Understanding CD-R & CD-RW

OSTA.org

**Optical Storage
Technology Association**

Optical Storage Technology Association (OSTA)
Market Development Committee

Author's Notes

It's often said that the only constant in the computer and consumer electronics industries is change. Nonetheless, CD-R and CD-RW have remained a constant and trusted companion for many. CD-R and CD-RW technologies have, of course, evolved over the years but change here has come in practical and tangible improvements to quality, performance and ease of use. Unique compatibility and affordability, at the same time, have made CD-R and CD-RW the popular storage choice of industry and consumers alike.

This paper replaces OSTA's earlier "CD-R & CD-RW Questions & Answers" document. Like its predecessor, it seeks to answer basic questions about CD-R and CD-RW product technology in an understandable and accessible way and to provide a compass pointing to sources of further information.

If you have suggestions to improve the effectiveness of this paper, please feel free to contact the author by email: hugh_bennett@compuserve.com.

Sincerely,

Hugh Bennett, President
Forget Me Not Information Systems Inc.

TABLE OF CONTENTS

PHYSICAL, LOGICAL AND FILE SYSTEM STANDARDS

What is the Orange Book?

Orange Book is the set of specifications created by Philips and Sony to define the optical signal characteristics, physical arrangement, writing methods and testing conditions for CD-R (Orange Book Part II) and CD-RW (Orange Book Part III) discs. First released in 1990, Orange Book originally dealt with only single speed CD-R recording but, with rapid advances since made in hardware and media technology, the specification grew to include CD-RW in 1996. Higher writing speeds continue to be incorporated as the industry evolves.

What are the different sections of CD-R and CD-RW discs?

Orange Book organizes CD-R and CD-RW discs into various sections serving distinct purposes. The Information Area is most fundamental and consists of a shallow spiral groove (pregroove) extending from the discs' inside to outside diameter. Encoded in the structure of this pregroove are speed control and Absolute Time In Pregroove (ATIP) time code information as well as other parameters critical for recorders to correctly write a disc. Several regions within this pregroove are reserved exclusively for recorder use.

The first is the Power Calibration Area (PCA), located in the inner portion of the disc, which is employed while determining the correct power level for the writing laser. Due to physical and practical design limitations on rotational velocity it is, generally speaking, not possible to conduct power calibrations at the inner diameter of the disc at speeds above 16x. A process of extrapolation is therefore used to determine suitable writing power for those higher speeds. Recently, Orange Book has designated the addition of another PCA located in the Lead-Out Area at the outer portion of the disc to provide the space necessary to conduct actual high speed write power calibrations.

Following the first PCA is the Program Memory Area (PMA) which is used as intermediate storage to record track information for all sessions written to the disc. Typically, the PMA is first followed by the Lead-In Area, containing table of contents information, followed by the Program Area which holds the written data tracks and finally the Lead-Out Area which indicates to a reading device that the end of the data has been reached.

What is a Multisession CD-R or CD-RW disc?

Multisession recording allows additional data to be written to a previously partially recorded CD-R or CD-RW disc. Each session on the multisession disc has its own Lead-In Area, Program Area and Lead-Out Area and may be connected to other sessions to function as a single volume (linked) or operate independently (multi-volume). In addition to being written by a recorder the first session of a multisession disc can be, alternatively, prerecorded (stamped) at the factory.

What is the difference between fixation and finalization?

Fixation is the process of completing a CD-R or CD-RW disc session by writing Lead-In (table of contents) and Lead-Out information. Once a disc is fixated it can then be played back in CD and DVD-ROM drives and recorders and consumer electronics devices compatible with the particular disc type and format. It is also possible to record additional information later to create a multisession disc. Finalization, on the other hand, completely closes the disc so no further material can be added.

What are the different writing modes?

CD-R and CD-R/RW recorders employ several different writing modes including Disc-At-Once (DAO), Track-At-Once (TAO), Session-At-Once (SAO), and packet writing. Be aware that not all recorders and software support all writing modes. If in doubt, consult with the product manufacturer.

During DAO recording the Lead-In Area, Program Area and Lead-Out Area of a CD-R or CD-RW disc are consecutively written in a single uninterrupted operation. DAO recording is only possible using a blank disc and, after recording is completed, no additional information can be written. Typically, DAO is used to write CD audio, CD-Text and discs destined for mass replication.

In contrast to DAO, TAO operates by turning the writing laser on and off at the beginning and end of each track and writes the Program Area of a disc before its Lead-In and Lead-Out Areas. It is possible to use a recorder to read from (or write additional tracks to) a TAO disc before a session is fixated. All TAO discs contain 2 to 3 second gaps between tracks (run-in, run-out and link blocks) but some recorders have the ability to vary the size of the gaps.

SAO is much like DAO in that the Lead-In Area, Program Area and Lead-Out Area are consecutively written in a single uninterrupted operation. However, the first session is not finalized so additional sessions can be added. Typically, SAO is used to write CD Extra (Enhanced Music CD) discs where the first session contains one or multiple audio tracks and the second session consists of multimedia computer data.

Packet writing records variable (CD-R) or fixed (CD-RW) sized chunks or "packets" of data to the disc for as many times as is needed to complete the writing of the user's files. In the case of a CD-R disc (which is not erasable) data may be added incrementally until the disc becomes full. CD-RW discs, on the other hand, are completely rewritable and thus are a little different from their CD-R cousins in that files can be added and deleted as needed.

What is ISO 9660?

The ISO 9660 standard was introduced in 1988 and is the most widely used file format for data (CD-ROM) discs. ISO 9660 defines a common logical format for files and directories so discs written to ISO 9660 specifications can be read by a wide array of computer operating systems (MS-DOS, Windows, Mac OS, UNIX, etc.) as well as consumer electronics devices. Due to the vast differences which exist among native file systems ISO 9660 takes a lowest common denominator approach resulting in a variety of restrictions upon the nature and attributes of files and directories. Three levels of interchange define these restrictions with level one being the most constraining and level three is the least (at the cost of compatibility with some operating systems). Various protocols are available to extend ISO 9660 to accommodate file system features specific to individual operating systems (longer file names, deeper directory structures, more character types, etc.) while preserving ISO 9660 compatibility with other platforms. These protocols include Joliet (Windows 95 and higher), Apple Extensions (Mac OS) and Rock Ridge (UNIX).

What is The Universal Disc Format (UDF)?

The Universal Disc Format (UDF) specification was first released by OSTA in 1995 and is designed to be a common logical file system for all removable optical storage media. Over the years various updates to UDF have been introduced to add new capabilities. For example, UDF 1.02 is the standard file system used for prerecorded and recordable DVD discs while UDF 1.5 is commonly employed for packet writing CD-R and CD-RW media. Most recently, UDF 2.0 has added full support for Windows NT, enhanced data security and improved CD-R functions while defining backward read capabilities between discs created with the new UDF 2.0 format and discs created with earlier versions of UDF.

What is a hybrid disc?

The term "hybrid" is popularly used to describe several different types of discs. The first kind of hybrid disc is one that contains multiple file systems, such as ISO 9660 and HFS (Mac OS). A second type of hybrid is a CD that contains applications designed to interact with the Internet so static data resides on the disc and live information is downloaded as needed from the Web. These discs are sometimes called "connected CDs." A third kind of hybrid is defined by Orange Book as a CD-R or CD-RW disc with a prerecorded (stamped) first session with the ability to potentially hold additional written sessions.

What is Running OPC?

Running Optimum Power Control (Running OPC) is a special technique used in many newer CD-R and CD-R/RW recorders that monitors and maintains the quality of the disc writing and ensures the accuracy of all the marks and lands lengths across the disc. The term Running OPC actually describes the general process that may be known by several trade names. Some differences in execution may be present to give some of these implementations competitive advantages over others.

RECORDING HARDWARE

What types of devices write CD-R and CD-RW discs?

All CD-R and CD-R/RW recorders write CD-R discs but only CD-R/RW recorders write both CD-R and CD-RW discs. Many DVD recorders also come combined with CD-R and CD-RW writing functions but be aware that there are exceptions. If in doubt, consult with the hardware manufacturer.

Are there audio CD recorders available that connect to stereo systems?

Several manufacturers offer consumer and professional audio CD recorders that connect, like cassette decks, to conventional stereo systems. Typically, they will record to CD-R or CD-R and CD-RW discs from either digital (CD, DAT, MD, etc.) or analog (cassette, vinyl record, radio, etc.) sources.

What do the numbers describing a CD-R or CD-R/RW recorder mean?

Manufacturers typically use a sequence of two, three or four numbers to express the maximum writing and reading speeds of a recorder. The generally accepted industry convention for a CD-R recorder has been for the first figure to indicate CD-R writing speed followed by CD reading speed for CD-R and prerecorded (pressed) data CDs. For a CD-R/RW recorder the first number usually indicates CD-R writing speed followed by CD-RW writing speed and then by the CD reading speed. In the case of a combination recorder a fourth number is included to indicate DVD reading speed. As examples, 8x12 usually means 8x CD-R write and 12x CD read while 48x12x48 typically indicates 48x CD-R write, 12x CD-RW write and 48x CD read. And for a combination recorder 24x10x40x12 denotes 24x CD-R write, 10x CD-RW write, 40x CD read, and 12x DVD read.

What types of CD-R and CD-R/RW recorder configurations are available?

Whether for PC, Mac or UNIX computers in desktop, laptop or notebook form, CD-R and CD-R/RW recorders are available in a wide variety of configurations to suit most needs. Several industry standard interfaces are available including SCSI, EIDE/ATAPI, Parallel, USB and IEEE 1394 for either internal or external recorder connection.

EIDE/ATAPI
The Enhanced Integrated Drive Electronics/ATA Packet Interface (EIDE/ATAPI) is the most popular method for connecting CD and DVD-ROM drives and hard disks as well as CD-R and CD-R/RW recorders to a computer. Since most computers already have EIDE/ATAPI built-into their motherboards no additional interface card is necessary. These devices are normally installed internally but many external recorders are actually EIDE/ATAPI models that use bridge technology to convert them to SCSI, USB or IEEE 1394 interfaces.

SCSI
The Small Computer Systems Interface (SCSI) or "scuzzy" interface is a high performance and flexible method of connecting to a computer many peripherals including scanners, CD and DVD-ROM and hard drives as well as CD-R and CD-R/RW recorders. In addition to long cable lengths, SCSI allows for both internal and external attachments. Some computers already have SCSI built-into their motherboards, but, more often than not, a SCSI interface card is required. Depending upon the specific product, a SCSI card may or may not be included with the CD-R/RW recorder bundle.

