National Bureau
of Standards

# Computer Science and Technology

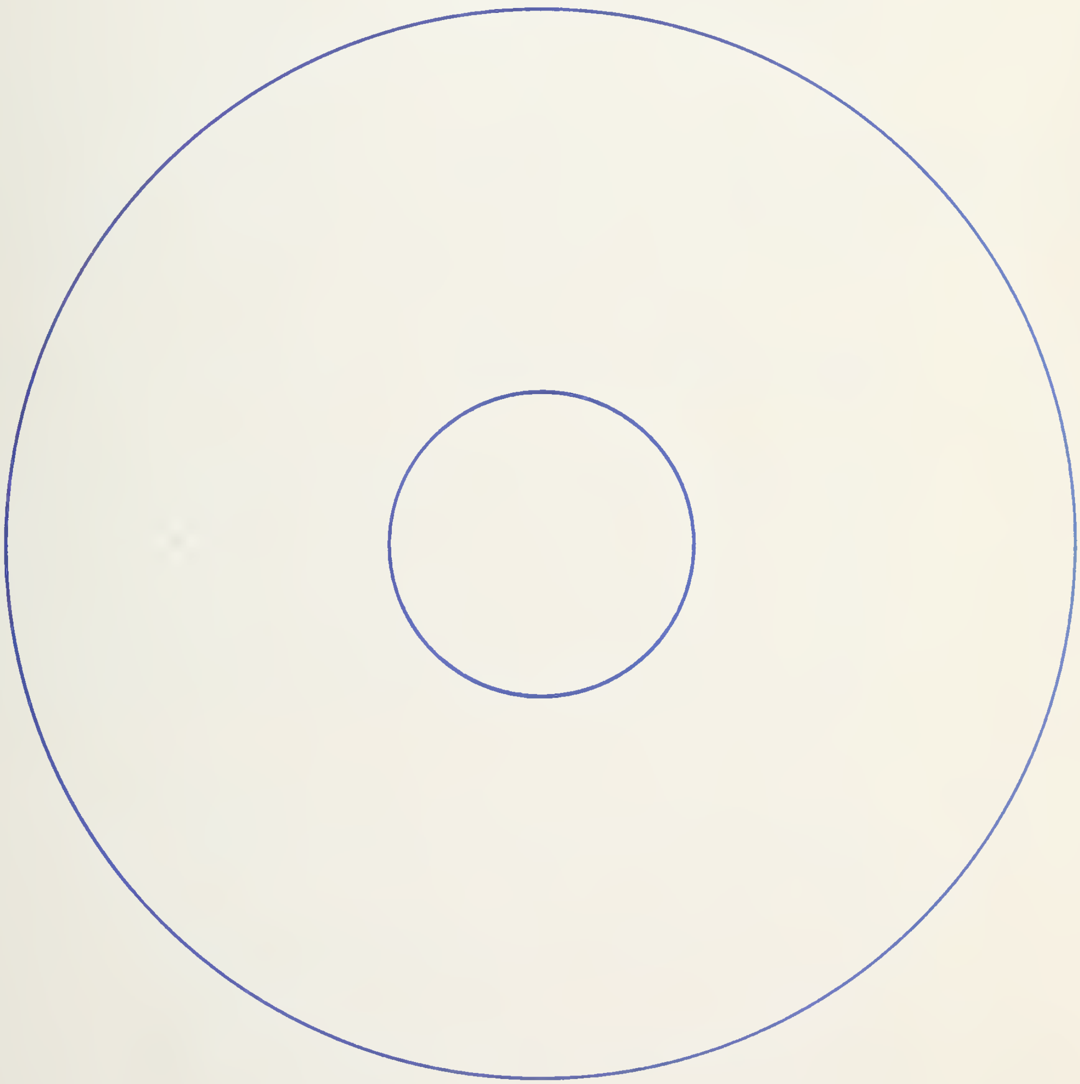


NBS Special Publication 500-111

Proceedings of the National Bureau of Standards/National Security Agency Workshop on

# Standardization Issues for Optical Digital Data Disk ($OD^3$) Technology

Held at National Bureau of Standards, Gaithersburg, Maryland, June 1-3, 1983



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## ABSTRACT

National Bureau of Standards/National Security Agency
Workshop on Standardization Issues for
Optical Digital Data Disk ($OD^3$) Technology

Jean B. Freedman
Editor

This report constitutes the proceedings of the National Bureau of Standards/National Security Agency jointly-sponsored Workshop on Standardization Issues for Optical Digital Data Disk ($OD^3$) Technology, held in Gaithersburg, Maryland, June 1-2-3, 1983. The objective of this workshop is to promote discussion and interchange among current and potential $OD^3$ users and suppliers, regarding the prospects for $OD^3$ data interchange standardization.

The workshop presentations include definitions of the physical, dimensional, optoelectrical, quality and data transfer characteristics of $OD^3$ media, as related to the drive performance. A range of $OD^3$ applications and their standards' requirements are also described. The various methods currently used for estimating media life expectancies and the potential for standardized terminologies and procedures for such assessments are discussed.

Many workshop participants noted that there were numerous complexities associated with $OD^3$ data interchange among systems. Data interchange parameters include the optical media sizes, their reflection and transmission characteristics, error detection and correction schemes, and numerous other parameters that are incorporated in the functional design of $OD^3$ media and systems.

The participants also noted the timeliness and importance of $OD^3$ data interchange standardization activities and gave priority to the development of an optical digital data disk lexicon. Many of the workshop participants also expressed an immediate need for standardized test and evaluation procedures for $OD^3$ media responses, life expectancies, and environmental requirements.



**Key words:** archival storage; cartridge; computer storage media; data interchange; data transfer interfaces; media life expectancy; optical digital data disk ($OD^3$); optical disk document scan applications; optical disk mass storage system applications; optical disk systems; standardization.

## INTRODUCTION

These proceedings include synopses of presentations and panel discussions from the National Bureau of Standards and National Security Agency jointly-sponsored Workshop on Standardization Issues for Optical Digital Data Disk ($OD^3$) Technology. The workshop was held on June 1-2-3, 1983, in Gaithersburg, Maryland, in response to the growing interest in the prospects for standardization of $OD^3$ media and systems.

A. The purpose and scope of the workshop includes the following:

(1) To examine the emerging $OD^3$ technologies and applications.

- Define the implementation of $OD^3$ technology in mass storage systems (MSS) and document scan systems.
- Discuss the test methods and techniques for determining life expectancies of unrecorded and recorded $OD^3$ media.
- Discuss the system relationships of $OD^3$ media, drive, and data channel interfaces.

(2) To determine the potential directions for standardization of $OD^3$ media and systems.

- Specify the physical, dimensional, optoelectrical, and data transfer characteristics that are required for $OD^3$ data interchange.
- Examine the data interchange problems associated with $OD^3$ technology.
- Assess the impacts of standards in a field consisting of emerging optical media and systems.
- Explore where standards could be useful for $OD^3$ unrecorded and recorded media, cartridge, and data transfer/command interfaces.
- Describe the role of the Institute for Computer Sciences and Technology (ICST) at the National Bureau of Standards (NBS) in the development of standards, and their participation in standards committee activities.

(3) To provide technical information and guidance towards the development of future standards, based on the expressed needs of users and suppliers.

- Establish the need for the development of standardized vocabularies and test procedures--specifically for use in the evaluation of $OD^3$ unrecorded media life and recorded data life.

B. Special Terms

The terminology '**optical digital data disk ($OD^3$)**' is gaining acceptance in the computer storage media community in order to differentiate this computer peripheral storage technology from optical disk technology which is used in audio and video home entertainment systems. The term was suggested in February 1983, by the Computer Storage Media Group of ICST.

A list of symbols, abbreviations, and acronyms used in this proceedings is in Appendix A.

A preliminary glossary written by a task group of the X3 Information Processing Systems Committee of the American National Standards Institute (ANSI) is in Appendix B.

C. Participants

Current and future $OD^3$ users, manufacturers, and technical experts presented papers, and participated in both panels and open discussions.

Forty-six current and potential optical disk users participated, representing twenty-seven different Federal and commercial organizations. These users were familiar with the applications of $OD^3$ technology, were original equipment manufacturers (OEM), and/or represented system integration companies. A list of the workshop participants is in Appendix C.

Twenty-seven $OD^3$ developers and suppliers participated; they represented sixteen organizations; four were consultants, one was a trade association delegate, and four were members of organizations engaged in computer storage media technologies other than $OD^3$.

**Since the workshop participants' contributions included descriptions of their professional experiences, references were necessarily made to specific suppliers and commercial products. The inclusion or omission of these companies or products in this report does not imply an endorsement or a criticism by the National Bureau of Standards or the National Security Agency.**

D. Data Collection

To compile these proceedings, notes were taken during the workshop presentations and panel discussions. This data was then synopsized and sent to each presentor for his/her review, additions, and deletions. After the participant's approval, the synopses were assembled, chronologically as the presentations and discussions occurred during the workshop, in an effort to record the essence of the information exchanged, in the form of these proceedings.

