The OSTA CD-R/DVD-ROM Compatibility Study

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OSTA CD/DVD Physical Compatibility Subcommittee
Brian J. Bartholomeusz (Eastman Kodak Company), Chairman

Editor's Notes

The storage industry in general has demonstrated a growing commitment to seamless backwards compatibility. Apart from the inherent technological elegance and rationality of this approach it is also a response to the unmistakable "voice of the customer" demanding protection of technology investments and information assets.

CD technology is an ubiquitous global distribution medium, and its recordable variants have made dramatic inroads due to their versatility, affordability and, most important, their promise of global standardization and compatibility. OSTA has played a leadership role in representing the interests of end users by actively championing compatibility and advocating rational technology migration pathways. To this end, OSTA embarked on a comprehensive series of CD-R/RW compatibility studies that have served to facilitate and demonstrate better compatibility between CD-R writers and media and CD-ROM readers. The present CD-R/DVD-ROM compatibility study is a logical extension of this activity, serving to forge a strong linkage between two rich and powerful storage formats. The future possibilities for synergistic growth of these product streams would appear to be without limit.

If you have any suggestions that might improve the accuracy or utility of this white paper please feel free to contact me or use the OSTA website (www.osta.org) Q&A facility.

Sincerely,
Brian J. Bartholomeusz, Eastman Kodak Company
Editor, OSTA CD-R/DVD-ROM Compatibility Study White Paper

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Introduction

By early to mid 1996, the surging growth of the CD-Recordable (CD-R) market appeared to be jeopardized by concerns, justifiable as it initially turned out, that CD-R discs would not be playable in DVD-ROM drives. This obviously was a cause of great concern for the CD-R industry, but even more so for the legions of CD-R users who were suddenly faced with the prospect of their technology investments, applications, and processes becoming rapidly obsolete. This unfortunate situation flew directly in the face of a clearly demonstrated and articulated desire by end users for orderly, seamless, and backwards compatible technology transitions. Compounding this confusion was the ambiguity of the many assurances by DVD hardware manufacturers that their products would be "fully CD compatible" when, in fact, many would not be compatible with CD-R.

Why the incompatibility? The dyes used for the active recording layer in CD-R discs are designed to function (for both writing and reading) in the wavelength range 775 nm to 795 nm, and they demonstrate a marked wavelength sensitivity, as depicted in Figure 1. DVD-Video players and DVD-ROM readers are based on 650 nm lasers, at which wavelength the reflectivity and signal levels emanating from CD-R discs are insufficient for reliable operation. There were some early attempts to render these signals usable by boosting the gain of the read channel electronics. After all, the dual layer DVD discs and the rewritable format have rather low reflectivity and require that signals from the disc be boosted for successful operation. Despite the fact that data from some CD-R discs was recoverable using this approach, the resulting cost and diminished reliability proved to be formidable obstacles.

Another solution that was advanced at this time was the use of so-called CD-R Type II media designed to produce required signal levels at both CD and DVD wavelengths. Despite some promising early results, this approach was hampered by the extreme difficulty of simultaneously achieving reliability at the DVD readout wavelength and the required level of compatibility and functionality at 780 nm. For example, the media had to possess multi-speed recording capability, good archival properties, seamless compatibility with the installed base of readers and players, etc.

Reacting and responding to these concerns and championing the cause of the exploding CD-R user base, the OSTA Physical Compatibility Sub-committee embarked on a vigorous campaign to articulate and publicize the value of creating a seamless linkage and transition between two very powerful and versatile storage technology product families. In response to

the sustained OSTA campaign and the clear message from the marketplace, in recognition of the tremendous synergistic business opportunities that exist, there was an avalanche of support from the DVD Industry beginning with OSTA member company Sony in mid 1996, that by now more or less assures the universal incorporation of CD-R functionality in DVD products and almost certainly in future DVD-ROM drives.