Parallel
CD-R/RW recorders that make use of a parallel interface connect to the computer using the same parallel port used by a printer and can only be installed externally. Depending upon the product, some recorders have pass-through arrangements allowing both a printer and recorder to be connected to the computer at the same time.

USB
The Universal Serial Bus (USB) is used to connect many types of peripherals to a computer including joysticks, mice, keyboards, printers, scanners and external CD-R and CD-R/RW recorders. Since USB is a plug and play interface computers do not have to be rebooted when a recorder is attached as these devices are automatically recognized by the system. And USB has been updated several times to accommodate the demands of increasingly faster peripherals. USB 1.1 interfaces are built into the motherboards of many systems and generally permit up to 4x CD-R/RW writing and 6x reading speeds. USB version 2.0 is an updated version of the specification allowing greater performance but typically requires an additional interface card. Most USB 2.0 CD-R/RW recorders are backward compatible and can operate at reduced speed when connected to older USB 1.1 systems.

IEEE 1394
Popularly known by trade names such as FireWire and i.LINK, IEEE 1394 is a high performance plug and play interface commonly used to connect computers to external hard disk drives and CD-R and CD-R/RW recorders as well as consumer electronics devices like digital camcorders, televisions and game consoles. IEEE 1394 interfaces come standard on many Macintosh systems and on some brands of PCs but, more often than not, an interface card is required.

What is buffer underrun?

An important point to remember about CD-R and CD-RW recording is that information must be written to a blank disc in a continuous stream. To help smooth out the flow in the data transfer rate from the computer, the recorder employs a memory buffer which, like a reservoir storing water for use when it is needed, caches data for when it is required by the recorder. As with a water reservoir, the key is to always have enough data in the buffer to satisfy the demands of the recorder, even if, from time to time, the computer can't supply the needed amount of information. If the buffer runs dry (a "buffer underrun") the disc is ruined.

How can buffer underrun be prevented?

Most current computer recorders incorporate advanced buffer underrun protection technology to eliminate buffer underruns but for units not so equipped there are a variety of common sense techniques that can be used to help minimize the possibility. These include ensuring that the recorder and writing software are properly configured, defragmenting the operating system and data source hard disk partitions, disconnecting from any networks, closing all other programs and disabling background tasks such as power managers and anti-virus software. In more stubborn cases additional measures to be considered include reducing writing speed as well as enabling the recording software to build a temporary image on the hard disk drive before recording.

What is buffer underrun protection?

In order to keep pace with the demands of ultra speed writing, recorder manufacturers have created new technologies for preventing buffer underruns. A recent innovation now known by a multitude of different trade names, buffer underrun protection utilizes a combination of recorder hardware, firmware and writing software to accomplish its task.

Buffer underrun protection functions by constantly monitoring the amount of data in the recorder's buffer during the writing of a disc and suspends recording if the amount available falls below a predetermined threshold. Once the buffer again accumulates sufficient data the recorder resumes writing precisely where it left off. Obviously, it's critical to leave as small a gap as possible between the previous and newly recorded sections so as to avoid producing an unreadable segment on the disc. Generally speaking, the gap length has been found to be well within the error correction capabilities of CD and DVD-ROM drives and players. As the technology matures the gap will continue to shrink.

RECORDING SOFTWARE

Is special software needed to use CD-R and CD-R/RW recorders?

The two main types of software needed to operate CD-R and CD-R/RW recorders, namely packet writing software and CD recording software (sometimes called premastering software), are available for most major operating systems. The majority of CD-R and CD-R/RW recorders include either one or both types as part of their purchase bundles. Be aware, however, that software from competing publishers may offer a different range of features. In addition, some current operating systems and standalone application software have built-in CD-R and CD-RW recording capabilities.

CD Recording Software
Unlike many removable storage solutions that are restricted to just housing and retrieving data, CD-R and CD-R/RW recorders are also used as powerful multimedia devices. In addition to providing the means to store, backup and distribute data on CD-R and CD-RW discs, many CD recording software packages also include the tools necessary to write or edit different content on CDs such as music, photos and video.

Taking the form of standalone applications, many recording software packages have the capability to create discs in different physical formats (eg. data, audio, video, hybrid, etc.) using various file systems (eg. UDF, ISO 9660, HFS, etc.) and support different file naming conventions (eg. Joliet, Rock Ridge, Apple extensions, etc.). Some can actually clean up clicks, pops, scratches and hiss from old music LPs or cassettes and lay out and print labels and jewel case inserts to personalize and identify discs after they are written. Depending upon the package, other capabilities may include the ability to duplicate CDs, assemble Red Book CD-DA or compressed digital audio compilation CDs a track at a time from different sources and even create photo and video albums.

Packet Writing Software
Packet writing software installs at the driver level and makes a CD-R or CD-R/RW recorder seem to the user as just another removable drive. Appearing the same as a floppy or hard disk, users write files to a CD-R or CD-RW disc by simply dragging and dropping the files over the recorder's icon or saving from within an application.

As with all removable storage systems, the first step in operating a CD-R or CD-R/RW recorder using packet writing software is to initialize the disc to prepare it to receive the user's data. After inserting a blank disc into the recorder the user is prompted by the computer to initialize the disc which is then ready to go after an automatic formatting procedure. Some products conduct background formatting where the disc is available to write shortly after initiating the process but others require formatting to complete before data can be written.

Packet writing records variable (CD-R) or fixed (CD-RW) sized chunks or "packets" of data to the disc for as many times as is needed to complete the writing of the user's files. In the case of a CD-R disc (which is not erasable) data may be added incrementally until the disc becomes full. CD-RW discs, on the other hand, are completely rewritable and thus are a little different from their CD-R cousins in that files can be added and deleted as needed. Typically, packet writing software records CD-R and CD-RW discs in OSTA's Universal Disc Format (UDF).

What is the storage capacity of CD-R and CD-RW discs formatted for packet writing?

After being formatted for packet writing use the storage capacity of CD-R and CD-RW discs is somewhat less than their unprepared state. For example, a 74 minute/650 MB (12 cm) CD-R disc has an initial formatted capacity of roughly 620 MB while an equivalent CD-RW disc stores approximately 530 MB after being formatted for random rewriting. Due to increased defect management overhead, a Mount Rainier formatted CD-RW disc is able to store roughly 30 MB less than its conventionally packet written counterpart.

Are CD-RW discs created using packet writing software from different publishers compatible with each other?

Generally speaking, it is possible to format a CD-RW disc using one publisher's packet writing software and write to the same disc using software offered from a different publisher. However, once data has been written to the disc only the software that was used to write the information can be used to append or rewrite other data. Greater writing interchangeability for CD-RW discs is, however, one of the primary goals of the new Mount Rainier format. It is advisable to consult with the appropriate software publisher for specific compatibility details.

What is Mount Rainier?

The Mount Rainier specification was developed in 2001 to provide the framework necessary for computer operating systems to seamlessly rewrite data CD-RW discs in a drag and drop fashion without the use of additional drivers or software. Through enhancements over the abilities of conventional packet writing software, including background formatting, recorder-based defect management, improved interchangeability and greater ease of use, Mount Rainier's goal is to make 3.5" floppy diskettes obsolete by replacing them with CD-RW discs for everyday data storage and interchange.

What is required to read and write Mount Rainier CD-RW discs?

Mount Rainier formatted CD-RW discs are rewritten on Mount Rainier-enabled CD-R/RW recorders. Since this specification is a recent innovation it is supported by only some of the latest recorders but it is expected that, over time, an increasing number of new units will incorporate Mount Rainier capability. In cases where the operating system being used does not offer Mount Rainier functions it will be necessary to employ additional software to format and rewrite discs. Typically, this comes as modified conventional packet writing software to allow the rewriting of Mount Rainier formatted CD-RW discs.

Mount Rainier formatted CD-RW discs are read on MultiRead-compliant CD-ROM drives, CD-R/RW recorders and MultiRead-compliant DVD-ROM drives and recorders. In situations where the operating system used does not offer Mount Rainier functions it is necessary to employ an additional software driver to read the discs. It is therefore advisable to consult with the appropriate hardware manufacturers and software publishers to verify the specific capabilities of your recorder, operating system and writing software.

RECORDING SPEED

How long does it take to write a CD-R or CD-RW disc?

The amount of time taken to write a disc depends upon the speed of the recorder, the writing method used by the recorder and the amount of information required to be written. Recording speed is measured the same as the reading speed of ordinary CD-ROM drives and players. At single speed (1x) a recorder writes 150 KB (153,600 bytes) of data (CD-ROM Mode 1) per second and at a multiple of that figure at each speed increment above 1x.

CD Read and Write Average Data Transfer Rates
(transfer rates indicated in bytes)

Read/Write Speed (CLV)	Audio (2,352 Bytes/Block)	CD-ROM Mode 1 (2,048 Bytes/Block)	CD-ROM Mode 2 (2,336 Bytes/Block)	CD-i/XA Form 1 (2,048 Bytes/Block)	CD-i/XA Form 2 (2,324 Bytes/Block)
1x	176,000	153,600	175,200	153,600	174,300
2x	352,800	307,200	350,400	307,200	348,600
4x	705,600	614,400	700,800	614,400	697,200
6x	1,058,400	921,600	1,051,200	921,600	1,045,800
8x	1,411,200	1,228,800	1,401,600	1,228,800	1,394,400
12x	2,112,000	1,843,200	2,102,400	1,843,200	2,091,600
16x	2,816,000	2,457,600	2,803,200	2,457,600	2,788,800
20x	3,520,000	3,072,000	3,504,000	3,072,000	3,486,000

Writing Modes
As the market for CD-R and CD-RW products came into its own writing speed accelerated due to rapid advances made in hardware and media technology. One breakthrough came in writing modes which permitted recorders to reliably operate beyond 20x speed. Available units now employ a variety of writing modes including Constant Linear Velocity (CLV), Zone Constant Linear Velocity (ZCLV), Partial Constant Angular Velocity (PCAV) and Constant Angular Velocity (CAV).

Constant Linear Velocity (CLV)
CDs were originally designed for consumer audio applications and initially operated using a CLV mode to maintain a constant data transfer rate across the entire disc. The CLV mode sets the disc's rotation at 500 RPM decreasing to 200 RPM (1x CLV) as the optical head of the player or recorder reads or writes from the inner to outer diameter. Since the entire disc is written at a uniform transfer rate it takes, for example, roughly 76 minutes to complete a full 74 minute/650 MB disc at 1x CLV. As recording speed increases the transfer rate increases correspondingly so that at 8x CLV writing an entire disc takes 9 minutes and at 16x 5 minutes. Recording time as well is directly related to the amount of information to be written so partial discs are completed in proportionally less time. But writing at higher speeds requires rotating the disc faster and faster (eg. 10,000 to 4,000 RPM at 20x CLV which places escalating physical demands upon both

media and hardware. Manufacturers have met this challenge by moving beyond the original CLV mode to obtain even higher performance.

