the imaging industry is going with non-proprietary architectures and solutions. These International Standards include (but are not limited to) those in the following list.

A.2 General International Standards

ISO/IEC 9171:1990 (all parts), *Information technology — 130 mm optical disk cartridge, write once, for information interchange*

ISO 9660:1988, *Information processing — Volume and file structure of CD-ROM for information interchange*

ISO/TR 12037, *Electronic imaging — Recommendations for the expungement of information recorded on write-once optical media*

ISO/IEC 13346 (all parts), *Information technology — Volume and file structure of write-once and rewritable media using non-sequential recording for information interchange*

ISO 15801, *Electronic imaging — Information stored electronically — Recommendations for trustworthiness and reliability*

ISO/IEC 17345:2005, *Information technology — Data interchange on 130 mm rewritable and write once read many ultra density optical (UDO) disk cartridges — Capacity: 30 Gbytes per cartridge (first generation)*

A.3 Optical disk International Standards

ISO 10995:2008, *Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of the archival lifetime of optical media*

ISO/IEC 10995:2008 specifies an accelerated aging test method for estimating the life expectancy for the retrievability of information stored on recordable or rewritable optical disks. This test includes details on the following formats: DVD-R/-RW/-RAM, +R/+RW. It may be applied to additional optical disk formats with the appropriate specification substitutions and may be updated by committee in the future as required.

ISO/IEC 10995:2008 includes the following:

— stress conditions;

— assumptions;

— ambient conditions:

  — controlled storage condition, e.g. 25 °C and 50 % RH, using the Eyring model,

  — uncontrolled storage condition, e.g. 30 °C and 80 % RH, using the Arrhenius model;

- evaluation system description;
- specimen preparation;
- data acquisition procedure;
- data interpretation.

The methodology of ISO/IEC 10995:2008 includes only the effects of temperature (T) and relative humidity (RH). It does not attempt to model degradation due to complex failure mechanism kinetics, nor does it test for exposure to light, corrosive gases, contaminants, handling, and variations in playback subsystems. Disks exposed to these additional sources of stress or higher levels of T and RH are expected to experience shorter usable life times.

ISO 29121:2009, *Information technology — Digitally recorded media for information interchange and storage — Data migration method for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks*

ISO 23868:2008, *Document management — Monitoring and verification of information stored on 130 mm optical media*

ISO 23868:2008 specifies test methods to determine the quality of data on recorded media and provides specifications enabling end-user organizations to monitor data quality and ongoing conformance with the error limits required for its class identified by the manufacturer of the drive/media. ISO 23868:2008 defines error rate monitoring capabilities and procedures associated with 130 mm optical media while being used in a production environment to ensure that data is still readable throughout the expected life of the media.

ISO/IEC 9171-1:1990, *Information technology — 130 mm optical disk cartridge, write once, for information interchange — Part 1: Unrecorded optical disk cartridge*

ISO/IEC 9171-1:1990 defines characteristics of the 130 mm (5,25 in) WORM optical disk media before it is formatted. Diameter, thickness, optical path length, and other characteristics are covered in this International Standard. The recording format is covered in ISO 9171-2:1990.

ISO/IEC 9171-2:1990, *Information technology — 130 mm optical disk cartridge, write once, for information interchange — Part 2: Recording format*

ISO/IEC 9171-2:1990 addresses the recording format of the 130 mm (5,25 in) WORM optical disk. The media characteristics are covered in ISO 9171-1:1990.

ISO 9660:1988, *Information processing — Volume and file structure of CD-ROM for information interchange*

This CD-ROM file system International Standard is independent of the operating system utilizing it.

ISO/IEC 10089:1991, *Information technology — 130 mm rewritable optical disk cartridge for information interchange*

ISO/IEC 10089:1991 describes data interchange characteristics and requirements for the 130 mm (5,25 in) rewritable optical disk. The disk is recorded using MO recording techniques. Two servo methods are defined in this International Standard and it also describes a disk with 320 MB of storage, per disk side.

ISO/IEC 10090:1992, *Information technology — 90 mm optical disk cartridges, rewritable and read only, for data interchange*

ISO/IEC 10090:1992 describes data interchange characteristics and requirements for 90 mm (3,50 in) rewritable optical disk. One servo method is defined in this International Standard and it describes a single-sided disk with 128 MB of storage per disk.

ISO/IEC TR 10091:1995, *Information technology — Technical aspects of 130 mm optical disk cartridge write-once recording format*

ISO/IEC TR 10091:1995 is a complement to ISO/IEC 9171-2 for the type A and B formats. It covers the figures that characterize each format, the relationship between these figures, and the technological background used to reach decisions concerning the formats; in addition, it gives some examples of implementation.

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

ISO/IEC 10149:1995 describes the physical and optical characteristics of the 120 mm (4,72 in) CD-ROM disk of approximately 550 MB capacity on a single side. Also detailed are the sector format and the error correction code (ECC) used.

ISO/IEC 11560:1992, *Information technology — Information interchange on 130 mm optical disk cartridges using the magneto-optical effect, for write once, read multiple functionality*

ISO/IEC 11560:1992 describes data interchange characteristics and requirements for 130 mm (5,25 in) write-once-read-many (WORM) optical disks that are recorded using MO recording techniques.

ISO/TR 12037:1998, *Electronic imaging — Recommendations for the expungement of information recorded on write-once optical media*

ISO/TR 12037:1998 applies to the removal of information recorded on WORM disk media when expungement is ordered by the court or administrative authority. Expungement requires the elimination of information.