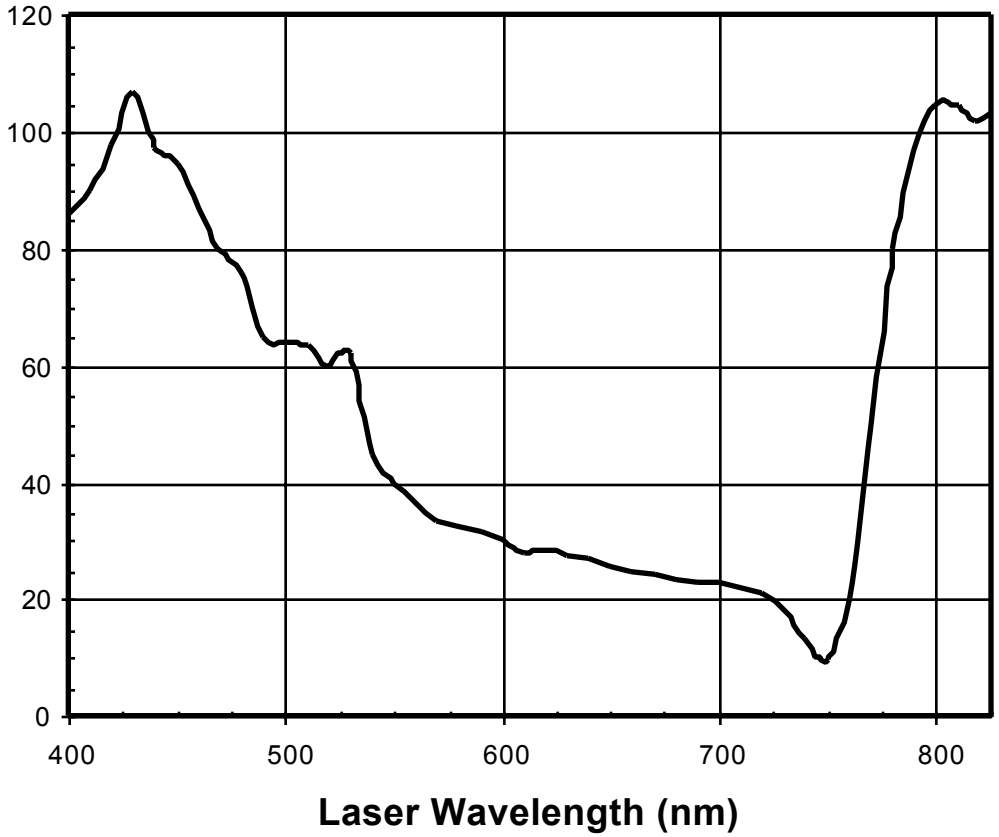

Figure 1*. The wavelength dependence of the reflectivity of a typical CD-R disc. Measurements were made in an ungrooved portion of the disc using a collimated beam. The actual reflectivity seen by an optical pickup unit will be different but will display a similar spectral sensitivity.*

What was the solution? In 1996, Sony proposed the use of a discrete dual laser pickup, one that combined a conventional, miniature CD-ROM pickup unit (containing a 780nm read laser) with a DVD-ROM pickup unit (based on a 650nm read laser). The former would handle CD format discs whereas the latter would be used for DVD discs. Figure 2 provides schematic depiction of this innovative hybrid solution which was described in some detail at the October 1996 OSTA meeting.

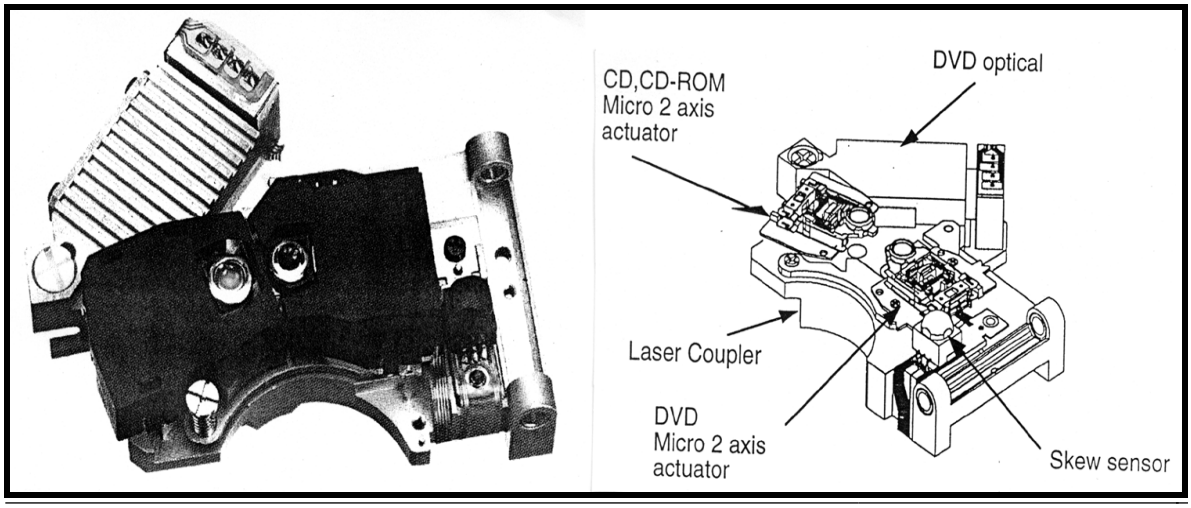

Figure 2. *The Sony dual discrete pickup unit that provided a technical pathway to ensure CD-R compatible DVD-ROM devices. The miniature CD-ROM pickup unit is derived from a proven commercial design; the so-called "laser coupler" pickup unit.*

Since Sony's announcement, a number of other companies have disclosed similar discrete, dual laser optical pickup units and, more recently, integrated dual laser devices that utilize a common optical pathway. The latter approach permits a higher degree of integration and, therefore, miniaturization.

The OSTA MultiRead Specification

The formalization of OSTA's commitment to championing and ensuring seamless compatibility between the rapidly growing installed CD-R/RW base and the emerging DVD format took the form of a detailed list of functional requirements which were released in 1997 by OSTA as the MultiRead Specification. This document not only provided the blueprint for implementing CD-RW media compatibility with CD-ROM drives but also documented how to facilitate CD-R and CD-RW media compatibility with DVD-ROM and other DVD drives.

The OSTA Compatibility Test

In addition to its advocacy of CD/DVD compatibility, OSTA, through the CD-Writable Physical Compatibility Subcommittee, embarked on an active testing program based on a proposal by M. Yokoyama of Sony. A carefully selected, thoroughly characterized suite of fully written CD-R

discs derived from the ongoing Phase II CD-R Compatibility Study were made available to DVD drive manufacturers for use during the product development phase. The goal was to provide the drive manufacturers with a representative sampling of discs their products were likely to encounter in the marketplace. Thirteen leading manufacturers comprising Acer Peripherals, Hitachi, JVC, LG Electronics, Matsushita Kotobuki, Mitsubishi Electric, NEC Home Electronics, Philips, Pioneer, Samsung, Sanyo, Sony, and TEAC, signed up as participants in the first round of the OSTA CD-R/DVD Compatibility Study, which began in earnest in June 1996.

The Sample Discs

1. 19 fully written 74 minute CDR discs (from leading manufacturers) all written with the same set of image test files.