Zone Constant Linear Velocity (ZCLV)
In contrast to CLV which maintains a constant data transfer rate throughout the recording process, ZCLV divides the disc into regions or zones and employs progressively faster CLV writing speeds in each. For example, a 40x ZCLV recorder might write the first 10 minutes of the disc at 20x CLV, the next 15 minutes at 24x CLV, the following 30 minutes at 32x CLV and the remainder at 40x CLV speed.

Partial Constant Angular Velocity (PCAV)
Some recorders make use of the PCAV mode which spins the disc at a lower fixed RPM when the optical head is writing near the inner diameter but then shifts to CLV part way further out on the disc. As a result, the data transfer rate progressively increases until a predetermined point is reached and thereafter remains constant. For example, a 24x PCAV recorder might accelerate from 18x to 24x speed over the first 14 minutes of the disc then maintain 24x CLV writing for the remainder of the disc.

Constant Angular Velocity (CAV)
The CAV mode spins the disc at a constant RPM throughout the entire writing process. Consequently, the data transfer rate continuously increases as the optical head writes from the inner to outer diameter of the disc. For example, a 48x CAV recorder might begin writing at 22x at the inner diameter of the disc accelerating to 48x by the outer diameter of the disc.

What is the difference between low and high speed CD-RW discs?

CD-RW media present additional problems in that it is not possible for one kind of CD-RW disc to support all recording speeds. Low speed discs are compatible with all CD-RW recorders and can only be written from 1x to 4x speeds. High speed discs, on the other hand, can be written from 4x to 10x but only on recorders bearing the high speed CD-RW logo.

Can CD-R and CD-RW discs written at different speeds be read back at any speed?

The speed at which a disc is written has nothing to do with the speed at which it can be read back in a recorder, CD-ROM or DVD-ROM drive.

Do some CD-R recording speeds produce better results than others?

Recorder and media manufacturers carefully tune their products to operate with each other across a wide range of speeds. As a result, equally high quality CDs are created when recording at almost all speeds. However, 1x presents a minor exception. Generally speaking, the physics and chemistry involved in the CD recording process seem to produce more consistent and readable marks in CD-R discs at 2x and greater speeds.

Can any CD-R disc be recorded at any speed?

In order to accommodate progressively higher recording speeds CD-R disc design and manufacturing has continued to evolve. Consequently, reliable operation is best achieved by following disc manufacturers' guidance with respect to the range of writing speeds formally supported by their respective discs, while acknowledging that this can change as recording specifications change. Additionally, new media companies and products continually enter the market and some recorder companies may test particular brands of discs more extensively than others. Thus it may be advisable to inquire of the recorder manufacturer for specific media recommendations.

Is there any way to prevent a recorder from writing a CD-R disc at too high a speed?

CD writing speed can be set at an appropriate level manually in all premastering software to correspond with the recommendations of the recorder and disc manufacturers. Beyond this, some of the latest recorders also employ systems to actively monitor the writing process and automatically adjust recording speed in order to achieve the optimum results.

PHYSICAL COMPATIBILITY

What types of devices read CD-R discs?

Once written, CD-R discs closely mimic the optical characteristics of prerecorded (pressed) CDs. As a result, they can be read on almost any computer CD-ROM drive, CD-R or CD-R/RW recorder or MultiRead-compliant DVD-ROM drive or recorder. Additionally, CD-R discs are compatible with most consumer electronics devices including portable, car and set-top CD audio players and MultiPlay-compliant DVD-Video players and recorders. All DVD devices that read CD-R discs do not necessarily display the MultiRead or MultiPlay logos. If in doubt, consult with the hardware manufacturer.

What types of devices read CD-RW discs?

Written CD-RW discs have slightly different optical characteristics (lower reflectivity and signal modulation) than prerecorded (pressed) and written CD-R discs and therefore are not as widely compatible. They can be read only on MultiRead-compliant CD-ROM drives, CD-R/RW recorders and MultiRead-compliant DVD-ROM drives and recorders. CD-RW discs are, in addition, compatible with some consumer electronics devices including MultiPlay-compliant portable, car and set-top CD audio players and MultiPlay-compliant DVD-Video players and recorders. Again, all CD and DVD devices that read CD-RW discs do not necessarily display the MultiRead or MultiPlay logos. If in doubt, consult with the hardware manufacturer.

What is MultiRead?

The MultiRead specification was created by OSTA in 1997 to provide hardware manufacturers with the requirements necessary to make CD-ROM drives and recorders read CD-RW discs. MultiRead also bridges the differences between CD and DVD technologies and provides the framework for DVD-ROM drives and recorders to read CD-R and CD-RW discs. Specifically, MultiRead requires that compatible drives read Red Book CD audio and CD-ROM information contained on prerecorded (pressed), CD-R and CD-RW discs.

**Examples of Discs Readable by
MultiRead-Compliant Drives and Recorders**

Type of Disc	CD-ROM Drive	CD-R Recorder	CD-R/RW Recorder	DVD-ROM Drive	DVD-R/-RW Recorder	DVD-RAM Recorder	DVD+R/+RW Recorder
CD-DA disc	yes	yes	yes	yes	yes	yes	yes
CD-ROM disc	yes	yes	yes	yes	yes	yes	yes
CD-R disc	yes	yes	yes	yes	yes	yes	yes
CD-RW disc	yes	yes	yes	yes	yes	yes	yes

What is MultiPlay?

The MultiPlay specification was created by OSTA in 2000 to provide hardware manufacturers with the requirements necessary to make CD and DVD consumer electronics devices play CD-R and CD-RW discs. Specifically, MultiPlay requires that all compatible devices play prerecorded (pressed), CD-R and CD-RW discs in Red Book audio format. As well, devices with CD-Text and VideoCD capabilities must also play these formats when written on CD-R and CD-RW discs.

Why can't all DVD devices read CD-R and CD-RW discs?

DVD format specifications deal with elements of disc design and not the hardware that reads them. As a result, DVD device manufacturers are free to incorporate whatever features they like into their products, including deciding which types of discs are supported. Consumer demand and cost considerations are taken into account by manufacturers who then construct their products and marketing accordingly.

In addition to these market forces a number of technical issues come into play. Despite appearances to the contrary, a CD and a DVD are distinctively different physically from each other. For example, a DVD disc uses a substrate half as thick as does a CD (0.6 mm vs. 1.2 mm) as well as smaller pit and lands and has less distance between the coils of the data track. A DVD is also read using a shorter wavelength laser (650 nm red vs. 780 nm infra-red) through an optical lens with a larger numerical aperture (0.60 vs. 0.45). Thus, DVD devices which also read prerecorded (pressed) CDs employ a number of tactics to accommodate these differences. However, a CD-R disc has its own unique construction so reading it requires additional hardware components.

Unlike the molded plastic pits of a prerecorded disc the optical responses of the organic dyes used in the recording layer of a CD-R disc are carefully designed to function in the 780 nm range used by CD drives and recorders. Consequently, when a CD-R disc is read using the shorter 650 nm DVD laser wavelength the signals returned from the disc are greatly diminished and may not be read reliably. DVD devices that are designed to read DVD and CD-R discs (such as those compliant with MultiRead and MultiPlay specifications) compensate for this problem by incorporating dual laser optical pickups to generate both 650 nm and 780 nm wavelengths.

A CD-RW disc is a little different. The optical response of the phase change material used in its recording layer is not as wavelength dependent as organic dye in a CD-R and can be read using a 650 nm laser. However, because a CD-RW disc has relatively low reflectivity and signal modulation the optical systems of some DVD devices may not be sensitive enough to read it.

DISC SIZE AND CAPACITY

What are the physical sizes of CD-R and CD-RW discs?

CD-R and CD-RW discs come in standard 12 cm (120 mm) and 8 cm (80 mm) sizes. The most popular is the larger 12 cm type which has the same physical dimension as most commercial audio CDs and computer software CD-ROMs. 8 cm discs are less common but, thanks to their smaller size, are gaining popularity for use in consumer electronic devices such as portable compressed digital audio players, digital still image cameras and data storage products like miniature CD recorders.

What about business card CD-R and CD-RW discs?

Beyond the conventional 8 cm and 12 cm sizes some manufacturers offer discs shaped like business and credit cards or in other novelty forms. These do not conform with Orange Book specifications and, as a result, may not write and play back in all recorders or reading devices. Following manufacturer instructions is always the best course.

What capacities of blank CD-R and CD-RW discs are available?

Manufacturers commonly express disc capacity in terms of how much Red Book digital audio (in minutes) and computer data (in megabytes) a disc can contain. Historically, 63 minute/550 MB (12 cm) and 18 minute/158 MB (8 cm) discs were once available but are now rendered obsolete by advances in recording technology. Currently, 74 minute/650 MB, 80 minute/700 MB (12 cm) and 21 minute/185 MB (8 cm) discs are the market standards.

What about 34, 90 and 99 minute CD-R discs?

A few media manufacturers have recently introduced 34 minute/300 MB (8 cm), 90 minute/790 MB and 99 minute/870 MB (12 cm) CD-R discs. To achieve these higher capacities such discs do not conform to Orange Book specifications and, as a result, may not write in all recorders, be accessible to all software or readable in all players and drives. Using 34, 90 and 99 minute CD-R discs is therefore not recommended.

How much information can actually be stored on CD-R and CD-RW discs?

The amount of information that can be written is determined by the disc's recording capacity as well as the physical and logical formats used.

Each of the five main CD physical formats devotes a different amount of space to user data (audio = 2,352 bytes/block, CD-ROM Mode 1 = 2,048 bytes/block, CD-ROM Mode 2 = 2,336/bytes/block, XA Form 1 = 2,048 bytes/block, XA Form 2 = 2,324 bytes/block). For any given data format disc capacity can be calculated by multiplying the appropriate user data area size by the CD data transfer rate of 75 blocks per second by 60 seconds by the minute size of disc. For example, a 80 minute disc written in CD-ROM Mode 1 format: user data area of 2048 bytes/block x 75 blocks/second = 153,600 bytes/second x 60 seconds = 9,216,000 bytes/minute x 80 minutes = 737,280,000 bytes. This rounds to roughly 700 MB (dividing by 1,024 to convert into KB and again by 1,024 to convert into MB). It should be noted, however, that in the real world capacity can vary slightly among discs from different media manufacturers.

For discs written with computer data the logical format used also consumes space available for user information. For example, the overhead for the first session of a multisession disc consumes 22 MB of space and each subsequent session thereafter uses 13 MB. And in the case of CD-RW discs which are formatted for random packet-writing, usable capacity is reduced by roughly 23%.