E. Program and Acknowledgements

The program for this Workshop on Standardization Issues for $OD^3$ Technology which is described within the contents of these Proceedings, was developed by a group consisting of Mark Goldberg of the National Security Agency, Michael Deese of Storage Technology Corporation, Edward LaBudde of LaBudde Engineering, and Jean Freedman, of the Institute for Computer Sciences and Technology, National Bureau of Standards.

The workshop program was structured into three days. Presentations and panel discussions were selected to define the characteristics of an Optical Media Unit and the Digital Data Channel Interfaces as Related to Drive Performance (June 1, 1983). The Applications for Digital Optical Storage and Test Methods for Determining Relative Media and Data Life were covered on June 2, 1983. Presentations and discussions on The Pursuit of $OD^3$ Data Interchange Standards concluded the program on June 3, 1983.

The successful development and organization of the workshop program stemmed from many spirited group meetings and discussions. These resulted in a creative and interactive workshop program, that has elicited widespread interest from both the potential users of the $OD^3$ technology, as well as from the suppliers and developers of $OD^3$ systems and their associated media.

I wish to express gratitude for the cooperation and diligent efforts put forth by the United States Government and industry experts on the program committee.

I also acknowledge the significant contributions made by two members of ICST to these proceedings. Those being Mr. Sidney B. Geller's technical editing assistance and Mrs. Candice E. Leatherman's exceptional production of this document, which benefited from her dedication and aesthetic secretarial skills.

Jean Freedman, Chair
Workshop on Standardization Issues for $OD^3$ Technology

National Bureau of Standards/National Security Agency
Workshop on Standardization Issues for Optical
Digital Data Disk ($OD^3$) Technology

## WELCOMING REMARKS

**James Burrows**
**National Bureau of Standards (NBS)**

Mr. Burrows welcomed the participants to the Workshop on Standardization Issues for Optical Digital Data Disk ($OD^3$) Technology and explained the role of Institute for Computer Sciences and Technology (ICST) at the National Bureau of Standards (NBS) in the development of computer and network standards. He noted that NBS/ICST works directly with industry and users in determining requirements for standards and participates in the development of national voluntary standards, through organizations such as the American National Standards Institute (ANSI). NBS/ICST also participates in international standards development activities which are carried out by the International Organization for Standardization (ISO) and other international groups.

The establishment of a national standard is a process that often takes five or more years to complete. NBS/ICST facilitates the standards writing process by chairing many groups and committees and by preparing technical specifications. Another important function of NBS/ICST is the preparation of guidelines which provide explanatory material and guidance to Federal ADP managers and others on the management and use of computers and good ADP operating practices. NBS/ICST also develops procedures for verifying the performance of products for conformance to standards.

Because of the cost and time required to participate, many users are unable to be active in the development of standards. NBS/ICST continues to serve as an advocate for the users in order to assure that their interests are not neglected. Another obstacle to the voluntary standards process is the lack of a mechanism for enforcing attendance at standards meetings or to compel necessary action on the part of committee members. Because most of the participants are not able to devote their full-time efforts to standards, NBS representatives on various standards committees can provide the important element of continuity, since this is their primary activity. NBS also serves as a source of information on standards activities to the Federal government at large.

Mr. Burrows encouraged the workshop attendees to continue to participate in the development of standards for $OD^3$.

National Bureau of Standards/National Security Agency
Workshop on Standardization Issues for Optical
Digital Data Disk ($OD^3$) Technology

## OPENING REMARKS

**John Riganati**
**National Bureau of Standards (NBS)**

Dr. Riganati described the rationale and the objectives of the workshop. The sponsors for this workshop are the National Bureau of Standards (NBS) which serves as the focal point for Federal ADP activity, and the National Security Agency (NSA) which is a significant user and developer of leading-edge technology.

Dr. Riganati called attention to the voluntary process by which standards are achieved through consensus. Vendors don't want the users to dictate their product lines, while users don't want to be held captive by a single vendor. He described the role of NBS as a laboratory-supported activity in its involvement with standards, and indicated that NBS has a full range of laboratory facilities as well as the technical competence which is required for the exploration and evaluation of a new technology. These factors provide a sound basis for formulating technical judgments upon which to base standards decisions.

One of the current interests at NBS is the characterization and assessment of the life expectancy of media used for data and image storage. NBS has always had a strong interest in new technologies and functions as a catalyst in bringing such technologies into productive use. It also serves as an independent arbiter in bringing together suppliers of new equipment and techniques with potential users.

The workshop participants were carefully selected in order to achieve a balance among product developers, users, government agencies, universities, and system integrators. Fifty-five percent of the participants are in the user category. Dr. Riganati encouraged the participants to give personal opinions when addressing technical issues, and to represent their business interests on matters of consensus.

Dr. Riganati announced that the workshop would be concerned with exploring the characteristics of a new system element, the $OD^3$. Some products are beginning to reach the market, while others are undergoing initial user evaluation. He sensed that the interest in $OD^3$ is now increasing rapidly, thus emphasizing the importance of a timely initiation of standards activities. He urged the participants to direct their attention to the media interchange issues.

Dr. Riganati also noted that there are various ways in which a market can develop. The first supplier to reach the market can create demand and establish a user community. However, as successive suppliers emerge, the market may become stratified; i.e., each vendor will develop its own constituency. The goal of NBS is to see a compatible market capable of media interchange, rather than a stratified one.

The timing of $OD^3$ standardization is considered to be too soon by some and by others, too late. One of the reasons for having this workshop is to ascertain how the participants view the timing of $OD^3$ standardization and also to provide an information source for planning future NBS standards activity.

National Bureau of Standards/National Security Agency
Workshop on Standardization Issues for Optical
Digital Data Disk ($OD^3$) Technology

## INTRODUCTION TO THE WORKSHOP PRESENTATIONS AND DISCUSSIONS

**Jean Freedman**
**National Bureau of Standards (NBS)**
**and**
**Mark Goldberg**
**National Security Agency (NSA)**

Jean Freedman, who both chaired the Workshop on Standardization Issues for $OD^3$ Technology and was also a member of the program committee, introduced the other members of the committee, namely, Mark Goldberg of the National Security Agency, Mike Deese of Storage Technology Corporation, and Edward LaBudde of LaBudde Engineering Corporation. Jean then reviewed the three-day workshop schedule. (She had explicitly reviewed it with each participant, weeks prior to the actual occurrence of the workshop, allowing the participants time to prepare.)

Jean called the participants' attention to the three days covered by the workshop program. As specified in the program (which is comprehensively covered in the Workshop Proceedings Table of Contents), the first day's presentations and discussions are devoted primarily to defining the characteristics of $OD^3$ media and system interfaces, and their relationships to the drive performance. The second day is dedicated to discussion of $OD^3$ applications and media testing and the third (final) day of the workshop covers the prospects and pursuit of $OD^3$ data interchange standards.

Mark Goldberg of NSA cautioned as to the difficulty of arriving at a standard, and noted that even a modest system change could have a ripple effect throughout an $OD^3$ system. He advised that the workshop participants consider whether any $OD^3$ media or system parameters could be standardized, and if so, what parameters?

# 1. DAY 1: WEDNESDAY, JUNE 1, 1983 - CHARACTERISTICS OF AN OPTICAL MEDIA UNIT AND THE DIGITAL DATA CHANNEL INTERFACES AS RELATED TO DRIVE PERFORMANCE

## 1.1 SESSION I PRESENTATIONS AND DISCUSSIONS - UNRECORDED OPTICAL MEDIA UNIT CHARACTERISTICS

### 1.1.1 THE CARTRIDGE AND DISK INTERFACES Physical, Labelling, and Handling

**By Boris Muchnik**
**Storage Technology Corporation (STC)**

Key words: cartridge; disk dust protection; environmental factors; media protection; standardization.

Introduction

Mr. Muchnik showed an STC cartridge containing an optical disk on a slide-out tray. In operation, the disk would be lifted from the tray (which is within the disk drive) and the disk would be spun outside the cartridge **(see fig. 1)**. He suggested a variety of factors that might be considered for standardization, discussed as follows.

Cartridge Requirements

The cartridge provides the media protection from contamination and abuse during handling and storage. Tradeoffs, which affect cost and function, should be considered in deciding to design a disk which can or cannot be removed from its cartridge. Since the environment in the drive is considered semi-clean, protection provided by the cartridge is less important once the cartridge is loaded. For example, if the disk remains in the cartridge, there must be a reading window. This requirement adds complexity to the cartridge design, and the window would also require cleaning. Spinning of the disk within the cartridge also risks contamination stemming from the cartridge.