2. One pressed (CD-ROM) disc with the identical test files.

The Test File Set

1. A total of approximately 72 minutes 8 seconds (72:08) were recorded onto each disc. (equivalent to 663,996,004 bytes)

2. The discs were written in mode 1 (2048) one track / single session.

3. The discs contained two directories: CDI and Photo_cd.

4. The CDI directory contained 33 data files (698,276 bytes).

5. The Photo_cd directory contained two subdirectories; Images and Rights and three data files (10,175,554 bytes).

6. The Images subdirectory contained 164 image files (653,121,535 bytes).

7. The Rights directory contained 1 data file (639 bytes).

The Test Schedule

April 15, 1997: Deadline for participant confirmation.

May 12, 1997: Detailed test plan and schedule communicated to participants.

May 20, 1997: Commencement of compatibility test.

June 9, 1997: Progress report and list of participants disclosed at OSTA meeting in San Francisco.

September 25, 1997: Phase 1 of study completed. All first round participants sent test results to test coordinator who combined them into a preliminary general report. Testing continues as Phase 2.

October 21, 1997: Results of Phase 1 of the study reported at the OSTA meeting in San Francisco.

January 15, 1998: Phase 2 of study completed. All participants sent test results to test coordinator who combined them with the Phase 1 results into a comprehensive general report.

February 3, 1998: Final results of the study reported at the OSTA meeting in San Francisco.

In the Future: Test discs to be made available to other manufacturers (on request) or to participants who wish to re-test them with modified or more advanced systems.

Detailed Test Procedure

1. Each company received the same set of 20 discs (19 CD-R discs and 1 pressed disc) according to the schedule. Each company was allocated two weeks for all the testing and data collection. Participants were instructed to handle the test discs with extreme caution, since they would have to be used by others.

2. After the testing was completed the 20 discs (19 CD-R + 1 pressed discs) were sent to the key contact person at the next company on the schedule (per the instructions of the test facilitator: Mr. Hiroshi Enomoto of Kodak Japan).

3. The specified parameters were tested using the current DVD-ROM product or platform. The test results were presented relative to those obtained for the pressed disk and communicated to Mr. Enomoto, who compiled all the results and maintained the confidentiality of the participants.

Test Parameters

1. **[average access time CD-R/average access time CD-ROM]**

2. **[average transfer rate CD-R/average transfer rate CD-ROM]**

3. **[read time CD-R/read time CD-ROM]** using files in CDI directory (33 data files - 698,276 bytes).

4. **verify** using files in CDI directory (33 data files - 698,276 bytes) *(optional)*

5. **average Error Rate** *(optional)*

Preliminary Results

Five companies had completed the test procedure by October 1997. This included, as outlined above, comparing the performance of CD-R discs relative to CD-ROM discs on DVD-ROM drives in various stages of development. The test parameters included access time, transfer rate, read time, and error rates and all resultant measurements were reported relative to those made on the pressed CD-ROM disc that contained the identical data set. This normalization was undertaken to remove from the test any minor system deviations and measurement variations and permit valid, across-the-board comparisons to be made.

The preliminary results, reported at the OSTA meeting on October 21, 1997, painted a very positive picture of the evolving compatibility and playability as seen in Figures 3-6. For example, more than 70% of the CD-R discs had an average access time that was within ± 10% of that measured for the pressed CD-ROM disc. More than 90% of the CD-R discs had an average data transfer rate that was within ± 10% of that for the pressed disc and more than 99% of the CD-R discs had a read time (for the specified directory) that was within ± 10% of that for the pressed disc. There was obvious room for improvement and certainly a range of measured performance capabilities depending on the development stage of one drive or another. However, this range of results and the resulting corrective action by manufacturers was exactly what this study was intended to accomplish.

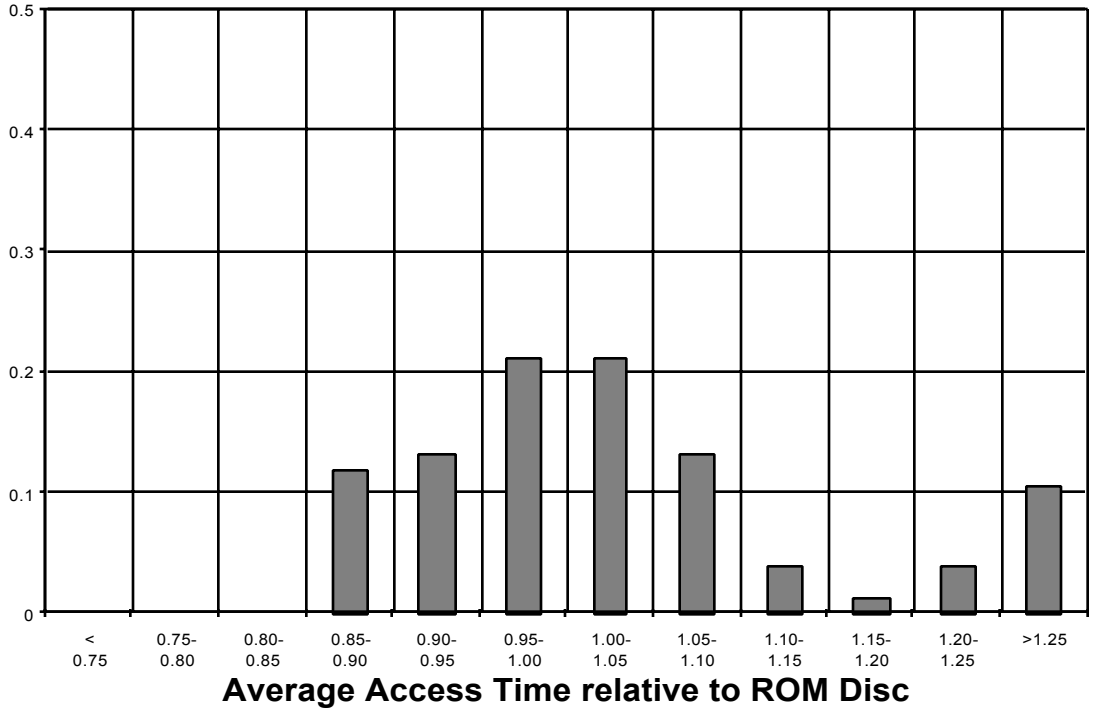

Figure 3. Normalized Average Access times for CD-R discs measured on DVD-ROM drives.