CD-R and CD-RW Disc Capacities
(capacities indicated in bytes)

Disc Size	Playing Time	Audio (2,352 Bytes/Block)	CD-ROM Mode 1 (2,048 Bytes/Block)	CD-ROM Mode 2 (2,336 Bytes/Block)	CD-i/XA Form 1 (2,048 Bytes/Block)	CD-i/XA Form 2 (2,324 Bytes/Block)
8 cm	18 min	190,512,000	165,888,000	189,216,000	165,888,000	188,244,000
8 cm	21 min	222,264,000	193,536,000	220,752,000	193,536,000	219,618,000
12 cm	63 min	666,792,000	580,608,000	662,256,000	580,608,000	658,854,000
12 cm	74 min	783,216,000	681,984,000	777,888,000	681,984,000	773,892,000
12 cm	80 min	846,720,000	737,280,000	840,960,000	737,280,000	836,640,000

What is the difference between 74 and 80 minute discs?

The only meaningful difference between most 74 and 80 minute discs is their storage capacity. Typically, this increase in usable space is achieved by tightening the coils of the pregroove (track pitch). This allows the disc to accommodate a longer pregroove and therefore a larger recordable area.

Are there any compatibility issues when using 80 minute instead of 74 minute discs?

Originally, 80 minute discs were specialized products for use in audio premastering studios but now have become commonplace and compatible with most software, recorders, readers and players. In some instances, however, older recorders and premastering software must be upgraded to accommodate 80 minute discs. It is, therefore, advisable to check with the manufacturers of your products and ensure that the latest versions of software and firmware are being used.

What is overburning?

Overburning (sometimes called oversizing) is the ability to write beyond the manufacturer's declared capacity on a CD-R or CD-RW disc. This is accomplished by using the disc's Lead-Out Area (reserved to indicate to a reading device that the end of the data has been reached) to store the additional user information. Although some recorders and premastering software packages have the ability to overburn a disc the practice is not permitted by Orange Book standards. Overburning might affect product warranties and result in lost data so it is not recommended.

AUDIO RECORDING

What is the Red Book?

Red Book is the set of specifications created by Philips and Sony to define the essential parameters for Compact Disc-Digital Audio (CD-DA). First released in 1980, Red Book has been adopted an international standard (IEC 60908:1999, Audio Recording — compact disc digital audio system) and forms the foundation for all other compact disc standards.

What types of audio CDs can CD-R and CD-R/RW recorders write?

CDs were originally designed for audio so it's only natural that CD-R and CD-R/RW recorders write discs in the official Compact Disc-Digital Audio (CD-DA) Red Book format for use in any CD audio compatible player. Just like their mass produced prerecorded (pressed) cousins, CD-R and CD-RW discs can hold up to 80 minutes of CD quality audio (44.1 Khz, 16 bit) using as many as 99 separate tracks. In addition to Red Book discs, recorders also write compressed digital audio CDs which, instead of holding conventional tracks, contain MP3, WMA or other compressed audio files. Depending upon the scheme used, one compressed CD-R or CD-RW disc holds as much as ten to twenty ordinary audio CDs and can be played back in devices enhanced for compressed digital audio listening such as compatible computers, personal, home and car CD players as well as many DVD-Video players.

What types of material can be used as sources for audio CD recording?

Depending upon the capabilities of the recorders and software used, CD-R and CD-RW audio discs can be written from either digital or analog sources. Digital material such as existing MP3 files or CDs are conveniently read directly from the hard drive, recorder or from a separate CD or DVD-ROM drive. To record analog sources such as LP records, cassette tapes, microphone or radio tuner inputs connected to a home stereo, signals are first digitized through the computer's sound card.

Digital
Digital audio material comes in many forms including compressed and uncompressed computer files such as MP3s, WMAs and WAVs, Compact Discs (CD), MiniDiscs (MD), Digital Audio Tapes (DAT), Digital Compact Cassettes (DCC) and Alesis ADAT. How they are handled by the computer for writing to CD varies depending upon the capabilities the individual recording system.

Digital Files
A popular way to create audio discs is to use uncompressed (WAV, PCM, etc.) and compressed (MP3, WMA, etc.) computer files as the recording sources. When producing a compressed digital audio CD these files are written to disc just as they come and, depending upon the recording software used, may be accompanied by MultiAudio or other navigational information. In the case of a Red Book audio CD, compressed files must first be uncompressed and translated into the correct format before recording. Historically, this had to be accomplished manually but most recording software now performs the conversion process automatically during the writing process. As with any audio recording it's important to remember that the sound quality of a written disc will be no better than the source material used. Higher resolution digital audio files obviously will produce better results.

CD
Recording CD to CD is much simpler than recording from analog sources since most CD and DVD-ROM drives are capable of transferring audio directly (Digital Audio Extraction) without the necessity of converting from analog to digital. As a result, CDs can often be recorded disc to disc using a CD or DVD-ROM drive as the audio source. Where a suitable drive is not available the recorder itself can be used as the audio source. In this case, the audio is read using the recorder and stored temporarily on the computer's hard drive until written out again.

DAT, MD, DCC, ADAT
Although the contents of DATs, MDs, DCCs and ADATs are already in digital form, most computers lack the proper connections for directly importing digital material. As a result the analog outputs from the source must be connected to the computer's sound card and the audio re-digitized. Since there is always a loss of quality in the conversion process, some manufacturers offer special sound cards that connect to the digital outputs of the source deck to transfer the audio to the computer while keeping it in quality digital form.

Analog
Analog audio equipment such as LP record players, cassette tape recorders, microphones and radio tuners use continuous electrical signals of varying voltages to record and play sound. Computers, on the other hand operate, in the digital world where everything is represented in binary form. Thus, before the computer can manipulate or record analog audio sources to a hard drive or a CD-R/RW disc, the sounds must be converted into digital form through the computer's sound card. Higher quality sound cards will produce better results but most cards are capable of recording at the 44.1 kHz frequency, 16 bit resolution used by audio CDs. Some recording software automates the conversion and writing processes into a few simple steps by performing time saving tasks such as detecting the silences between songs to automatically split the music into separate tracks.

What is MultiAudio?

The MultiAudio specification was created by OSTA in 2001 to provide a standardized structure for compressed digital audio files (MP3, WMA, etc.) written onto removable optical media, such as CD-R and CD-RW discs. This uniformity allows these discs to be played back in the same way on any compatible device including MultiAudio-compliant computer software media players and consumer electronics devices such as CD and DVD audio and video players. To accomplish this goal MultiAudio requires that, in addition to compressed digital audio files, an appropriately formatted disc also must contain a defined table of contents which the playing device will use for file navigation. In addition, the specification allows playlists to be created to organize material so it can be accessed by categories such as genre, album, artist or even in custom groupings created by the user. MultiAudio formatted discs are created by standard recording software packages and CD-R/RW recording-enabled audio jukebox applications which support the MultiAudio specification. Written discs can then be played back in MultiAudio compliant devices and even in compressed digital audio units not supporting the specification, albeit in a more limited fashion. Since MultiAudio is simply an organizing system it's important to remember that the types of discs and specific compressed digital audio file formats supported depend upon the individual capabilities of the particular devices or software employed.

Can consumer compact disc audio recorders write to any CD-R or CD-RW media or are special discs required?

Even though general purpose CD-R and CD-RW discs and their consumer audio versions appear for all practical purposes identical, only blank media bearing the "Compact Disc Digital Audio Recordable" (CD-DA Recordable) and "Compact Disc Digital Audio Rewritable" (CD-DA Rewritable) logos can be written in consumer audio recorders. The reason for this restriction is to comply with international copyright agreements. A special Disc Application Code present in the ATIP information of a CD-DA Recordable/Rewritable disc's pregroove wobble identifies it specifically for audio use. Consumer audio recorders are programmed to reject discs not containing the correct code. By adopting this safeguard various countries and other authorizing jurisdictions may selectively apply copyright levies to the price of blank discs intended for consumer audio use while exempting those destined for computer or professional applications.

Does using lower CD-R recording speeds and lower capacity media produce better sounding discs?

High speed CD-R writing often creates discs with low I3 and I11 signal amplitudes (optical signals generated from the smallest and largest marks) and 80 minute discs achieve their capacity by packing marks and lands more tightly together. These result in reduced recording and playing margins and sometimes lead to perceptible sound degradation, especially in older CD audio players which may not employ equalization (signal boosting). Consequently, many high speed recorder manufacturers recommend creating audio discs at reduced writing speeds while some recorders even limit their maximum speed to 24x when writing audio discs. In addition to slower recording speeds, some manufacturers also suggest using 74 minute instead of 80 minute discs. Several of the latest recorders even offer special writing modes which record audio discs with longer marks and lands than would normally be the case, albeit at the expense of some capacity. For example, an 80 minute disc written with longer marks and lands might only hold 74 minutes of audio and a 74 minute disc just 68 minutes of material.

DIGITAL PICTURES ON CD

What are the differences between Photo CD and Kodak Picture CD?

Eastman Kodak developed Photo CD and Picture CD to deliver and store high quality digital image files of pictures taken with conventional cameras and film. Photo CD was introduced in 1992 and is intended for professional and commercial applications while Picture CD came to market in 1999 aimed at the average consumer. Generally speaking, Photo CD discs store images using a proprietary file format (Image Pac) in, depending upon the version, five to six levels of resolution (128 x 192 to 2048 x 3072 or 4096 x 6144 pixels). Picture CD, on the other hand, employs the more common JPEG format in one resolution (1024 x 1536 pixels). In terms of capacity, Photo CD discs hold approximately 100 images and additional pictures can be added at later times. With Picture CD, however, images from a single roll of film are written at the time of original processing only. In addition, Photo CD compatible computer software is required to view and use Photo CD images but Picture CDs include on the discs a range of Windows and Macintosh applications to display, organize, enhance and email images.

What hardware is required to view images on Photo CD and Kodak Picture CD discs?

Both Photo CD and Kodak Picture CD discs are written in industry standard multisession (Mode 2, Form 1) format and are therefore playable on most computer CD-ROM drives and MultiRead-compliant (or other CD-R compatible) DVD-ROM drives and recorders. Historically, Photo CD images could be displayed on TV sets connected to dedicated Photo CD and multi-purpose Compact Disc Interactive (CD-i) players. These devices, however, are no longer available. Most recently, a few DVD-Video player models have come along incorporating Picture CD viewing capability.

Can DVD-Video players display digital still images written on CD-R and CD-RW discs?