The cartridge design must incorporate protection from environmental factors such as temperature, humidity, and altitude, vibration, and non-operational shock.

Prerequisite to a meaningful standards effort is the need for definitions, including such items as the disk-unit dimensions, thicknesses, axial position of the disk surface, and axial movement.

Mr. Muchnik suggested the following $OD^3$ cartridge characteristics may be considered for standardization:

(1) Physical size and weight
(2) Keying
(3) Restraint of disk in cartridge
(4) Machine/human readable ID
(5) Disk support structure for disk within drive

(6) Disk removal in drive
(7) Features for tamper-proofing
(8) Over-limit temperature indication
(9) Machine-handling features
(10) File protection, write inhibit
(11) Features for sensing that the cartridge is present, mounted, and ready

## Discussion

Mr. Muchnik noted that the OD$^3$ cartridge was primarily designed for disk dust protection in particle sizes ranging from 25 to 200 $\mu$m (1000 to 8000 $\mu$in), since the thickness of the disk overcoat was sufficient to cause defocusing of dust smaller than 25 $\mu$m (1000 $\mu$in). (Particles of this size would not be detected.)

He noted that studies are underway to ascertain the air quality in different locations, to provide guidance for environmental testing. He noted that there was some dust filtration in the drive, but that dust protection is ultimately the result of several factors in the disk/cartridge configuration.

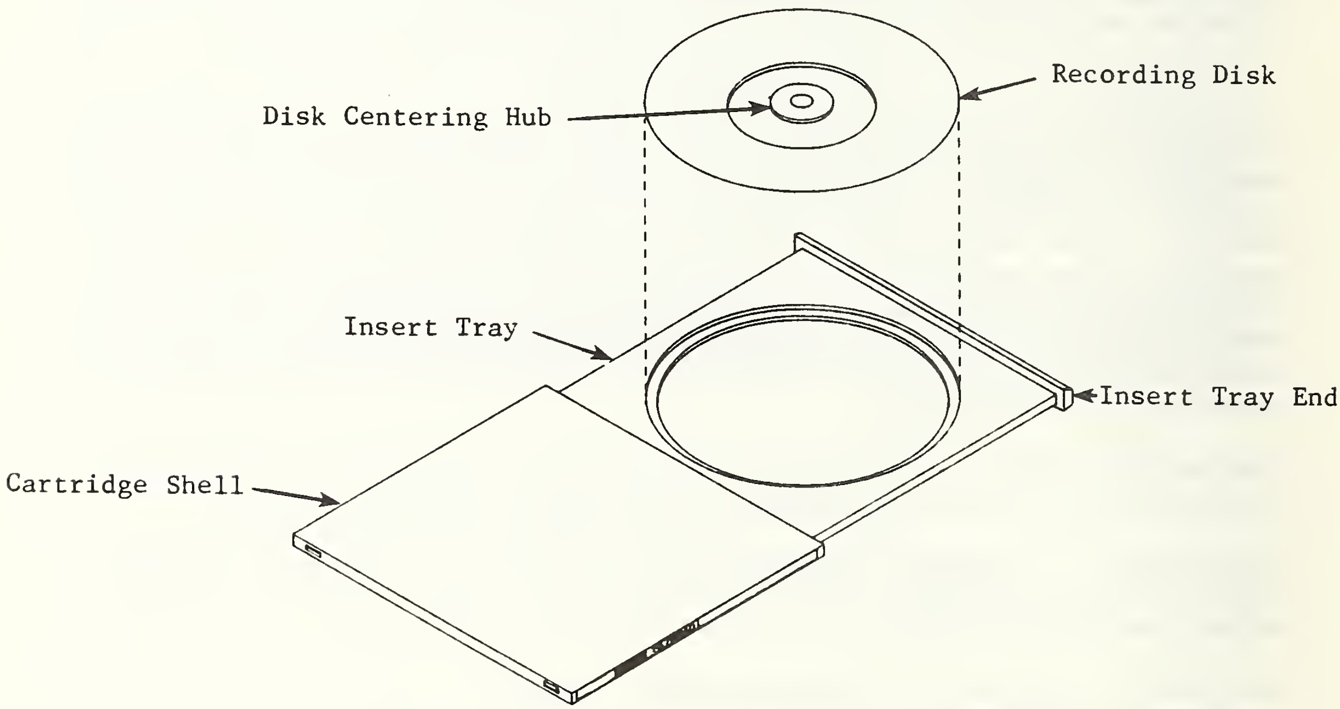



Figure 1. Cartridge Assembly
(Muchnik - Storage Technology Corporation)

## 1.1.2 PHYSICAL AND MECHANICAL CHARACTERISTICS OF AN UNRECORDED OPTICAL MEDIA UNIT: SPECIFIABLE PARAMETERS REQUIRED FOR DATA INTERCHANGE

**By Philip Scheinert**
**Burroughs Corporation**

Key words: dimensions; disk zones; geometry; mechanical properties; physical interface; surface characteristics.

### Introduction

Mr. Scheinert concentrated his presentation on the specifiable parameters required for data interchange. He proposed that standards should deal with the minimum set of physical and mechanical characteristics required to allow data interchange for Optical Media Units (OMU). He loosely grouped these characteristics into the following four categories:

(1) Optical Digital Data Disk Geometry
(2) Optical Digital Data Disk Dimensions
(3) Optical Digital Data Disk Mechanical Properties
(4) Optical Digital Data Disk Surface Characteristics

### (1) Optical Digital Data Disk Geometry

| Specification | Definition/Description | Standard Required Because of Direct Interaction with: |
|---|---|---|
| Recording Zone | Region of the OMU which may be accessed and written on and read by an optical memory drive unit. Within this zone, all recording (information) layer performance specifications must be met. | Translator |
| Handling Zone | Region of the OMU which may be physically contacted by a mechanical handling mechanism. | Handling Mechanism/ Cartridge |
| Clamping Zone | Region of the OMU which will be in contact with the drive unit spindle and clamping mechanism. | Spindle/Clamping Mechanism |
| Edge | Geometry of the outer and/or inner edge of the OMU pertaining to handling and/or clamping. | Handling and/or Clamping Mechanism |
| Physical Location of OMU Surfaces | Regions to which the OMU surfaces are restricted. | Objective, Cartridge |

Mr. Scheinert introduced a figure to illustrate various disk zones **(see fig. 1)**. These include: a small handling zone at the periphery of the disk, a clamping zone around the spindle hole, and a recording zone occupying the annular space between these two.

He introduced a figure designating regions lying adjacent to the faces of the disk showing the domain of the disk and protective coating **(see fig. 2)**.

(2) Optical Digital Data Disk Dimensions

| Specification | Definition/Description | Standard Required Because of Direct Interaction with: |
|---|---|---|
| Outside Diameter | Defines greatest dimension of OMU | Cartridge/Handling Mechanism |
| Inside Diameter | Defines hole size | Spindle/Clamping Mechanism |
| Noncircularity of the Outside Diameter<br><br>Noncircularity of the Inside Diameter | Noncircularity may be defined as the deviation from a perfect circle whose center is the mechanical center of the OMU. The mechanical center of the OMU is the center of the mathematical circle which is the least squares fit to the OMU contour. | Cartridge/Handling Mechanism |
| Concentricity | Difference in the mechanical center locations of the inner and outer diameters of the OMU | Spindle, Tracking |
| Thickness in the Clamping Zone | Thickness of the OMU that will be contacted by the drive unit disk clamp | Clamping Mechanism |

(3) Optical Digital Data Disk Mechanical Properties

| Specification | Definition/Description | Standard Required Because of Direct Interaction with: |
|---|---|---|
| Mass | Mass used instead of weight for non-earth surface environments | Spindle Motor |
| Unbalance | Product of the total mass of the OMU and the distance between the center of gravity of the disk and the axis of the disk | Spindle, Tracking |
| Protective Layer Hardness | Hardness description (scale) will be determined by specific test method | Environment, Cleaning |
| Clamping Zone Hardness | Hardness description (scale) will be determined by specific test method | Clamping Mechanism |
| Handling Zone Hardness | Hardness description (scale) will be determined by specific test method | Handling Mechanism |

(4) Optical Digital Data Disk Surface Characteristics

| Specification | Definition/Description | Standard Required Because of Direct Interaction with: |
|---|---|---|
| Recording Surface Axial Runout | (Zmax-Zmin) for cylindrical coordinates with $\theta$ the rotation direction, specifying the rotation plane, and Z being perpendicular to the rotation plane | Focus Motor |
| Recording Surface Axial Acceleration | Second derivative of Z ($\theta$) with respect to | Focus Motor |
| Protective Layer Static Characteristics | Characteristics with respect to static charge and decay and dust attraction and retention | Objective, Cartridge and Drive Environment |

He noted that the disk surface should not be "sticky," either due to electrostatic attraction or to being hygroscopic.