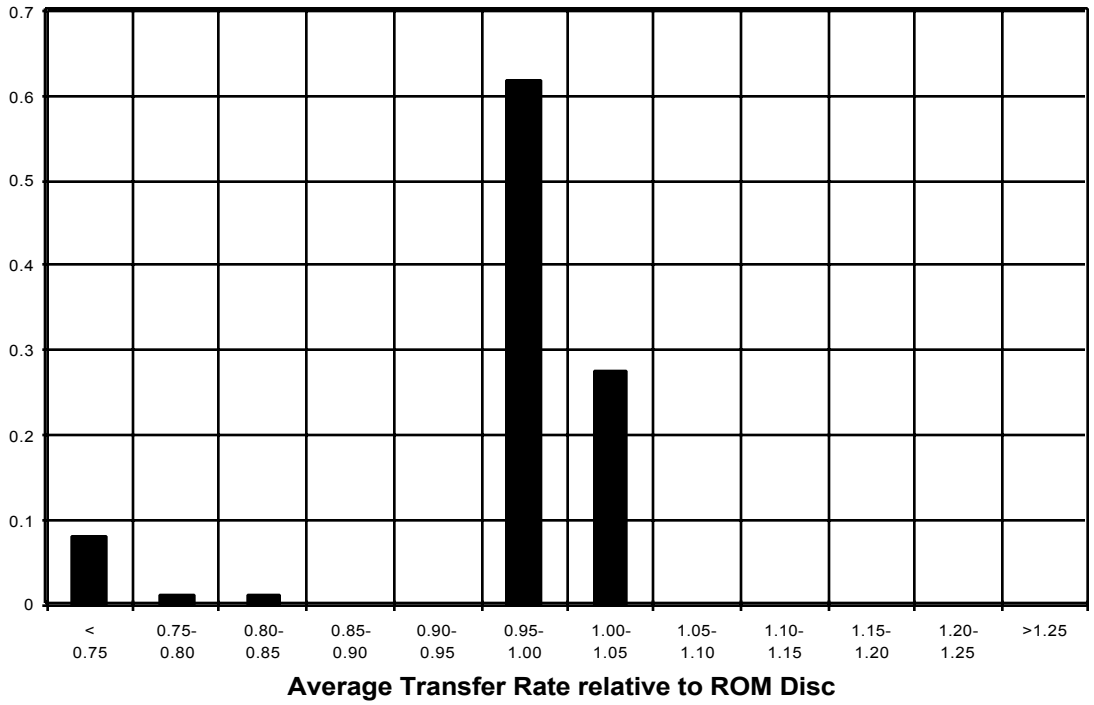

Figure 4. Normalized Average Transfer rates for CD-R discs measured on DVD-ROM drives. The lower than expected values were caused by the drives defaulting to lower read speeds as part of their retry strategy.

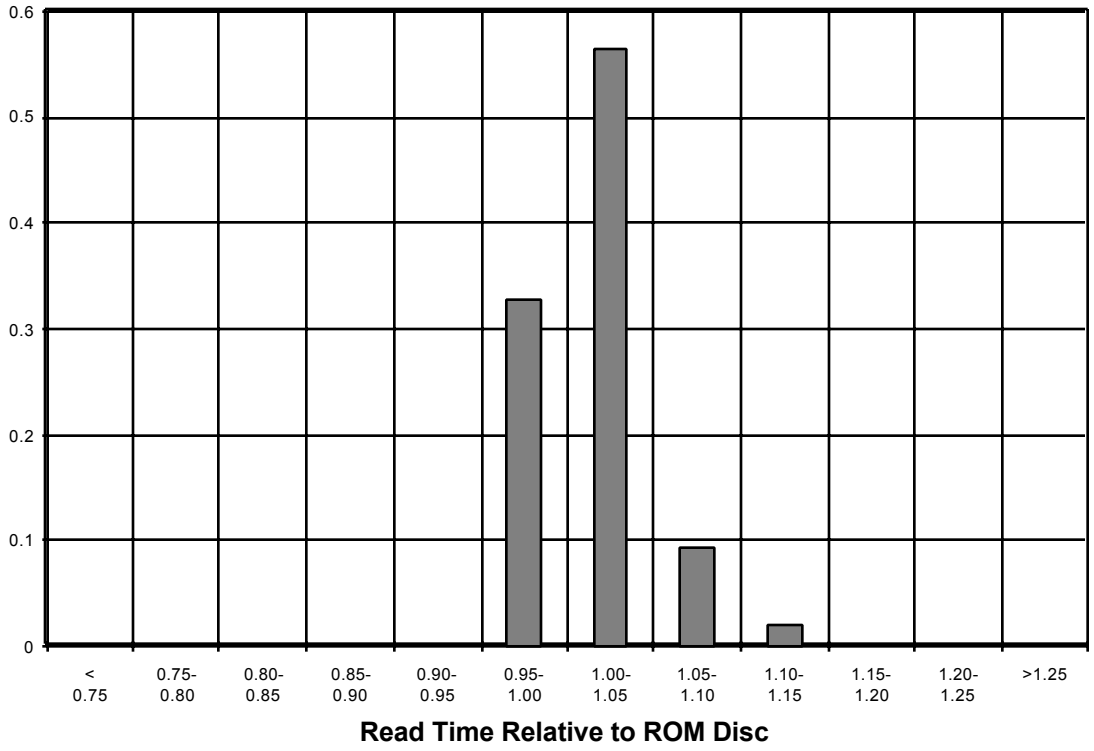

Figure 5. Normalized Read Time for a specified directory on CD-R discs measured on DVD-ROM drives.