In addition to select DVD-Video player models which are compatible with commercially produced Kodak Picture CDs some devices display JPEG images written to standard ISO 9660 formatted CD-R and CD-RW discs. It is anticipated that once OSTA's MultiPhoto/Video specification is released more manufacturers will incorporate digital image viewing capabilities into their DVD-Video and even, perhaps, other consumer electronic devices. It is also possible to use a CD-R or CD-R/RW recorder and software to create Video CD 2.0 formatted discs containing slideshows of digital images which can be played back on many MultiPlay-compliant (or other CD-R or CD-RW compatible) DVD-Video players. Be aware, however, that not all DVD-Video players support the Video CD format and not all recording software creates Video CD slideshow discs.

What is MultiPhoto/Video?

The MultiPhoto/Video (MPV) specification is a collaborative effort between OSTA and the International Imaging Industry Association (I3A) and is currently under development. This specification will provide a standardized structure for still image digital photographs (JPEG, etc.) and video (eg. MPEG, AVI, etc.) stored on fixed and removable storage media, such as writable CD and DVD discs, flash memory cards and hard disk drives. This uniformity enables computer software and consumer electronics devices to more easily process collections of digital photographs and video and to play them back in the same way on any compatible device. To accomplish this goal MPV requires that, in addition to digital image files or video, an appropriately formatted storage medium must contain a defined table of contents and descriptive information (metadata) which the playing device will use for file navigation. In addition, MPV can also act as a protocol for exchanging information between software applications and services. It is expected that MultiPhoto/Video formatted CD-R and CD-RW discs will be created by a broad range of software including CD recording packages as well as digital camera, scanning, imaging and multimedia authoring software which support the MPV specification. Written discs could then be played back in MPV compliant devices and even in systems not supporting the specification, albeit in a more limited fashion. Since MultiPhoto/Video is simply an organizing system it is important to remember that the types of storage media and specific image and video file formats supported depend upon the individual capabilities of the particular devices or software employed.

DUPLICATION, REPLICATION AND PUBLISHING

What alternatives are available to copy CDs?

There are several different methods available to make one or multiple copies of existing CDs ranging from single CD-R and CD-R/RW recorders to specialized devices that automatically duplicate and label discs and, for large runs, commercial mass replication. Options are distinguished by cost, speed, convenience and capability. When dealing with commercial software and audio discs keep in mind copyright laws and that copy protection systems may be employed to hinder straightforward duplication.

Computer CD-R and CD-R/RW Recorders

By far the quickest and least expensive way to duplicate a disc is to simply copy it using a computer outfitted with a CD-R or CD-R/RW recorder combined with off the shelf writing software. In addition to creating discs from scratch many basic writing software packages duplicate most standard CD formats. Specialized copying software is also available with more sophisticated capabilities such as the ability to make backups of copy protected discs and even the power to simultaneous duplicate to multiple recorders. But remember that the ability of a system to copy specific disc formats depends upon the individual capabilities of the software, reader and recorder used. It is therefore advisable to check with the respective manufacturers for specific information.

Typically, discs are duplicated CD to CD by using the computer's CD-ROM or DVD-ROM drive as the master source feeding the copying recorder. In cases where a separate reading drive is not available the master is first downloaded to the computer hard drive using the reading ability of the recorder and later written back to a blank disc using the same recorder. Employing the hard disk as an intermediate copying step is also a common tactic used when dealing with poor quality source discs or other situations where computer systems are not fast enough to keep up to the speed set on the recorder.

CD Duplication Systems

For copying larger numbers of discs various dedicated CD duplication solutions are available including machines that function by themselves or with the assistance of an operator. These configurations can either sit as standalone units or may be attached as computer peripherals. The most common devices are hand-fed tower systems which employ a number of CD-R or CD-R/RW recorders chained together for simultaneous duplication from either a master CD or from a hard drive. Also widely used are automated products incorporating robotic disc handling systems which mechanically load and unload one or more recorders. Sometimes disc label printers are included to produce a handful or even hundreds of finished discs per hour. Historically large and expensive, many CD duplication systems are now compact and affordable and within reach of many for personal and office use. A number of companies also offer commercial CD duplication services to perform short run work in quick turnaround times.

CD Mass Replication

In contrast to CD duplication which is usually performed on a small scale at the desktop level, CD mass replication is typically used to make huge quantities of discs such as commercial audio CDs and software CD-ROMs. These prerecorded (pressed) discs are manufactured from a mold in a factory setting and are created using a series of industrial processes including premastering, mastering, electroplating, injection molding, metallization, spin coating, printing and advanced quality control. In addition to manufacturing discs many replication companies offer companion services including packaging, printing, distribution and fulfillment.

What is CD publishing?

Somewhat like CD duplication equipment, CD publishing systems employ CD-R or CD-R/RW recorders but are used to create quantities of unique discs from different computer files rather than just to make multiple copies of a single master disc. Employing robotic disc handling systems and integrated label printers, many of these devices can be accessed over computer networks and shared much like office laser printers. Examples of CD publishing applications include retail audio CD vending kiosks, creating CD-Rs containing cheque images or monthly banking records, archiving computer-generated billing records to disc in place of microfilm and accepting conventional 35 mm film resulting in digital pictures on CD-R discs.

Can CD-R and CD-RW discs be protected against copying?

Historically, copy protection technologies were only available to protect prerecorded (pressed) discs but a variety of methods are now available to deter copying the contents of CD-Rs and CD-RWs, to authenticate media and even to forensically trace the origin of discs. Such capabilities are included in some CD-R and CD-R/RW recorders or may be offered as features in software tools as well as duplication and publishing systems.

DISC LABELING

What alternatives are available to label CD-R and CD-RW discs?

There are several different labeling methods available for CD-R and CD-RW discs ranging from hand writing, to adhesive labels, specialized devices that print directly onto the disc surface and ultimately the various commercial printing solutions. Each option is distinguished by cost, speed and convenience as well as by durability and the visual quality of the result. But keep in mind that applying any kind of label modifies the disc in a significant way. Thus, product warranties can be affected and unforeseen consequences may arise. It is, therefore, advisable to always follow manufacturer directions.

Hand Writing
By far the quickest and least expensive way to label a disc is to simply write on its top surface. Using a soft fiber or felt-tipped permanent marker is preferable but be aware that the solvents in some types of inks can migrate through the disc surface and potentially damage the reflective and dye layers beneath. The part of the disc least vulnerable to injury is the center clamping or hub area. Beware ballpoint pens or other sharp writing instruments as they may deform the disc substrate and delaminate the disc layers thereby causing information to become unreadable. Some discs are specially coated to accommodate handwritten labels and even some special markers are available and intended for such use.

Adhesive Labels
A more attractive way to label a disc is to apply an adhesive label. Several manufacturers offer inkjet and laser printer compatible products specifically designed for labeling discs as well as positioning devices to help with centering. Full surface or "donut-style" labels are preferable to partial stickers but be aware that any adhesive label can potentially upset the balance of a disc when playing back, especially at high speeds, causing excessive noise, vibration and data retrieval problems. Heat, humidity, handling and the passage of time can also compromise the stability of adhesive labels causing separation from the disc surface and even interfere with the drive. Sticky labels may not be the best choice when archiving important data as some types of label adhesives can react with and compromise the disc over time. Remember too that, once applied, labels should never be removed or repositioned. Even smoothing air bubbles can concentrate physical stresses in a small area and delaminate the disc.

Specialized Disc Printers
A range of specialized disc printing devices is also available to label discs in larger numbers and for imparting a more polished appearance. Currently, desktop products employing inkjet, thermal transfer and re-transfer technologies are available for directly labeling on the disc surface.

Inkjet

Inkjet printing technology has been available for many years and has proven extremely popular with consumers due to its high quality and cost effectiveness. Inkjet printers function by ejecting liquid ink from a print head onto the surface of a specially coated "inkjet-printable" disc. These special discs have an extra coating, called an Ink Absorption Layer (IAL), which receives the ink from the printer and allows it to stay in place long enough to dissipate its solvents and properly dry. Inkjet printers produce high-resolution full color images but there is a downside in that resulting labels can be smudged by high humidity or damp fingers. Inkjet printed discs should not be stored or shipped in form-fitting soft plastic envelopes as the chemicals used to keep the package materials supple can soften the inks causing the label to stick to the sleeve and potentially delaminate the disc when removed. Using jewelcases or other containers that do not come into direct contact with the printed surface is best.

Thermal Transfer

Unlike inkjet printers which spray liquid ink, thermal transfer printers convey solid pigment from a coated ribbon onto the surface of a disc through a combination of heat and pressure. Typically used to produce monochrome and spot color labels, thermal transfer printing does not require specially coated discs to accept the ink from the printing process. The results are, as well, reasonably durable. However, some disc surfaces give better results than others and offer more protection from potential damage during the printing process. Consequently, discs are available which feature special coatings optimized for thermal transfer printing. For labeling situations where discs share a largely common background appearance but vary slightly from disc to disc or among groups of discs some thermal transfer solutions can align and overprint their output onto partial images already screen printed onto the surface of the disc.

Re-transfer

More recently, re-transfer printers have come to market and function by applying heat and pressure to convey solid resins from an ink ribbon to a compliant intermediate film and then to the surface of the disc. Typically re-transfer systems produce photo-realistic color labels which are smooth and highly durable. Only certain types of disc surfaces are suitable for re-transfer printing including those optimized for thermal transfer use as well as some inkjet-printable surfaces and "crystal" protective coatings.

Commercial Printing

Various methods are used to commercially decorate discs including screen, offset, pad and flexographic printing. These are large-scale industrial processes typically used to label large numbers of discs with the same pattern or in situations when precise color matching is required for critical items such as company logos. In addition to desktop disc labeling, many duplication companies and replicators offer commercial printing services.

DISC HANDLING, STORAGE AND DISPOSAL

What is the best way to handle and store a CD-R or CD-RW disc?

A disc should always be handled by grasping its outer edges, center hole or center hub clamping area. Avoid flexing the disc, exposing it to direct sunlight, excessive heat and/or humidity, handle it only when being used and do not eat, drink and smoke near it. Discs should be stored in jewel cases rather than sleeves as cases do not contact the discs' surfaces and generally provide better protection again scratches, dust, light and rapid humidity changes. Once placed in their cases discs can be further protected by keeping them in a closed box, drawer or cabinet. For long-term storage and archival situations it is advisable to follow manufacturer instructions. For further information consult the international standards for preserving optical media (ISO 18925:2002, Imaging materials — optical disc media — storage practices).

Should fingerprints and dust be cleaned off a CD-R or CD-RW disc?