## Discussion

Mr. Scheinert indicated that his presentation referred primarily to single-sided disks, but could be extended to double-sided. He did not address the cartridge issue as such, but said that some form of protection was assumed. The suggestion was made that the standard should provide a minimal set of values rather than an optimal set, thereby giving vendors an opportunity to supply a range of products. (Environmental conditions could be noted in the appendix of the standard.)

Mr. Scheinert felt that questions on friction and clamping factors should be addressed mainly in the drive specification. Centering of the disk is performed by fingers which apply pressure to the disk to center it on the spindle. The present tolerances are approximately 0.05 mm (0.002 in), but he expects manufacturing to go to 0.025 mm (0.001 in) at just a slight extra cost. He felt that the expense of a hub per disk could be avoided. It was suggested by a workshop participant that the radius of gyration should be specified, since it affects the ability to accelerate a disk.

With regard to a cartridge, Mr. Scheinert stated that he expected the disk to be handled from the outside and clamped from the inside. He was asked about the effect of entrapped air, due to the closeness of the disk surface to the cartridge. He felt that this should be addressed in the drive/cartridge requirements.

The question of specifying the hardness of the overcoat was raised. It was argued that an abrasion specification might be more appropriate. Mr. Scheinert then indicated that hardness may not be the correct (or only) term to specify in the mechanical properties of the protective layer (and the clamping and handling zones). "Hardness" was used to indicate that mechanical properties of these regions must be specified, because of interaction with the drive, cartridge, and environment. It was further suggested that the specification of proper cleaning methods might be more appropriate than an abrasion specification. Mr. Scheinert noted that static charge is a main factor in dust adhesion for particles below approximately 100 $\mu$m (4000 $\mu$in). The importance of avoiding moisture was stressed.

A widely-held opinion of participants was that the number of specifications should be kept to a minimum, and that the market would shake out the inferior products. It was noted that the United Kingdom tends to view such standards as procurement documents, whereas in the United States, a purchaser is expected to include much more information in the procurement document. One common U.S. requirement is to include methods of testing for compliance with the specification.

The use of hubs to achieve more precise centering was further discussed. It was noted that if the responsibility for maintaining proper centering is placed solely on the spindle rather than using hubs, then—if the machine gets out of adjustment—all disks will be in trouble. Whereas, if a hub in a particular disk goes bad, only that disk will malfunction. It was observed that a spindle will operate with many more disks than vice versa. It was stated that hubs would be prohibitively expensive, but this was countered by the experience with floppy disks, where the cost continues to decrease despite the addition of hubs to the disks.

Before the discussion, Mr. Scheinert acknowledged that it might be appropriate to allow a difference of a few thousandths of an inch of spacing between the recording zone and the active portion of that zone.

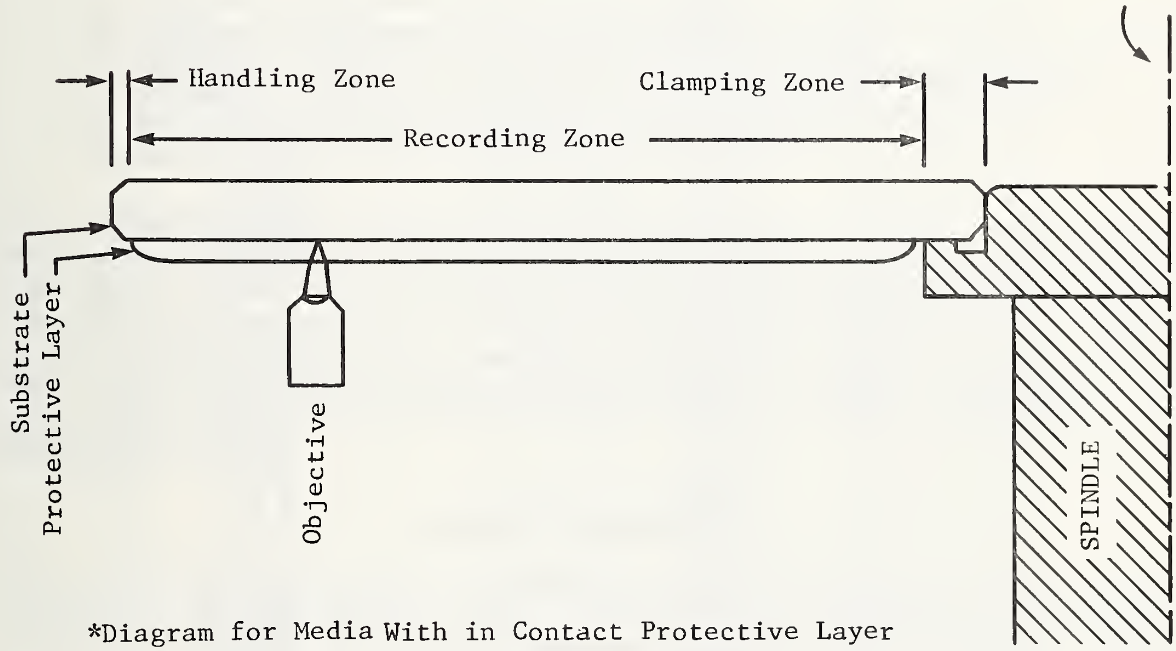
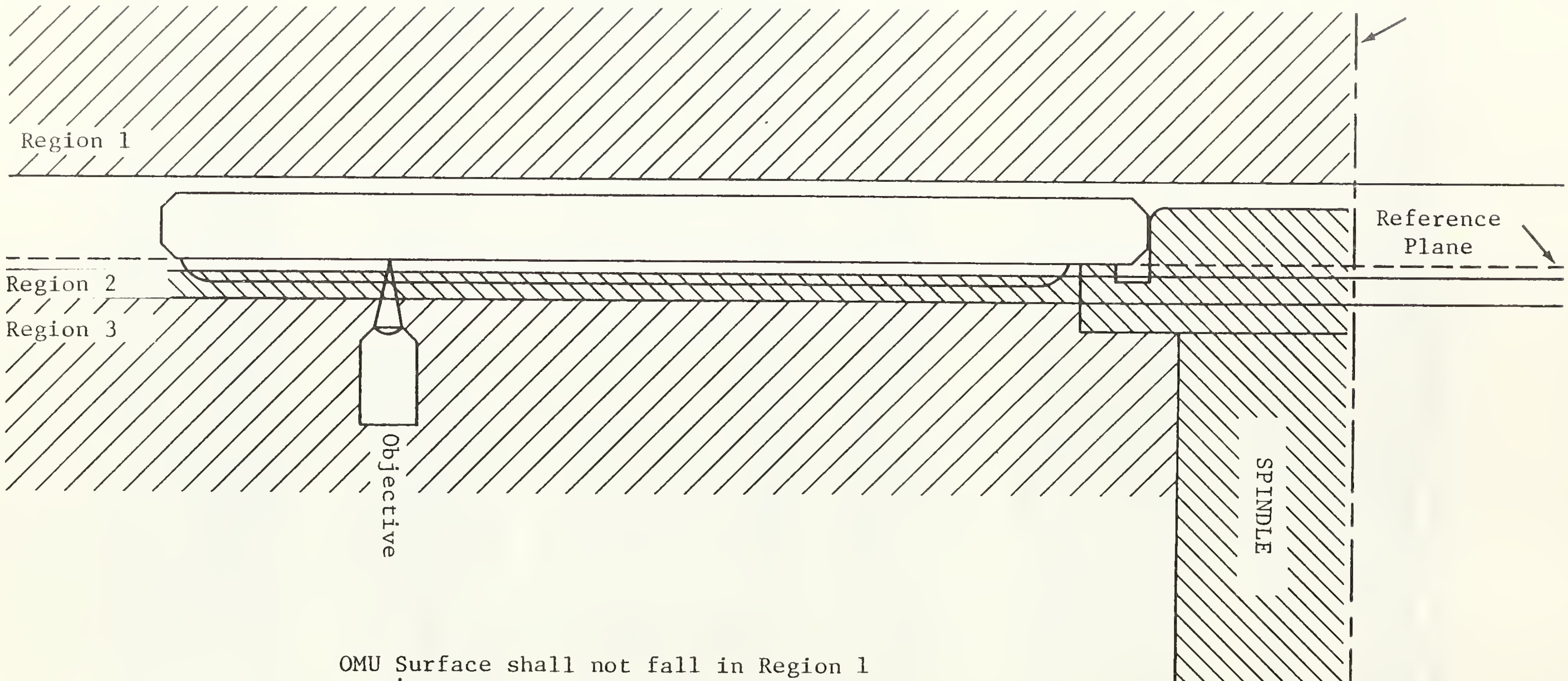



Figure 1. Single Sided OMU*
(Scheinert - Burroughs Corporation)




OMU Surface shall not fall in Region 1
OMU Surface shall not fall in Region 3
Protective Layer Surface must fall in Region 2

Figure 2. Single Sided OMU
(Scheinert - Burroughs Corporation)

### 1.1.3 OPTICAL CHARACTERISTICS OF A DISK/CARTRIDGE MEDIA UNIT

**By Roland Malissin**
**Thomson-CSF**

Key words: absorptance of the sensitive layer; angle of the protective component (versus beam axis)—often referred to as tilt angle; birefringence; protective component--often referred to as protective layer; reflectance of the sensitive layer; self protected disk; sensitive layer; surface defects, thickness of the protected component.