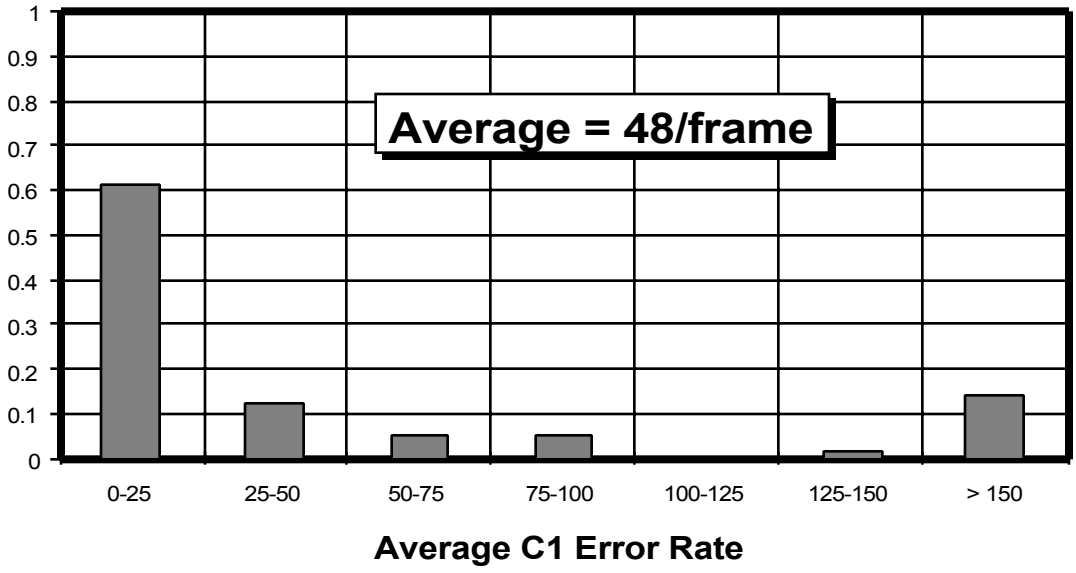

Figure 6. Average C1 Error Rate for CD-R discs measured on DVD-ROM drives. The average value reported for the pressed CD-ROM control samples was 37/frame.

The Final Results

Between October 1997 and February 1998 an additional five DVD-ROM drives (in various stages of development) were tested as part of the study. As before, there was a discernible compatibility range though, as seen in Figures 7 and 8, there was no clear localization of poor or good combinations. There were a few instances where a particular media/drive combination performed noticeably differently from the general population. However, in other instances, that particular drive or disc performed just as well as the others and therefore it is not possible to pinpoint specific "bad" discs or drives. It is likely that these anomalous incidents were a manifestation of some subtle interaction between the drive and disc, something that would not be surprising given the immature state of some of the systems employed. For example, in Figure 8, Drive #6 reported a very low transfer rate for the pressed CD-ROM control disc. This served to elevate the transfer rate of many of the CD-R discs to unrealistically high relative rates. This was certainly not reflected in the performance of these particular discs with other drives and is probably a symptom of a malfunctioning or faulty drive or components more than anything. This issue is being investigated but it has been established that the drive in question is a very early prototype high speed DVD-ROM drive. Hopefully, the results obtained as part of this study will provide the impetus to rectify this deficiency and aid in the development of a robust final product. Figures 9 & 10 present the same information plotted as a function of the particular drive that was used. It serves to highlight the observed range of performance capabilities of the population.

Figures 11-13 depict the aggregate access times, transfer rates, and read times (all normalized with respect to the pressed CD-ROM control disc). Quite a large fraction of the discs, particularly on the more mature test drives, performed at the rated level. However, there were, as before, some fraction of the disc/drive combinations whose performance suggested room for improvement.