CD technology is robust and employs several design elements to minimize the effects of fingerprints and minor scratches on data integrity. The first line of defense comes from the physical structure of the disc and the location of the data-bearing marks and lands. The reading laser beam shines through the disc's substrate focusing beyond the contaminated surface and directly on the marks and lands beneath. In concert with advanced error detection and correction capabilities minor debris and abrasions are largely ignored. That said, handling care should be taken as above and a dusty disc should be blown off so that the dust does not enter the drive mechanism and accumulate on the lens or other optical components. It should also be noted that fingerprints, dust and scratches have a greater impact on recording than is the case with reading since the contaminants reduce the effectiveness of the writing laser by obscuring its beam from the disc's recording layer.

What is the best way to clean a CD-R or CD-RW disc?

Dirty discs should be carefully cleaned using a soft dry lint-free cloth or camera lens tissue. Holding the disc by its outer edges or center hole gently wipe outward from the center hub toward the outside edge of the disc (just like the spokes of a bicycle wheel). Do not wipe the disc using circular motions as any scratches created will do the least damage if they cut across the track of marks and lands. More stubborn fingerprints or stains can be removed using a soft dry lint-free cloth lightly moistened with water or a commercially available CD cleaning fluid. Do not use vinyl record cleaners, lacquer thinner, gasoline, kerosene, benzene or other solvents, as they may damage the disc. Manufacturer directions should always be followed.

Can scratched and damaged CD-R and CD-RW discs be restored?

Often it is less expensive and makes more sense to transfer the data from a damaged disc onto a new one rather than to try to restore the problem disc. For dealing with more badly damaged situations consumer disc repair kits are available while several companies offer CD restoration and resurfacing equipment and services. See the resource listing in the appendix for contact information.

Is it possible to recover data from damaged CD-R and CD-RW discs?

Several software packages are currently available which diagnose disc problems and help recover deleted, unreadable or otherwise inaccessible information. A number of companies also offer commercial CD data recovery services. See the resource listing in the appendix for contact information.

What is the best way to destroy unwanted CD-R and CD-RW discs?

For office and high volume production situations various CD destruction options are available including mechanical shredders, desktop devices which employ heat and pressure to make disc unreadable and grinders which abrasively remove the disc's reflective and data-bearing recording layers. A number of companies also offer commercial CD destruction services and deal with classified or other sensitive materials. See the resource listing in the appendix for contact information.

Can unwanted CD-R and CD-RW discs be recycled?

A number of companies offer CD recycling services and are able to reclaim some of the materials used in the disc's construction. See the resource listing in the appendix for contact information.

DISC LONGEVITY

How many times can a CD-RW disc be rewritten?

As is the case with all optical storage media using phase change technology there is a limit to the number of times the recording layer in a CD-RW disc can be reliably switched between its crystalline and amorphous states. Currently, CD-RW discs can be rewritten approximately 1000 times.

What is the shelf life of unrecorded CD-R and CD-RW discs?

The unrecorded shelf life of a CD-R or CD-RW disc is conservatively estimated to be between 5 and 10 years.

How long will data recorded on CD-R and CD-RW discs remain readable?

The life span of a written disc depends upon a number of factors including such things as the intrinsic properties of the materials used in the disc's construction, its manufactured quality, how well it is recorded and its physical handing and storage. As a result, the life span of a recorded disc is extremely difficult to estimate reliably. However, to calculate disc life spans within some practical timeframe blank media manufacturers do conduct accelerated age testing by subjecting samples of their discs to environments much beyond those experienced under normal storage conditions. Generally speaking, only the effects of varying temperature and humidity are considered. These test results are then used to predict how long a disc will remain readable under more normal storage conditions. Since questionable testing and measurement procedures can seriously impact upon and compromise these estimates several international standards have been developed which specify procedures to be used conducting accelerated testing and analyzing the resulting data from prerecorded (pressed) and recordable CDs:

ISO 18921:2002, Imaging materials — Compact discs (CD-ROM) — method for estimating the life expectancy based on the effects of temperature and relative humidity

ISO 18927:2002, Imaging materials — Recordable compact disc systems — method for estimating the life expectancy based on the effects of temperature and relative humidity

For years now many media manufacturers have performed their own lifetime evaluations using these or a variety of other homegrown tests and mathematical modeling techniques. Historically, manufacturers have claimed life-spans ranging from 50 to 200 years for CD-R discs and 20 to 100 years for CD-RW. Be aware, however, that disc producers, manufacturing methods and materials change over time as do applications and cost imperatives. Consequently, those concerned with disc longevity

should consult the appropriate international standards and their media manufacturer for more particular information.

It is important to remember, however, that nothing lasts forever and that technologies inevitably change. Well-designed products, such as CD-R and CD-RW, allow for seamless transition to the next generation and ultimately, since they embody digital information, contents can be transferred to future storage systems as becomes necessary to preserve whatever has been stored on the discs.

DISC TESTING AND VERIFICATION

Is it necessary to verify a CD-R or CD-RW disc after recording?

Verifying discs after writing helps maintain an appropriate quality level. The amount of ongoing integrity checking and data verification that may be necessary is really a question of acceptable risks for any particular application. For example, letting recording software conduct data comparisons immediately after writing is usually sufficient in casual settings but critical data archiving and large-scale duplication may call for more comprehensive testing. This is due to the differences that often exist among recorders, drives and players. For example, recorders typically incorporate higher quality optical systems and lenses with slightly larger numerical apertures than do reading devices. Consequently, successfully verifying a written disc on a recorder does not guarantee broad playing compatibility, especially in cases where disc jitter is marginal.

How can the quality of a written CD-R or CD-RW disc be assessed?

Several methods can be used to assess the quality of a written disc. These include measuring its optical signals, examining the integrity of its physical and logical formats, performing interchange testing and conducting data verification. Each method is a piece of the quality testing puzzle. The extent to which a disc needs to be tested depends, of course, upon the imperatives of the application.

At a basic level it is possible to confirm that information has been correctly written to a disc by comparing it against the source material using the verification features found in many off the shelf writing software packages. When somewhat more detailed analysis is warranted, interchange testing can be performed to provide some practical indication of real-world compatibility. To accomplish this, audio CDs are played back in a number of consumer audio players to check for quality issues while data discs are checked in a variety of CD-ROM and DVD-ROM drives to make sure that recorded information is completely recoverable and at speeds established by the manufacturers. Specialized computer software controlling everyday CD-ROM drives can also be used to read a disc at a lower level of organization to verify that its physical and logical formats conform to industry specifications.

For situations which require appraising the more fundamental physical characteristics, a number of commercial analysis tools are available to examine the optical signal characteristics of a recorded disc and thus identify low-level errors. Typically, these devices are standalone or computer-attached and employ CD audio or CD-ROM drives specially modified to measure various disc parameters and provide descriptive reports. As is the case in testing generally, results can vary significantly among inspection systems so, to maintain continuity, discs should always be evaluated on the same pieces of equipment. Commercial CD testing companies offering quality verification services using such devices are also widely available.

An important question which has always existed for compact disc testing is the uncertainty of the relationship between the results derived from evaluating discs on low-level analyzers and real world disc performance in the installed population of reading and playing devices. Over the years a succession of groups and companies have labored to reconcile these two product classes through the use of various multi-point calibration discs and other vehicles. However, given the extremely rapid technological evolution of reading and playing devices it is impossible to conclusively establish any definitive link between measured and actual performance, especially for marginal discs.

When assessing disc quality keep in mind the huge number of variables involved. These include such things as the discs with their different types, batches and manufacturers, recording software and hardware in their many varieties and versions, diverse recording conditions encountered, different test equipment employed, operators of differing experience and even the handling of the discs themselves. Consequently, judgements should be made on a relative rather than absolute basis.

DISC CONSTRUCTION AND MANUFACTURING

What is the construction of a CD-R disc?

Just like all kinds of CDs a CD-R disc is a sandwich of a number of layers. First comes a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. On top of this substrate is an organic dye recording layer (cyanine, phthalocyanine or azo) followed by a thin metal reflective layer (gold, silver alloy or silver) and finally an outer protective lacquer coating. Some discs are also topped with additional layers that improve scratch resistance, increase handling durability or provide surfaces suitable for labeling by inkjet or thermal transfer printers.

How are CD-R discs made?

Current CD-R disc manufacturing lines are extremely efficient, incorporating all major production elements to produce a staggering number of discs. The first step in producing a CD-R disc is to create the polycarbonate plastic substrate using an injection molding process. The dye layer is applied using spin coating and the reflective layer by means of cold planar magnetron sputtering. The lacquer overcoat is then applied by another spin coating procedure followed by ultraviolet curing. Additional durability or printable layers are typically applied using screen printing methods.

Why are the recording surfaces of various kinds of CD-R discs different colors?

Due to the intrinsic absorption spectrums of the various dyes, the thickness of the layers and the type of reflector materials used the recording side of a CD-R disc can appear many different colors including shades of green, yellow and blue. For many years the color of a disc was incidental in its design but some manufacturers now intentionally aim for specific visual effects. For example, CD-R discs are now available which mimic the look of prerecorded (pressed) CDs and tinted substrates are sometimes even used to make discs appear black or exotic colors. Keep in mind, however, that disc operation is not affected by its visual appearance. While the human eye perceives a rainbow of colors, all of the discs function the same way when illuminated by the 780 nm laser of a CD-ROM drive or recorder.

What are the differences between the dyes - cyanine, phthalocyanine and azo?

The recording layer of a CD-R disc is composed of one of cyanine, phthalocyanine or azo dye and, although each has its own recording and longevity characteristics, they all serve the same purpose. Over time, there has even been a steady convergence in their properties.

Information is written to a CD-R disc by means of a laser to heat and alter the dye sufficient to create a pattern of marks and thereby mimic the pits of a molded CD. Although each dye is tuned to absorb light in the range of 780 nm, they all respond differently to the writing laser. Some dyes become bleached from exposure to the beam while the others create permanent features and deform the underlying substrate. In addition, each dye requires a different laser intensity and duration to properly form marks.

Early CD-R discs employed cyanine-based dye exclusively and recording conditions defined in Orange Book Part II standards were tuned around cyanine characteristics. As the market evolved discs using phthalocyanine and azo dyes emerged and specifications changed to reflect the new reality. Since then, recorders select write strategies appropriate for the type of dye and carefully control the laser beam as required to achieve the best results with all types of media.

In terms of their composition, quenchers (metal dithiochelates, benzenaminium salts, etc.) are normally added to cyanine dyes to increase light stability while phthalocyanine and azo dyes are intrinsically less sensitive to light exposure after recording.

Remember that CD-R discs are complex engineering marvels so when it comes to choosing among them keep in mind the importance of selecting products based on your particular requirements rather than focusing on any one characteristic.

What is the construction of a CD-RW disc?