ISO 12142:2001, *Electronic imaging — Media error monitoring and reporting techniques for verification of stored data on optical digital data disks*

ISO/TR 12654:1997, *Electronic imaging — Recommendations for the management of electronic recording systems for the recording of documents that may be required as evidence, on WORM optical disk*

ISO/IEC 13346 (all parts), *Information technology — Volume and file structure of write-once and rewritable media using non-sequential recording for information interchange*

ISO/IEC 13346 describes the logical volume (disk) and file structure for optical disks. It includes standardized extensions to ECMA 167.

ISO/IEC 13403:1995, *Information technology — Information interchange on 300 mm optical disk cartridges of the write once, read multiple (WORM) type using the CCS method*

ISO/IEC 13481:1993, *Information technology — Data interchange on 130 mm optical disk cartridges — Capacity: 1 gigabyte per cartridge*

ISO/IEC 13490:1995 (all parts), *Information technology — Volume and file structure of read-only and write-once compact disk media for information interchange*

ISO/IEC 13490:1995 is also issued as ECMA 168, 2nd Edition (4 parts), December 1994.

ISO/IEC 13490:1995 is also known as the Frankfort Specification. This International Standard applies to read only and write once CD media which promises equal enrichment for UNIX, Macintosh, OS/2, and Windows NT. The Frankfort spec also supports the incremental update capability that is lacking in ISO 9660. ECMA 168 will conform to the Orange Book Specification.

ISO/IEC 13549:1993, *Information technology — Data interchange on 130 mm optical disk cartridges — Capacity: 1,3 gigabytes per cartridge.*

ISO/IEC TR 13561:1994, *Information technology — Guidelines for effective use of optical disk cartridges conforming to ISO/IEC 10090*

ISO/IEC TR 13561 provides guidelines for the control scenario including formatting, defect management, the usage of control zone data, etc. of drives which claim conformance to ISO/IEC 10090 in order to achieve better usability of the 90 mm optical disk cartridges conforming to ISO/IEC 10090.

ISO/IEC 13614:1995, *Information technology — Interchange on 300 mm optical disk cartridges of the write once, read multiple (WORM) type using the SSF method*

ISO/IEC 13614:1995 specifies the characteristics of 300 mm optical disk cartridges (ODC) providing for embossed information and for data to be written once and read multiple times (WORM). Defines the conditions for conformance testing and reference drive, the mechanical and physical characteristics of the cartridge, the format of the information, the characteristics of the embossed information, the optical characteristics, and the minimum quality of user-written data.

ISO/IEC 13842:1995, *Information technology — 130 mm optical disk cartridges for information interchange — Capacity: 2 Gbytes per cartridge*

ISO/IEC 13842:1995 specifies the conditions for conformance testing and the reference drive; the environments in which the cartridges are to be operated and stored; the mechanical, physical and dimensional characteristics of the cartridge; the format of the information on the disk; the magneto-optical characteristics of the disk; and the minimum quality of user-written data on the disk.

ISO/IEC 14517:1996, *Information technology — 130 mm optical disk cartridges for information interchange — Capacity: 2,6 Gbytes per cartridge*

ISO/IEC 14517:1996 defines a series of related 130 mm optical disk cartridges (ODCs). Gives the conditions for conformance testing and the reference drive; mechanical, physical, and dimensional characteristics; the format of the information; the magneto-optical characteristics; and the minimum quality of user-written data.

ISO/IEC 15286:1999, *Information technology — 130 mm optical disk cartridges for information interchange — Capacity: 5,2 Gbytes per cartridge*

ISO/IEC 15485:1997, *Information technology — Data interchange on 120 mm optical disk cartridges using phase change PD format — Capacity: 650 Mbytes per cartridge*

ISO/IEC 15486:1998, *Information technology — Data interchange on 130 mm optical disk cartridges of type WORM (Write Once Read Many) using irreversible effects — Capacity: 2,6 Gbytes per cartridge*

ISO/IEC 16969:1999, *Information technology — Data interchange on 120 mm optical disk cartridges using +RW format — Capacity: 3,0 Gbytes and 6,0 Gbytes*

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

ISO/IEC 17341:2006 specifies the mechanical, physical, and optical characteristics of 120 mm rewritable optical disks with capacities of 4,7 GB and 9,4 GB. It specifies the quality of the recorded and unrecorded signals, the format of the data, and the recording method, thereby allowing for information interchange by means of such disks. The data can be written, read, and overwritten many times using the phase change method. These disks are identified as +RW.

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

ISO/IEC 17345:2006, *Information technology — Data Interchange on 130 mm Rewritable and Write Once Read Many Ultra Density Optical (UDO) Disk Cartridges — Capacity: 30 Gbytes per Cartridge — First Generation*

ISO/IEC 17345:2006, an ECMA-approved standard, covers the UDO disk format from Plasmon.

ISO/IEC 18093:1999, *Information technology — Data interchange on 130 mm optical disk cartridges of type WORM (Write Once Read Many) using irreversible effects — Capacity: 5,2 Gbytes per cartridge*

ISO 18925:2008, *Imaging materials — Optical disc media — Storage practices*

ISO/IEC 20162:2001, *Information technology — Data interchange on 300 mm optical disk cartridges of type WORM (Write Once Read Many) using irreversible effects — Capacity: 30 Gbytes per cartridge*

ISO/IEC 22092:2002, *Information technology — Data interchange on 130 mm magneto-optical disk cartridges — Capacity: 9,1 Gbytes per cartridge*

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