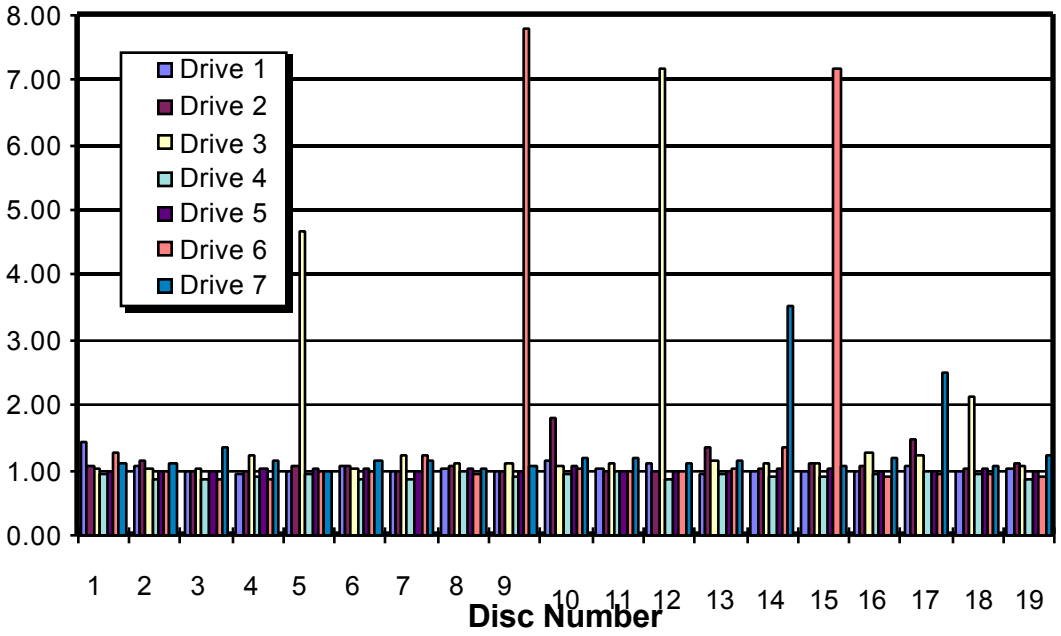

Figure 7. Normalized average access times for various disc/drive combinations.

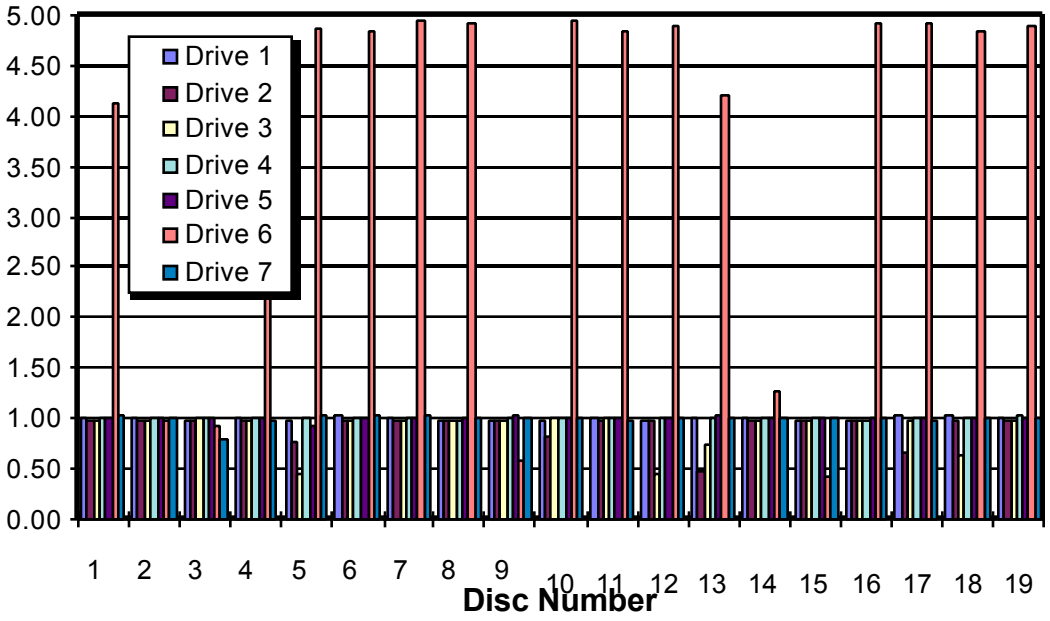

Figure 8. Normalized average transfer rate for all the disc/drive combinations. Note that Drive #6 reported a very low value for the pressed CD-ROM control disc resulting in unrealistically high transfer rates for many of the CD-R discs.

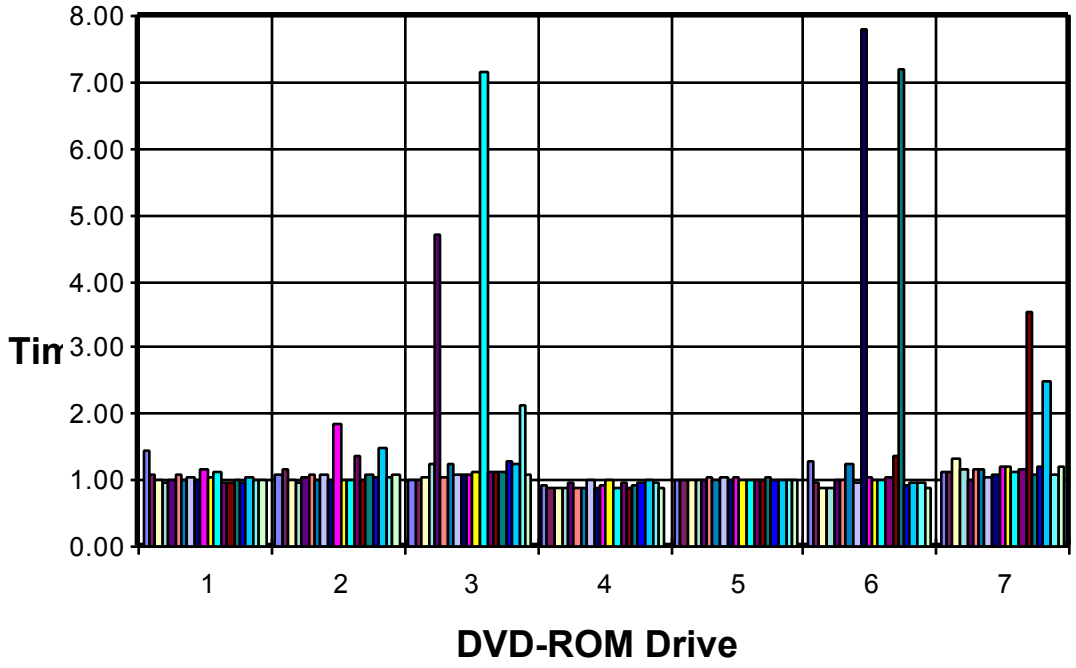

Figure 9. Normalized average access times for various disc/drive combinations.