To allow information to not only be written but also re-written many times over, CD-RW disc construction is more complex than that of CD-R. A CD-RW disc uses a six-layer design beginning with a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside edge of the disc. Next comes a dielectric layer (zinc sulfide and silicon dioxide), followed by a phase change alloy recording layer (indium, silver, tellurium, and antimony), another dielectric layer, a thin metal reflective layer (aluminum) and finally a protective lacquer overcoat.

How are CD-RW discs made?

As with CD-R, producing CD-RW discs involves using multiple manufacturing stages including injection molding, sputtering, spin coating, ultraviolet curing and quality inspection. The first step is to create the substrate by injection molding. The dielectric layers, phase change recording and reflective layers are applied to the substrate using cold planar magnetron sputtering. Spin coating and ultraviolet curing are then used to apply the protective lacquer coating. Since the sputtering process lays down the phase change alloy in its amorphous condition powerful lasers are used to initialize the disc and return the recording layer back to its crystalline state.

Are there any meaningful differences among blank discs produced by different manufacturers?

As with all products, discs produced by competing companies are distinct from one another because they may employ different designs, use materials from various suppliers and are manufactured by different factories, equipment and workers. However, all blank discs conform to Orange Book Part II (CD-R) or Part III (CD-RW) specifications and should work in all recorders. Discs are differentiated based on brand names, quality and consistency, features, price and packaging. Some recorder companies may test particular brands of discs more extensively than others so it may be advisable to inquire of the recorder manufacturer for specific recommendations depending on particular applications.

APPENDIX A — SUGGESTED FURTHER READING AND RESOURCES

BOOKS

Apple Computer, Inc. *The Apple CD-ROM Handbook: A Guide to Planning, Creating, and Producing a CD-ROM*. Reading: Addison-Wesley, 1992.

Bouwhuis, Gijs, et. al. *Principles of Optical Disc Systems*. Bristol: Adam Hilger, 1985.

Brown, Martin C. *CD Recordable Solutions*. Cincinnati: Muska and Lipman, 2001.

Caffarelli, Fabrizio, and Deirdre Straughan. *Publish Yourself on CD-ROM: Mastering CDs for Multimedia*. New York: Random House, 1992.

Chambers, Mark L. *Hewlett-Packard Official Recordable CD Handbook*. Foster City: IDG Books, 2000.

Chambers, Mark L. *Recordable CD Bible*. Foster City: IDG Books, 1997.

Chambers, Mark L. *CD and DVD Recording for Dummies*. New York: Hungry Minds, 2001.

Marchant, Alan B. *Optical Recording: A Technical Overview*. Reading: Addison-Wesley, 1990.

Ogletree, Terry William, and Todd Brakke. *The Complete Idiot's Guide to Creating Your Own CDs*. 2nd ed. Indianapolis: Macmillian, 2002.

Pahwa, Ash. *The CD-Recordable Bible: An Essential Guide for Any Business*. Wilton: Eight Bit Books, 1994.

Purcell, Lee. *CD-R/DVD: Disc Recording Demystified*. New York: McGraw-Hill, 2000.

Purcell, Lee, and David Martin. *The Complete Recordable-CD Guide*. Alameda: Sybex, 1997.

Pohlmann, Ken C. *The Compact Disc Handbook*. 2nd ed. Madison: A-R Editions, 1992.

Pohlmann, Ken C. *Principles of Digital Audio*. 4th ed. New York: McGraw-Hill, 2000.

WHITE PAPERS

Bennett, Hugh. *Running Optimum Power Control: Data Integrity in CD-Recording*. Santa Barbara: Optical Storage Technology Association, 1998.

Busk, Philip J. et. al. *Compact Disc Terminology*. 2nd ed. Wilmington: Disc Manufacturing, Inc., 1993.

Busk, Philip J. *Integrating Mixed-Mode CD-ROM*. Wilmington: Disc Manufacturing, Inc., 1992.

DeMoulin, Robert, Toshi Iizuka, and Rod Volturno. *CD Recordable Handbook: A Guide to Choosing the Right CD Recorder for You.* 2nd ed. San Jose: Ricoh Corporation, 1995.

Disc Manufacturing, Inc. *A Glossary of CD and CD-ROM Terms*. Wilmington: DMI, 1993.

Disc Manufacturing, Inc. *An Overview to Multimedia CD-ROM Production*. Wilmington: DMI, 1992.

Eastman Kodak Company. *Data Integrity on CDs*. Rochester: Eastman Kodak Company, 1995.

Eastman Kodak Company. *Permanence, Care, and Handling of CDs: Including CD-ROM, Writable CD, and Kodak Photo CD*. Rochester: Eastman Kodak Company, 1995.

Eastman Kodak Company. *Why Kodak Writable CD Media with Infoguard Protection System?* Rochester: Eastman Kodak Company, 1995.

Hamelinck, Dirk, Bob Ijtsma, and Eggert Gudmundsson. *Mount Rainier: Drag and Drop Data on CD-RW*. Eindhoven: Royal Philips Electronics, 2000.

Multi Media Masters and Machinery. *A 'Revolution' in CD-R and DVD-R Spin Coating*. Yverdon-les-Bains: Multi Media Masters and Machinery, 1999.

Multi Media Masters and Machinery. *CD-R and DVD-R: Ready for the Present, Prepared for the Future*. Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Multi Media Masters and Machinery. *The Next Wave in Optical Storage: CD-RW and Rewritable DVD*. Yverdon-les-Bains: Multi Media Masters and Machinery, 2000.

Philips Electronics. *Basic Principles of CD-Recordable/Rewritable Digital Audio*. Eindhoven: Philips Electronics, 1998.

Philips Electronics. *CD-ReWritable: How it Works*. Eindhoven: Philips Electronics, 1997.

Plextor Europe. *The Process of Writing*. version 1.0. Zaventem: Plextor S.A./N.V., 2002.

Royal Philips Electronics. *Thermo-Balanced Writing*. Eindhoven: Philips Electronics, 2001.

Roohi, Misty. *More than CD: Enhanced CD Formats*. Wilmington: Disc Manufacturing, Inc., 1996.

Summers, Clayton. *Introduction to ISO 9660*. Wilmington: Disc Manufacturing, Inc., 1995.

Warner, Josh. *The Enhanced CD Fact Book Version 1.01*. Cupertino: Apple Computer, 1995.

STUDIES

Doculabs, Inc. *Compatibility of CD-R Media, Readers, and Writers*. Chicago: Doculabs, 1997.

Hartke, Jerome L. *CD-R Media Survey*. Marlborough: Media Sciences, 2000.

Optical Disc Manufacturing Association. *Variation of Measurement*. Milford: ODMA, 1995.

Optical Storage Technology Association. *CD-R/DVD-ROM Compatibility Study*. Santa Barbara: OSTA, 1998.

Optical Storage Technology Association. *CD-R Compatibility Study Phase 1*. Santa Barbara: OSTA, 1997.

Optical Storage Technology Association. *CD-R Compatibility Study Phase 2*. Santa Barbara: OSTA, 1998.

Stinson, Douglas, Fred Amell, and Nick Zaino. "Lifetime of Kodak Writable CD and Photo CD Media." *SIGCAT DISCourse* 9.1 (1995): 1+.

PERIODICALS

Computer Technology Review	www.wwpi.com
EMedia, the Digital Studio Magazine	www.emedialive.com
Medialine	www.medialinenews.com
One to One	www.oto-online.com
Optical Disc Systems	www.opticaldisc-systems.com
Software Business Magazine	www.softwarebusinessonline.com
Tape Disc Business	www.tapedisc.com

PRINT DIRECTORIES

Billboard International Disc/Tape Directory	www.billboard.com
EMedia, the Digital Studio Magazine Buyer's Guide	www.emedialive.com
The Gold Book	www.oto-online.com
The International DVD and CD Plant Directory	www.oto-online.com

EXHIBITIONS AND TRADE SHOWS

AES	www.aes.org
CeBIT	www.cebit.de
COMDEX	www.comdex.com
Digital Content Delivery Expo	www.dcdexpo.com
International Consumer Electronics Show	www.cesweb.org
Media-Tech Expo	www.media-tech.net
NAB	www.nab.org
PC Expo	www.techxny.com
Replication Asia	www.replicationasia.com

GENERAL INFORMATION WEB SITES

Andy McFadden's CD-Recordable FAQ	www.cdrfaq.org
BurnWorld	www.burnworld.com
CD Freaks	www.cdfreaks.com
CD Media World	www.cdmediaworld.com
CDR Zone	www.cdr-zone.com
CDR-Info	www.cdrinfo.com
CDRLabs	www.cdrlabs.com
CDROM-Guide	www.cdrom-guide.com
CD-RW Central	www.cdrwcentral.com
cd-rw.org	www.cd-rw.org
Digital Drives	www.digitaldrives.com

GENERAL INFORMATION INTERNET NEWSGROUPS

comp.publish.cdrom.hardware
comp.publish.cdrom.software
comp.publish.cdrom.multimedia
alt.comp.periphs.cdr

INDUSTRY ASSOCIATIONS AND ORGANIZATIONS

1394 Trade Association	www.1394ta.org
CDs21 Solutions	www.cds21solutions.org
Consumer Electronics Association (CEA)	www.ce.org
Industrial Technology Research Institute (ITRI)	www.itri.org.tw
International Disc Duplicating Association (IDDA)	www.discdupe.org
International Federation of the Phonographic Industry (IFPI)	www.ifpi.org
International Optical Disc Replicators Association (iODRA)	www.iodra.com
International Recording Media Association (IRMA)	www.recordingmedia.org
Optical Disc Manufacturing Association (ODMA)	www.odma.com
Optical Storage Technology Association (OSTA)	www.osta.org
Orange Forum	www.orangeforum.or.jp
SCSI Trade Association	www.scsita.org
USB Implementers Forum	www.usb.org

LICENSING AND STANDARDS ORGANIZATIONS

American National Standards Institute (ANSI)	www.ansi.org
ECMA International	www.ecma.ch
International Committee for Information Technology Standards	www.ncits.org
International Electrotechnical Commission (IEC)	www.iec.ch
International Organization for Standardization (ISO)	www.iso.org
Optical Storage Technology Association (OSTA)	www.osta.org
Philips Intellectual Property and Standards	www.licensing.philips.com

APPENDIX B — INDUSTRY AND PRODUCT CONTACTS

MARKET RESEARCH AND CONSULTING FIRMS

Cahners In-Stat Group	www.instat.com
Forget Me Not Information Systems Inc.	73144.1631@compuserve.com
Gartner, Inc.	www.gartner.com
IDC	www.idcresearch.com
InfoTech, Incorporation	www.infotechresearch.com
Magnetic Media Information Services (MMIS)	www.mmislueck.com
Santa Clara Consulting Group	sccg@pacbell.net
Strategic Marketing Decisions (SMD)	www.smdcorp.com
Techno Systems Research Co., Ltd. (TSR)	phone: 03-3866-4505
Understanding and Solutions	www.uands.com