#### Introduction

Mr. Malissin considered the following optical characteristics of a disk/cartridge media unit in his presentation:

(1) What cartridge, what disk?
(2) Disk/cartridge parameters producing optical effects.
(3) Effects of the geometrical parameters of the protective component.
(4) Effects of the optical parameters of the protective component.
(5) Effects of the surface of the protective component.
(6) Optical effects of the sensitive layer.

Mr. Malissin began his presentation by showing a binary decision tree, based on several design factors, which were related to the degree of protection of the disk **(see fig. 1).** These factors considered (a) whether a cartridge was used, (b) whether the disk remained inside the cartridge during operation, (c) was there a shutter opening in the cartridge, and (d) was the cartridge dust-proof? He visualized the disk as having a sensitive layer protected by a protective component. The protective component was viewed as either a window, a disk component, or the substrate **(see fig. 2).**

#### Optical Characteristics

The optical path was illustrated, consisting of a normally convergent beam passing through air, an air/dielectric diopter, a dielectric associated with the protection components, and the sensitive layer **(see fig. 3).** The protective component should be of uniform thickness, in which case its outer surface will be parallel with the sensitive surface. Distortion of the spot can occur if the protective component does not have its nominal thickness, its surface is not normal to the beam axis, the refractive index does not have its nominal value, it exhibits birefringence, or there are surface defects at the air/dielectric diopter **(see fig. 3).** The sensitive layer may show variations in reflectance and absorption, and these may be functions of wavelength. Changes in the size and shape of the focused spot can directly affect the readout and can result in loss of servo tracking. Impacts of the surface sensitivities on the media response are **shown in figs. 4, 5, 6, and 7.**

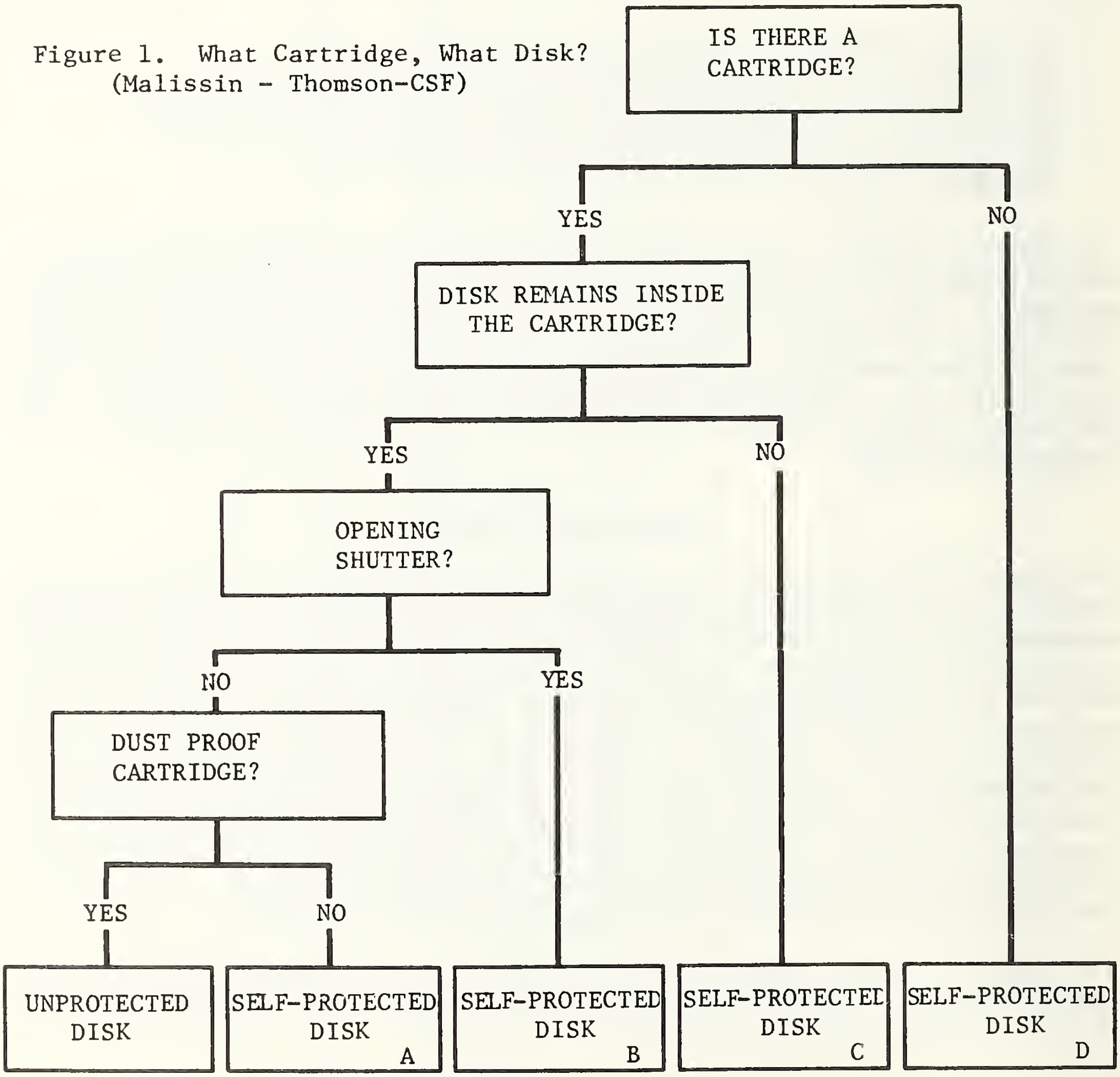
The effect of surface defects depends on the size of the defect image at the sensitive surface. A speck will cast a defocused shadow, and this will have a change in the signal level associated with it.

## Discussion

Mr. Malissin noted that these parameters can vary over a disk, from one disk to another, and can also change with time. It is necessary to establish a range of allowable variations for acceptable operation and to remain within this range over all operating conditions.

As to the thicknesses of the layers, he noted that these will be dependent on the application. He indicated that there can be a loss of power resulting from specks of extraneous matter, the lost power being roughly proportional to the total area of all the specs on the surface, inside the light spot. He noted that these specks are generally not completely opaque. When asked about mass store systems for high-end versus low-end applications, he replied that the optical considerations may be more critical in the high-end applications. (Applications are discussed on Day 2, Session 1, see section 2.1.)

Figure 1. What Cartridge, What Disk?
(Malissin - Thomson-CSF)