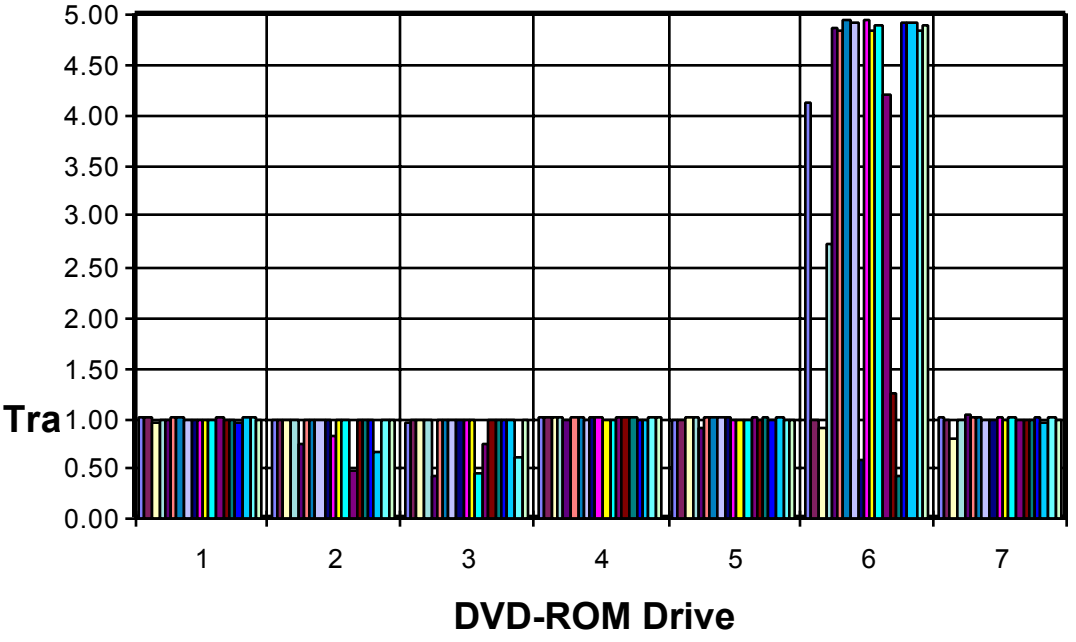

Figure 10. Normalized average transfer rate for all the disc/drive combinations. Note that Drive #6 reported a very low value for the pressed CD-ROM control disc resulting in unrealistically high transfer rates for many of the CD-R discs.

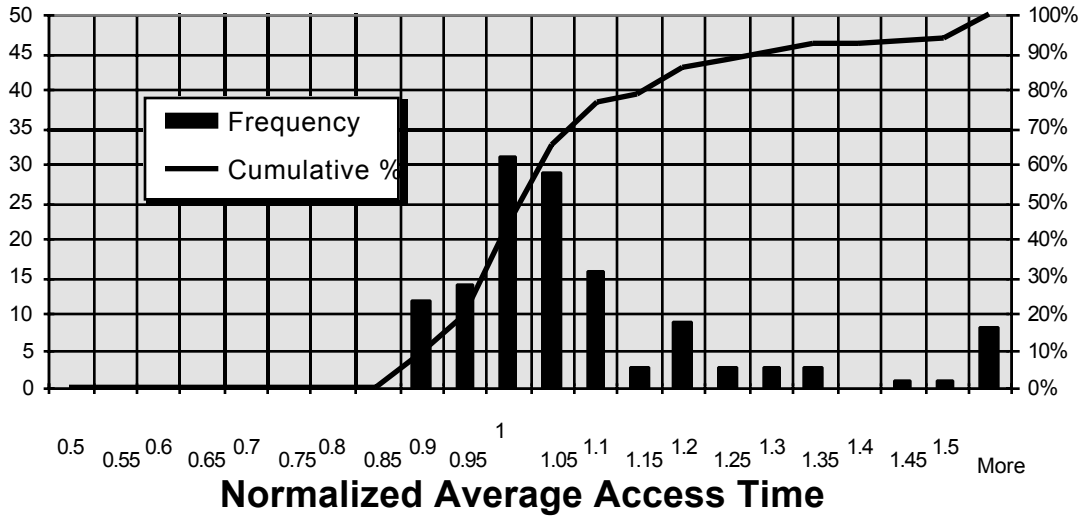

Figure 11. Histogram depicting global normalized average access time for all disc/drive combinations.

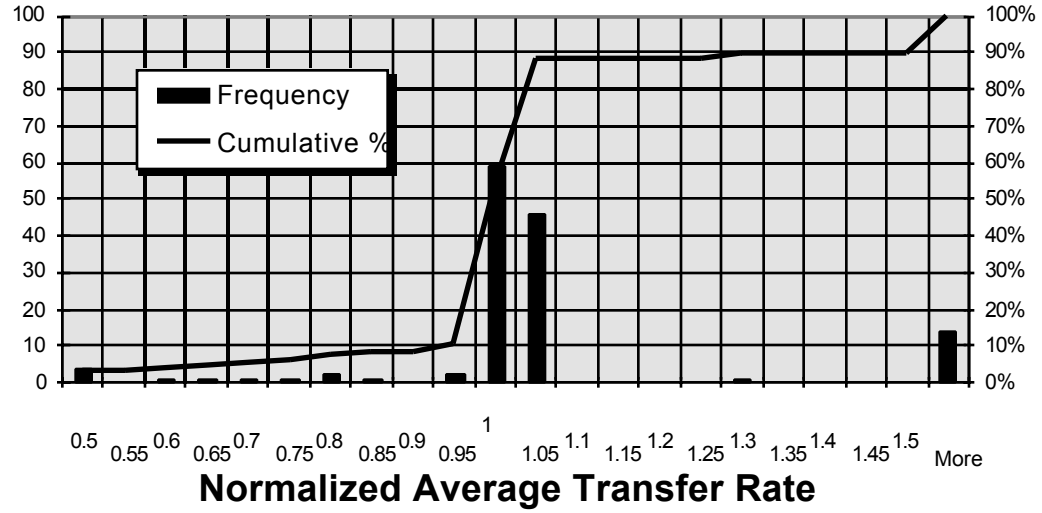

Figure 12. Histogram depicting global Normalized Average Transfer rate for disc/drive combinations.