DUPLICATION AND PUBLISHING SYSTEMS

Alea Systems, Inc.	www.alea.com
Alera Technologies, LLC.	www.aleratec.com
An Chen Computer Co. Ltd.	www.copystar.com.tw
Ashby Industries, Inc.	www.ashbyindustries.com
Bernardini SRL	www.bernardini-srl.com
CopyPro, Inc.	www.copypro.com
Copytrax Technologies	www.copytrax.com
Cyclone USA	www.cdcyclone.com
Discmatic	www.discmatic.com
DixxPli USA	www.dixxpli.com
Hoei Sangyo Co., Ltd.	www.hoei.co.jp
ILY Enterprise Inc.	www.ily.com
Imedia Technologies (IMT)	www.imt-sa.com
Interactive Media Corporation	www.interactivemediacorp.com
JukeBox Information Systems	www.jbis.com
LSK Data Systems GmbH	www.lskdata.de
Luminex Software, Inc.	www.luminex.com
MediaFORM, Inc.	www.mediaform.com
Mediatechnics Systems	www.mediatechnics.com
Microboards Technology	www.microboards.com
Microsynergy	www.idt-microsynergy.com
Microtech Systems	www.microtech.com
Niscoa, Inc.	www.niscoa.com
Nistec Corporation	www.nistec.co.jp
Odixion USA	www.odixionusa.com
OptoMedia Storage Solutions Limited	www.optomedia.co.uk
Orient Instrument Computer Co., Ltd.	www.orient-computer.co.jp
Otari, Inc.	www.otari.com
Primera Technology	www.primeratechnology.com
Rimage Corporation	www.rimage.com
Rimax International	www.rimax.net
R-Quest Technologics, LLC	www.r-quest.com
Terra Computer Systems	www.terra.cz
The Logical Company	www.u-master.com
T.S. Solutions	www.ts-solutions.com

Telex Communications, Inc.   www.telex.com
Verity Systems   www.veritysystems.com
Young Minds, Inc.   www.ymi.com
Wytron Technology Co. Ltd.   www.wytron.com.tw

DISC LABELS AND PRINTERS

Alera Technologies, LLC.   www.aleratec.com
Avery Dennison Corporation   www.avery.com
Burlington Paper   www.burlingtonpaper.com
CopyPro, Inc.   www.copypro.com
Fellowes   www.fellowes.com
Kyso Inc.   www.kyso.com
MediaFORM, Inc.   www.mediaform.com
Memorex Products   www.memorex.com
Neato   www.neato.com
Odixion USA   www.odixionusa.com
Primera Technology   www.primeratechnology.com
Rimage Corporation   www.rimage.com
Verity Systems   www.veritysystems.com

DISC MANUFACTURERS/BRANDS

Alera Technologies, LLC.   www.aleratec.com
CDA Datenträger Albrechts GmbH   www.cda.de
CMC Magnetics Corp.   www.cmcdisc.com
Daxon Technology Inc.   www.daxontech.com
Doremi Media Co., Ltd.   www.doremi4u.co.kr
Emtec-Multimedia Inc.   www.datastoremedia.com
Fujifilm Computer Products   www.fujifilmmediasource.com
Gigastorage Corporation   www.gigastorage.com
Imation Corp.   www.imation.com
KDG Mediatech AG   www.kdg-mt.com
Lead Data Inc.   www.leaddata.com.tw
Maxell Corporation   www.maxell.com
Memorex Products   www.memorex.com
Mitsui Advanced Media, Inc.   www.mitsuicdr.com
Moser Baer India Ltd. (MBI)   www.glyphicsmedia.com
Moulage Plastique de L'Ouest (MPO)   www.hi-space.com
PNY Technologies   www.pny.com
Prodisc Technology Inc.   www.prodisc.com.tw
Quantegy, Inc.   www.quantegy.com
Ritek Corporation   www.ritek.com.tw
Sony Electronics Inc.   www.mediabysony.com
Summit Hi-Tech Pte Ltd.   www.smsummit.com.sg
Taiyo Yuden Co. Ltd.   www.yuden.co.jp
TDK Electronics Corp.   www.tdk.com
Techo Plus Digital Disc   www.technoplus.it
Verbatim Corporation   www.verbatim.com
Viva Magnetics Limited   www.viva.com.hk

RECORDER MANUFACTURERS/BRANDS

Actima Technology Corporation	www.actima.com.tw
Alera Technologies, LLC.	www.aleratec.com
AOpen Inc.	www.aopen.com
Behavior Tech Computer Corp.	www.btc.com.tw
BenQ Corporation	www.benq.com
CenDyne Inc.	www.cendyne.com
CyberDrive	www.cyberdrive
Digital Research Technologies	www.dr-tech.com
Hewlett-Packard Company	www.hp.com
Hi-Val	www.hival.com
I/O Magic Corporation	www.iomagic.com
Imation Corp.	www.imation.com
Infinite Data Storage (IDS)	www.infinitedtastorage.com
Iomega Corporation	www.iomega.com
LG Electronics Inc.	www.lge.com
Lite-On IT	www.liteonit.com
Matsushita Kotobuki Electronics Industries, Ltd.	www.mke.panasonic.co.jp
Micro Solutions Inc.	www.microsolutions.com
Mitsumi Electric Co., Ltd.	www.mitsumi.com
Philips Electronics	www.philips.com
Pioneer Electronics	www.pioneerelectronics.com
Plextor Corp.	www.plextor.com
Ricoh Company	www.ricoh.com
Samsung Electronics Co., Ltd.	www.samsung.com
Sanyo Electric Co., Ltd.	www.burn-proof.com
Sony Corporation	www.sony.com
TDK Electronics Corp.	www.tdk.com
Teac Corporation	www.teac.com
Toshiba	www.toshiba.com
Ultima Electronics Corp.	www.ultima.com.tw
Yamaha Corp.	www.yamaha.com

RECORDING SOFTWARE PUBLISHERS

Ahead Software	www.nero.com
Aplix Corporation	www.aplix.com
B.H.A. Software Corporation	www.bhacorp.com
Charismac Engineering	www.charismac.com
Elaborate Bytes	www.elby.ch
Fangmeier Sytemprogrammierung	www.feurio.com
Gear Software	www.gear.com
Golden Hawk Technology	www.goldenhawk.com
HyCD, Inc.	www.hycd.com
NewTech Infosystems	www.ntius.com
Oak Technology	www.oaktech.com
Padus, Inc.	www.padus.com
PoINT Software and Systems	www.pointsoft.de
Roxio, Inc.	www.roxio.com
Software Architects, Inc.	www.softarch.com
Veritas Software	www.veritas.com
VOB Computersysteme GmbH	www.vob.de

JUKEBOXES AND NETWORK STORAGE

ASACA Corporation	www.asaca.com
ASM GmbH & Co. KG	www.asm-jukebox.de
DAX Archiving Solutions	www.smartdax.com
DISC, Inc.	www.disc-storage.com
JVC Professional Products Company	pro.jvc.com
Kubik Enterprises Inc.	www.kubikjukebox.com
Luminex Software, Inc.	www.luminex.com
Pioneer Electronics	www.pioneerelectronics.com
Plasmon	www.plasmon.com
PowerFile, Inc.	www.powerfile.com
Procom Technology, Inc.	www.procom.com

DISC QUALITY ANALYSIS AND TESTING

Adivan High Tech AG	www.adivan.com
aeco NV	www.aecogroup.com
AudioDev	www.audiodev.com
CD Associates, Inc.	www.cdassociates.com
Cube Technologies GmbH	www.cube-tec.com
Clover Systems	www.cloversystems.com
DaTARIUS Technologies GmbH	www.datarius.com
Eclipse Data Technologies	www.eclipsedata.com
Efocus International Ltd.	www.efocus.co.uk
Quantized Systems	www.quantized.com
Sony Precision Technology, Inc	www.sonypt.com
StageTech Developments AB	www.stagetech.se

DISC REPAIR, RESTORATION AND DATA RECOVERY

Action Front Data Recovery Labs, Inc.	www.actionfront.com
Acodisc	www.acodisc.com
ArrowKey, Inc.	www.cdrom-prod.com
AuralTech	www.auratech.com
CD Data Guys	www.cddataguys.com
CD Recovery Services	www.cdrecovery.com
Compact Disc Repairman, Inc.	www.cdrepairman.com
Digital Innovations	www.digitalinnovations.com
ESS Data Recovery	www.savemyfiles.com
Naltech	www.naltech.com
Ontrack Data International	www.ontrack.com
Skippy Disc	www.skippydisc.com

DISC DESTRUCTION AND RECLYCLING

Alera Technologies, LLC.	www.aleratec.com
CD ROM Incorporated	www.cdrominc.com
Ecodisk	www.ecodisk.com
EcoMedia	www.ecomedia.com
GBC ModiCorp Limited	www.gbcmodi.com
Greendisk	www.greendisk.com
Hammacher Schlemmer and Company	www.hammacher.com
Hetzel Elektronik-Recycling GmbH	www.her-online.de
Intimus Business Systems	www.intimus.com
Lacerta Group, Inc.	www.lacerta.com
MBA Polymers, Inc.	www.mbapolymers.com
MRC Polymers	www.mrcpolmers.com
Niscoa, Inc.	www.niscoa.com
Sony Disc Manufacturing	www.sdm.sony.com

ABOUT OSTA

The Optical Storage Technology Association (OSTA) was incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products. The organization's membership includes manufacturers and resellers from three continents, representing more than 85 percent of worldwide writable optical product shipments, working together to educate consumers and shape the future of the optical storage industry. Included among OSTA's many accomplishments are its groundbreaking CD-R compatibility efforts, development of the Universal Disc Format (UDF) as well as the MultiRead, MultiPlay, MultiAudio and MultiPhoto/Video (MPV) specifications.

ABOUT THE AUTHOR

Hugh Bennett is president of Forget Me Not Information Systems Inc., an optical storage reseller, systems integrator and industry consultant based in London, Ontario, Canada. Hugh is a contributing editor and columnist for *EMedia* and *TapeDisc Business* magazines, chairman of the Canadian Advisory Committee for ISO/IEC JTC1/SC23 and the author of numerous white papers, studies and educational campaigns.

<div align="center">

Optical Storage Technology Association (OSTA)
19925 Stevens Creek Blvd.
Cupertino, CA 95014, USA
phone: (408) 253-3695
fax: (408) 253-9938
web: www.osta.org

</div>