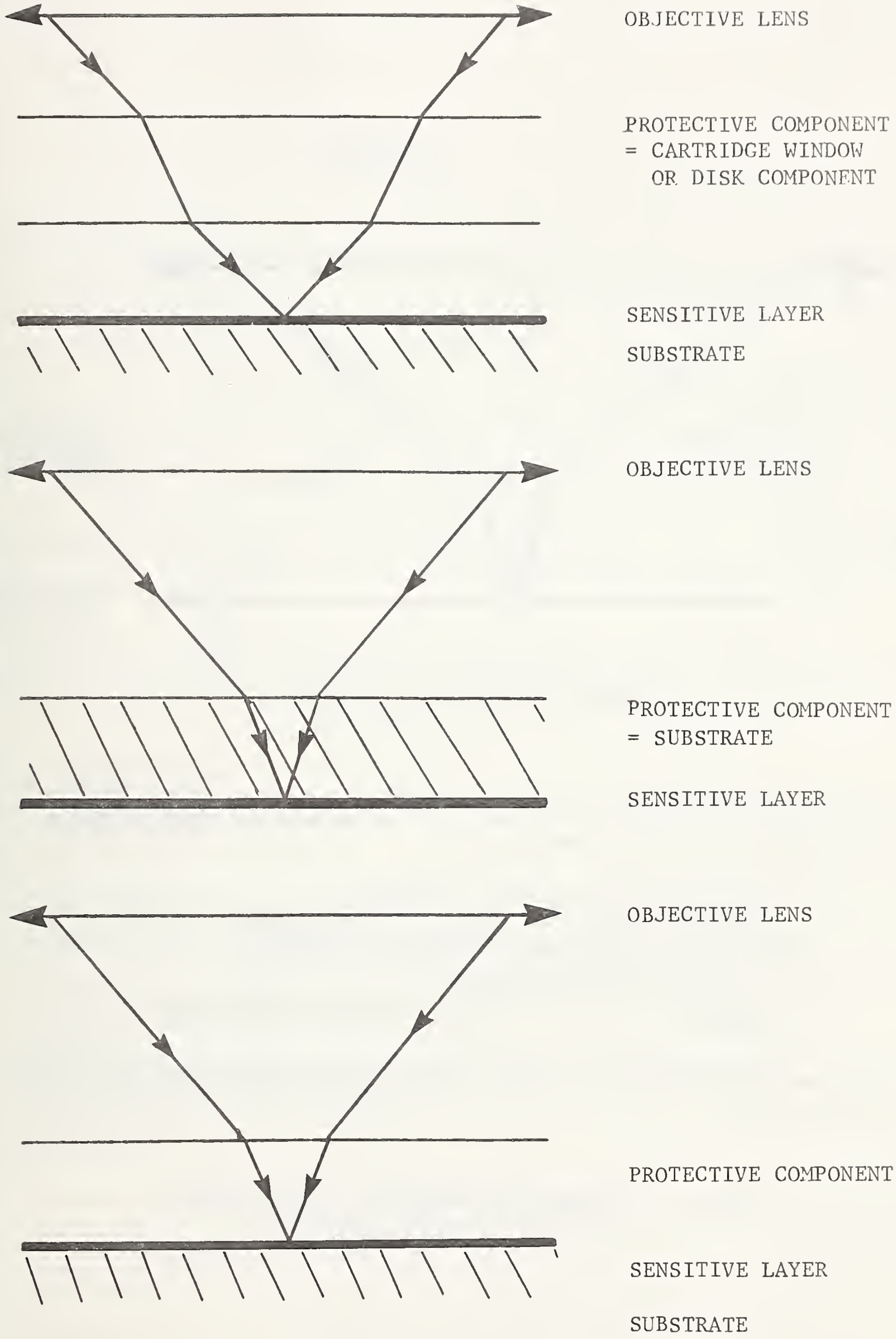
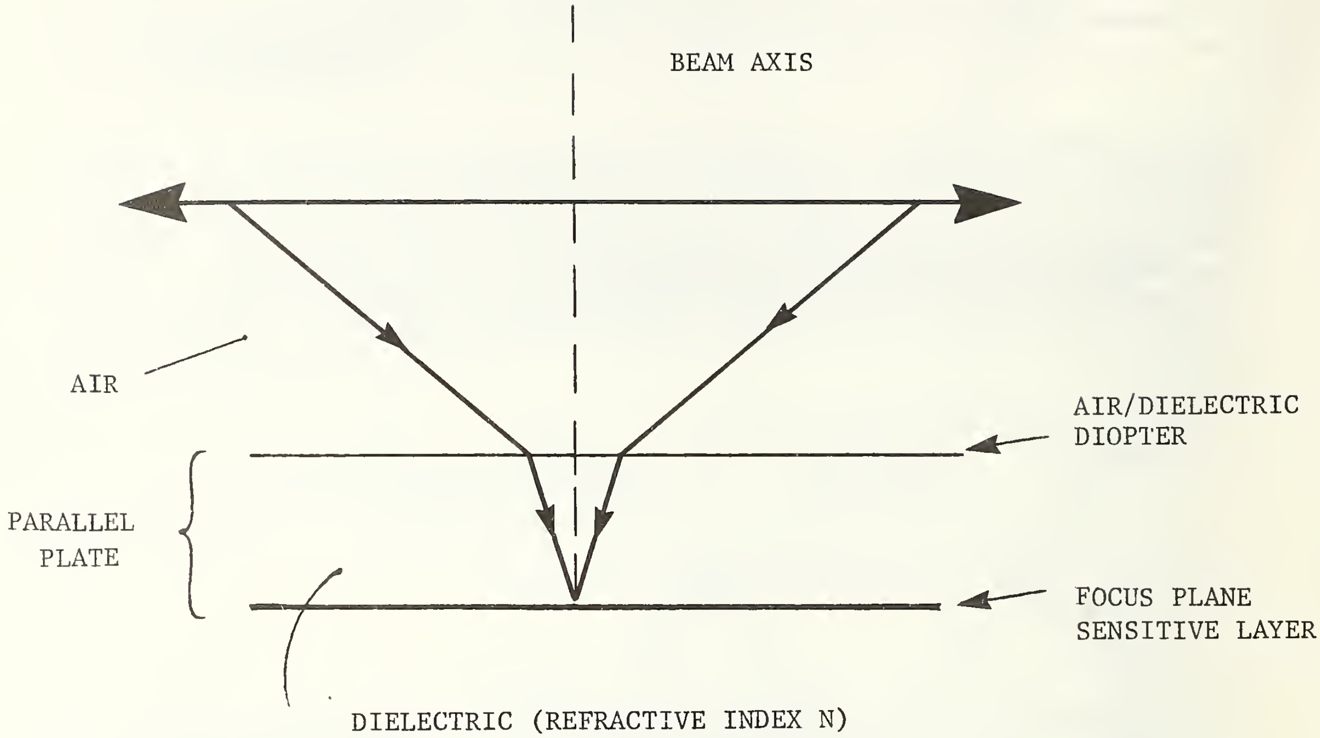



Figure 2. Protective Element Some Possible Cases
(Malissin - Thomson-CSF)

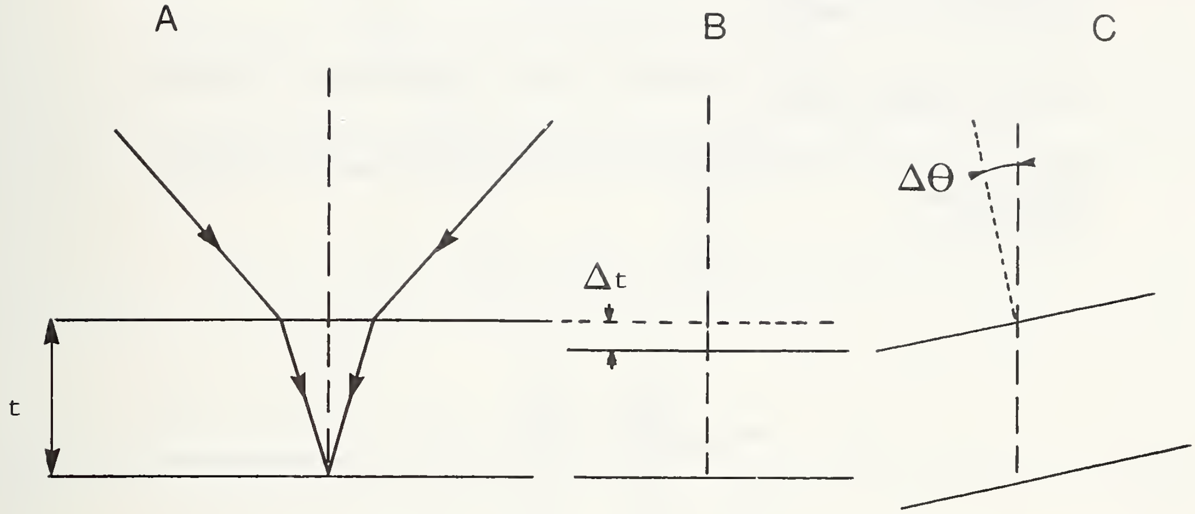



The parallel plate on the path of the convergent beam produces distortion of the focused spot if:

- . It has not its nominal thickness,
- . It is not normal to the axis of the beam,
- . It has not its nominal refractive index,
- . It exhibits birefringence,
- . There are surface defects at the air/dielectric diopter.

The sensitive layer can show itself variation of reflectance and absorptance.

Figure 3. Parameters Producing Optical Effects
(Malissin - Thomson-CSF)




A NOMINAL CASE
B THICKNESS ERROR
C ANGLE ERROR

- The thickness error increases the focused spot diameter; the angle error introduces widening and asymmetry of the spot.

- Both lead to a loss of sensitivity during recording and to a loss of definition during read out.

- Both can eventually mislead the optical sensors used for focusing and radial tracking.