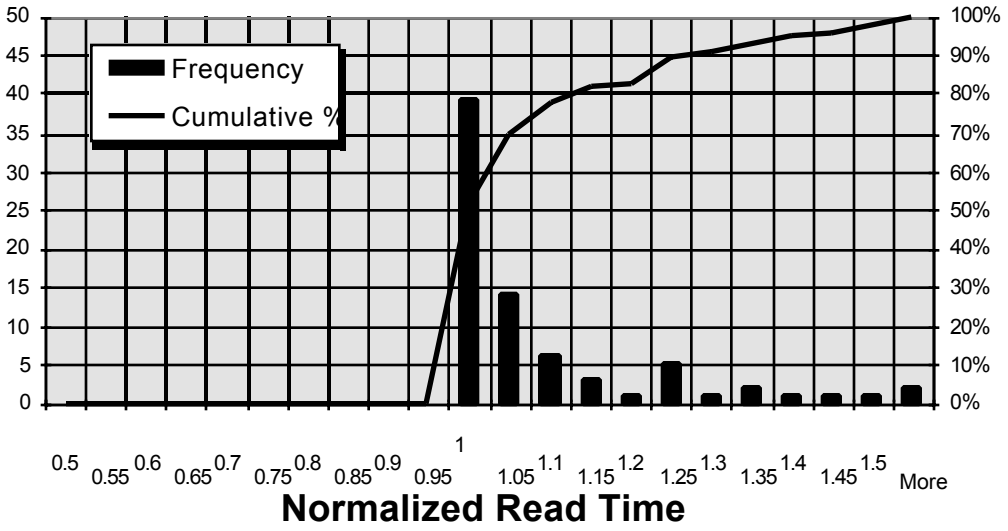

Figure 13. Histogram depicting global Normalized Average Read time for disc/drive combinations.

Summary

- The average CD-R access time was 1.08 times that of the control disc (removing 4 data points that were clearly outliers). 78% of the CD-R average access times were < 110% of those of the control disc.

- The average CD-R transfer rate was 0.98 times that of the control disc (removing the 13 data points associated with Drive #6 that were clearly outliers). 89% of the average transfer rates for the CD-R discs were > 90% of those of the control disc.

- The average CD-R read time was 1.12 times that of the control disc. 80% of the read times for the CD-R discs were < 110% of those of the control disc.

The Future

It is envisioned that after the first round of testing is completed (in February 1998) the test discs will be made available to any company desiring to do additional testing and product refinement.

An Added Dimension: CD-ReWritable

In keeping with OSTA's mission of championing compatibility between optical storage formats the study was expanded to include the newly announced CD-ReWritable (CD-RW) format. Due to timing issues, this was an optional feature of the current study but will no doubt become an integral part of any similar initiatives in the future.

Participants were provided with a number of fully recorded CD-RW discs (containing the OSTA test file set). In a move that was widely welcomed, they were permitted to keep some of these indefinitely for testing purposes. The others, obtained from a variety of manufacturers, were circulated to all participants with the CD-R test suite. Results from the CD-RW testing was not merged with the results obtained from the CD-R discs but were for the express use of CD-RW media community for development purposes.

The Bottom Line

Ultimately what is most significant about the OSTA CD-R/DVD compatibility study is that it highlights the value of manufacturers, applications developers, and end users cooperatively working together to deliver solutions that are of unquestioned value and benefit to all concerned and which ultimately increase the viability and longevity of optical storage technology. It is gratifying to note that almost all leading manufacturers have now implemented CD-R compatibility into their DVD-ROM products and some, even into their recordable and rewritable products as well.

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Table 1. *CD/CD-R/DVD Physical Format Comparison Chart (*courtesy of *Hugh Bennett*)

	CD-ROM	CD-R	DVD-ROM
DISC			
Disc diameter	120mm	120mm	120mm
Disc thickness	1.2mm	1.2mm	1.2mm (2 x 0.6mm)
Disc structure	Single substrate	Single substrate	Two bonded substrates
Track pitch	1.6µm	1.6µm	0.74µm
Minimum pit length	0.83µm (1.2m/s) 0.972µm (1.4m/s)	0.83µm (1.2m/s) 0.972µm (1.4m/s)	0.4µm (single layer) 0.44µm (dual layer)
Data layers	1	1	1 or 2
Max. data capacity	550MB (1.4m/s) 650MB (1.2m/s)	550MB (1.4m/s) 650MB (1.2m/s)	4.7GB x 2 (single layer) 8.54GB x 2 (dual layer)
Reflectivity	> 0.70	> 0.65	45 to 85% (single layer) 18 to 30% (dual layer)
OPTICAL SYSTEM			
Read out laser wavelength	770 to 830nm	770 to 830nm	650/635nm
Numerical aperture	0.45	0.45	0.60
Read laser power	< 0.7mw	< 0.7mw	< 1.0 mw