Figure 4. Geometrical Parameters
(Malissin - Thomson-CSF)

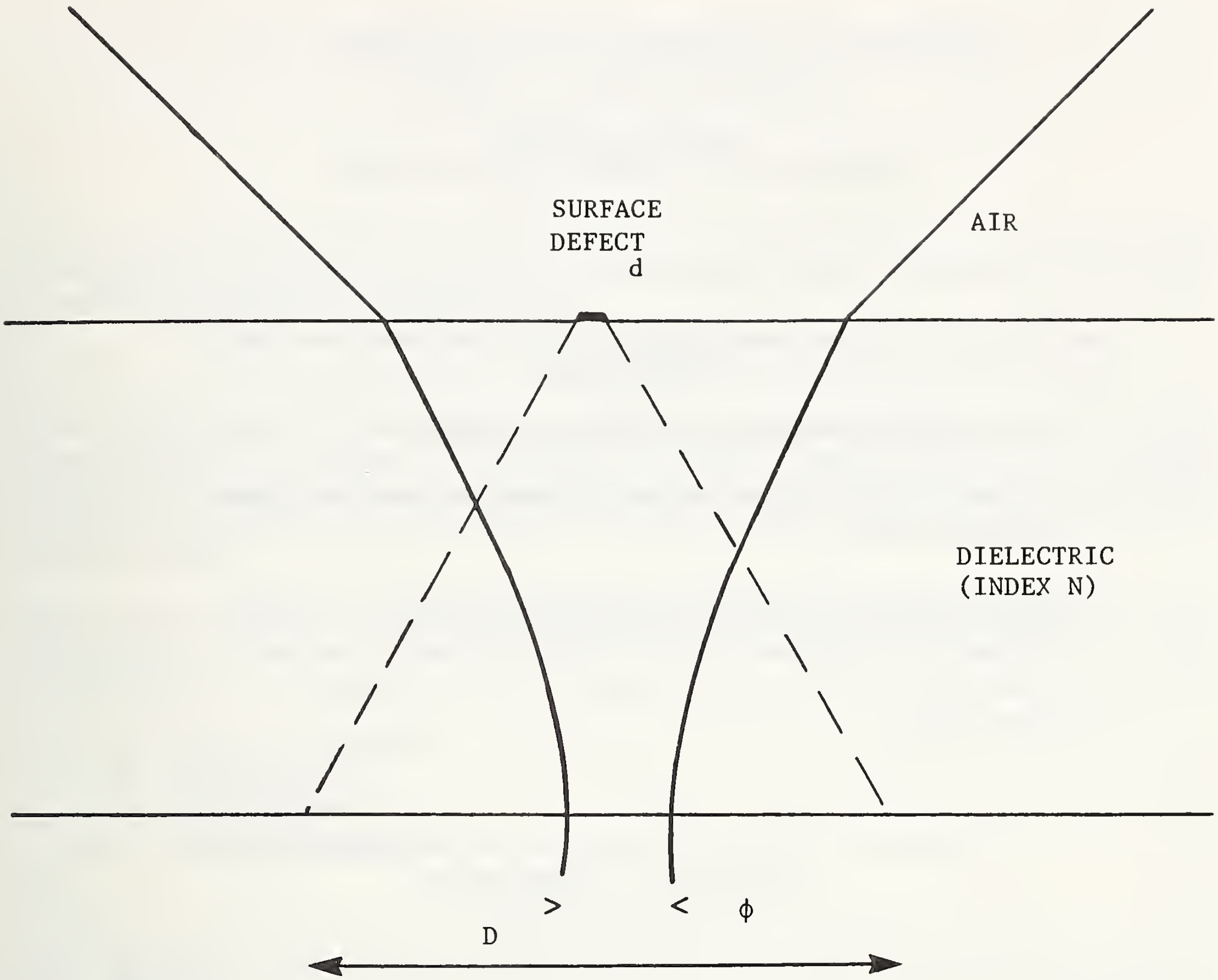
OPTICAL PARAMETERS

- Error on the mean value of the refractive index increases the focused spot diameter.

- Inhomogeneity of the refractive index introduces distortion of the focused spot.

- Birefringence of the material introduces distortion of the focused spot.

Figure 5.
(Malissin - Thomson-CSF)




ϕ = FOCUSED SPOT DIAMETER
d = DEFECT SIZE
D = DIAMETER OF DEFECT AS SEEN IN THE FOCUS PLANE

If $D \gg \phi$, the defect produces a small loss of power inside the focused spot but no distortion of the spot, the lost power being radiated into a wide area.

Conversely if D is in the range of $\phi$ the focused spot is distorted.

Figure 6. Surface Defects
(Malissin - Thomson-CSF)

- Reflectance "R" and absorptance "A" of the disk are both essentially characteristics of the sensitive layer itself.

  . "A" and "R" can change or not with wavelength

  . "A" and "R" can change across a disk and from one disk to another one.

- . Variations of "R" lead to changes in: data read out, radial tracking and focusing signal level.

  . Variations of "A" lead to changes in: recording sensitivity.

Figure 7. Optical Effects of the Sensitive Layer (Malissin - Thomson-CSF)

## 1.1.4 QUALITY CHARACTERISTICS OF AN OPTICAL DISK RECORDING SURFACE

By Miguel Capote
Optical Coating Laboratory, Inc. (OCLI)

Key words: birefringence; blemishes; defects; dust; index of refraction; overcoats; overcoat thickness; thickness variation.

### Introduction

Mr. Capote directed his remarks primarily to the characterization of the disk overcoat and its blemishes. He discussed the topic of media overcoat with emphasis on such factors as overcoat constraints, dust size, and apparent flatness. He also noted the types of observed overcoat blemishes, their impact, and an approach to their remedy.

Mr. Capote advocates keeping specifications of $OD^3$ quality characteristics to the minimum. He suggested the following overcoat constraints be specified to assess disk quality:

(1) Thickness variation
(2) Index variation
(3) Birefringence
(4) Dust particle size

### Overcoat Constraints

(1) **Thickness variation over entire surface:** $\pm 15$ μm for a numerical aperture of .65 NA.

Variations in overcoat thickness can result in spot defocusing. The absolute thickness constraint is the same for both thin 0.170 μmm (0.007 μin) and thick 1.200 μmm (0.005 μin) coatings, therefore dimensional control becomes more stringent (percentagewise) for the thicker coatings.

(2) **Index variation:** ($\pm 1$% batch to batch)

Index variation can vary $\pm 5$% if compensated by thickness (thickness X index = constant).

(3) **Birefringence:** (Less than $\lambda/20$)

Birefringence includes signal modulation and asymmetric optical effects.

(4) **Dust Particle Size:** The following overcoat and particle dimensions produce a 25% drop in peak irradiance:

| Overcoat Thickness | Particle Diameter |
|---|---|
| 0.170 μmm (0.007 μin) | 30 μm (1200 μin) |
| 1.200 μmm (0.005 μin) | 225 μm (9000 μin) |

The worst case occurs when a perfectly absorbing dust particle is located at the center of the beam. It was noted that dust impacts the transmitted power and the peak irradiance.

Most surfaces are sensitive to the peak irradiance threshold. An occasional cleaning of the disk is considered essential. In addition to removing dust and surface film, there may also be accumulated corrosion products that should be removed.

Disk surface axial runout can be detected and measured by observing the variations in focus motor current during disk rotation **(see fig. 1)**.

## Surface Blemishes

Surface blemishes can be observed by viewing the photodetector output and are of two types, positive and negative **(see fig. 2)**. Positive blemishes are those which produce extraneous signals where none should exist, while negative blemishes are those which cause signal level losses or signal dropouts. Large blemishes can result from imbedded dust **(see fig. 3)**. The focus system servo error signal shows an erratic excursion which may span many bits, perhaps 50 or more. Focus accuracy may be lost in the vicinity of the blemish which can result in the loss of many bits.

The proposed approach to dealing with blemishes is to employ error-free writing in which the software relocates the data so that the data is error-free when it is first written. This overcomes the effect of blemishes at the cost of a slight reduction in disk capacity rather than at the expense of the data integrity. The implication is that the blemish rate affects the disk capacity rather than the data integrity.

Mr. Capote displayed a U-shaped curve which showed that there is a minimum cost per bit based on the trade-off between the disk yield and the disk capacity as functions of the allowable defect rate **(see fig. 4)**.

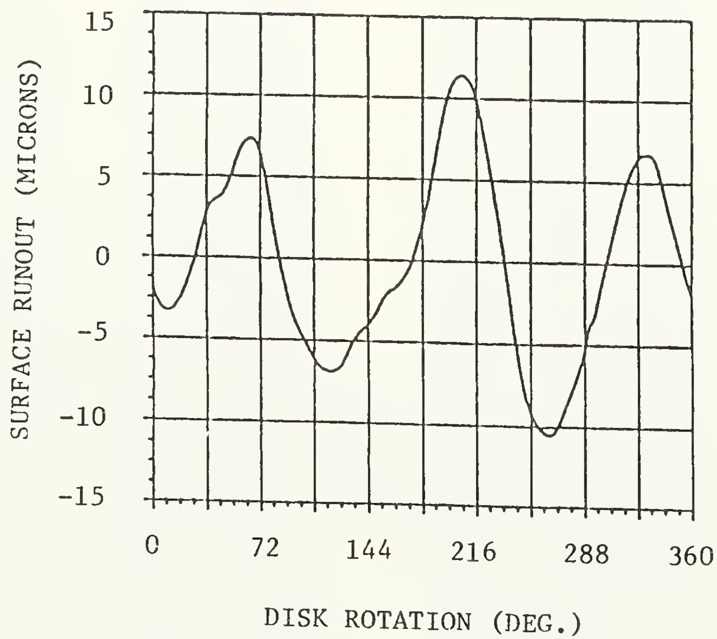
## Discussion

Mr. Capote was asked about the relative merits of disk cleaning versus data protection through the relocation of the data during writing. He suggested that an error rate count could be developed which indicated when the need for disk cleaning occurred. Mr. Capote was asked if there was a trade-off between the use of more expensive drives as compared to more expensive disks. He responded that most hardware designs call for error relocation schemes as described. The cost of implementing these is minimal compared with the cost of other hardware features.

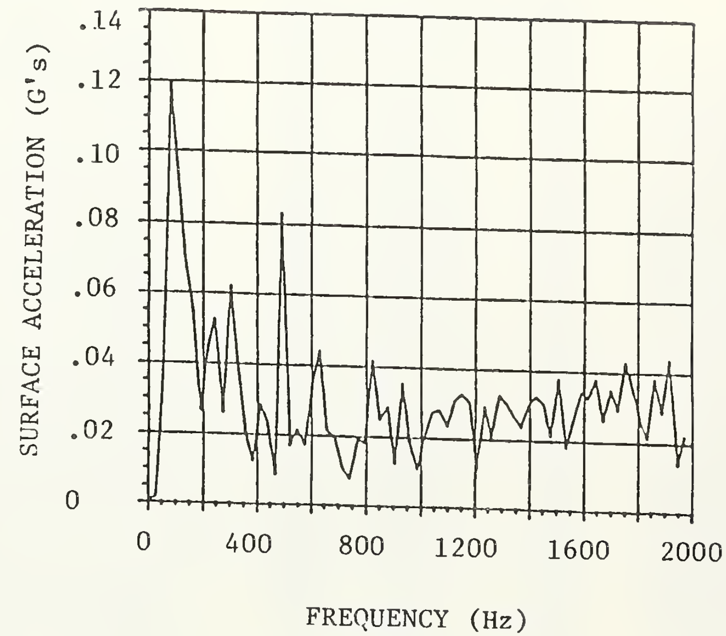
It was observed that a distinction should be made between defects in the coatings and the defects in the sensitive recording surface. Mr. Capote also noted that he was emphasizing defects occurring during manufacture rather than those that might occur with time in use.

Mr. Capote was asked if an air separation could diminish the effects of blemishes, and he replied that the air space was not an appropriate solution due to the subsequent increased manufacturing complexity.

DISK SURFACE -- AXIAL RUNOUT
OVERCOAT THICKNESS VARIATIONS ====== APPARENT DEFOCUS
TECHNIQUE -- FOCUS MOTOR CURRENT METHOD




DISK AXIAL RUNOUT MEASURED BY FOCUS MOTOR CURRENT METHOD

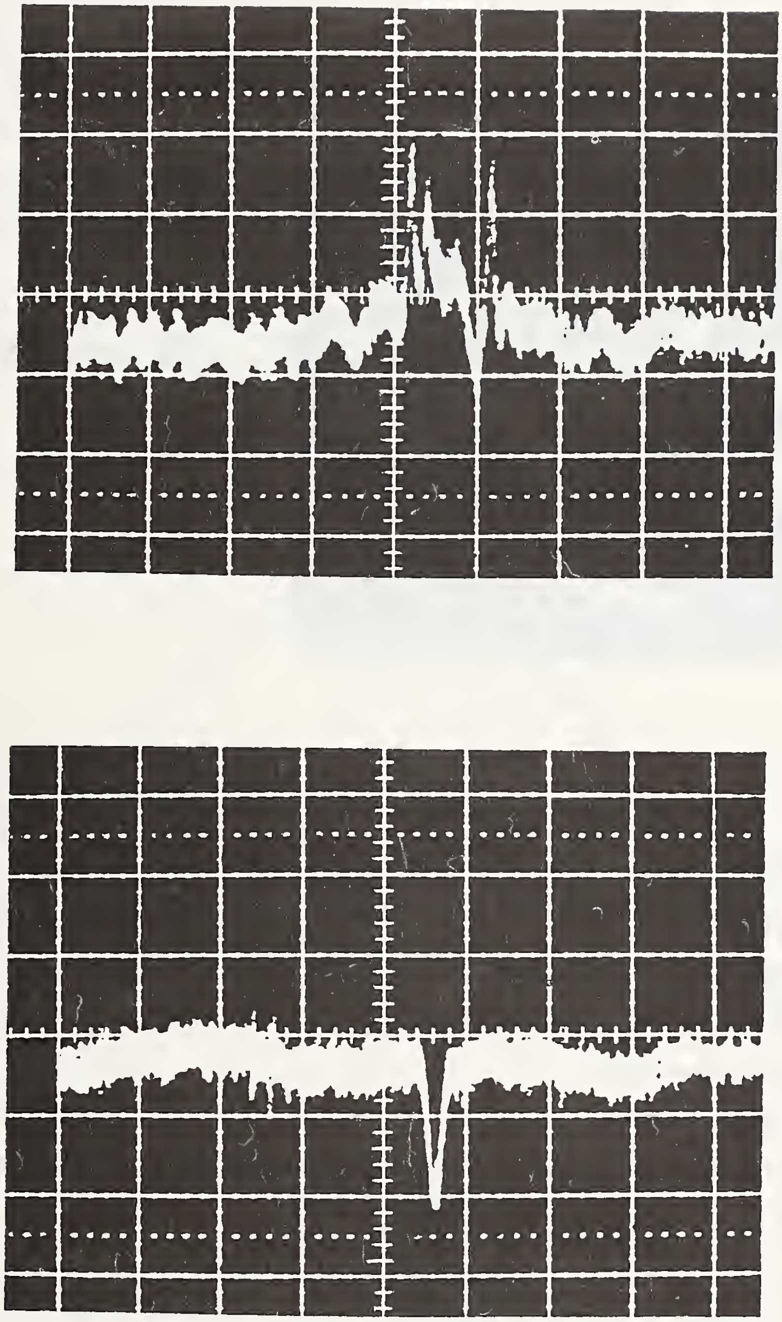



SPECTRUM OF DISK SURFACE ACCELERATION MEASURED BY FOCUS MOTOR CURRENT METHOD WHILE DISK SPINS AT 1667 RPM

REFERENCE: J. LEKOWICZ AND D. H. COHEN, IBM CORPORATION, PROCEEDINGS, TOPICAL MEETING ON OPTICAL DATA STORAGE, OPTICAL SOCIETY OF AMERICA, JANUARY 1983.

Figure 1.
(Capote - OCLI)

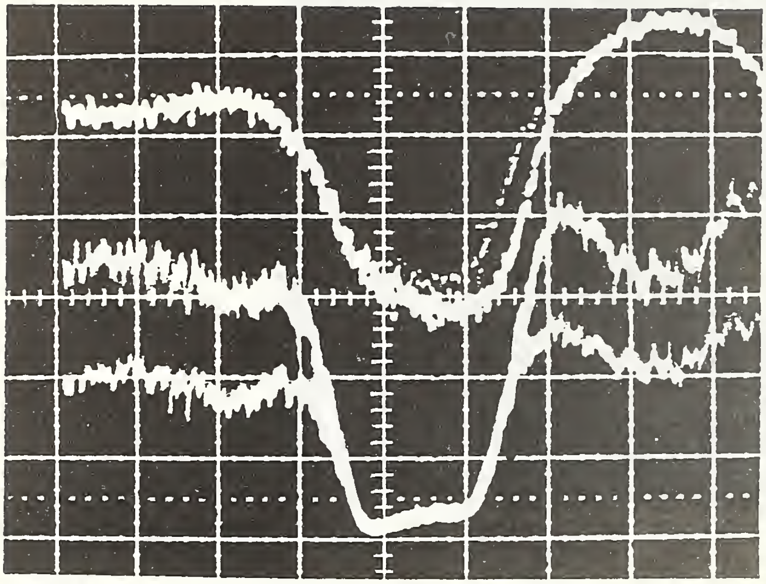
10 mV/div, 20 μsec/div



POSITIVE BLEMISH

NEGATIVE BLEMISH

Figure 2. Surface Blemish Detection
(Capote - OCLI)



FOCUS ERROR SIGNAL

.5v/dis, .2ms/div

READ DETECTOR

50mv/div, .2ms/div

CHARACTERISTICS

- Rare, 1-4 per disk
- Caused by imbedded dust particle
- Can be eliminated at expense of yield
- Affects focus severely
- 50 or more bits across

Figure 3. Large Blemish
(Capote - OCLI)

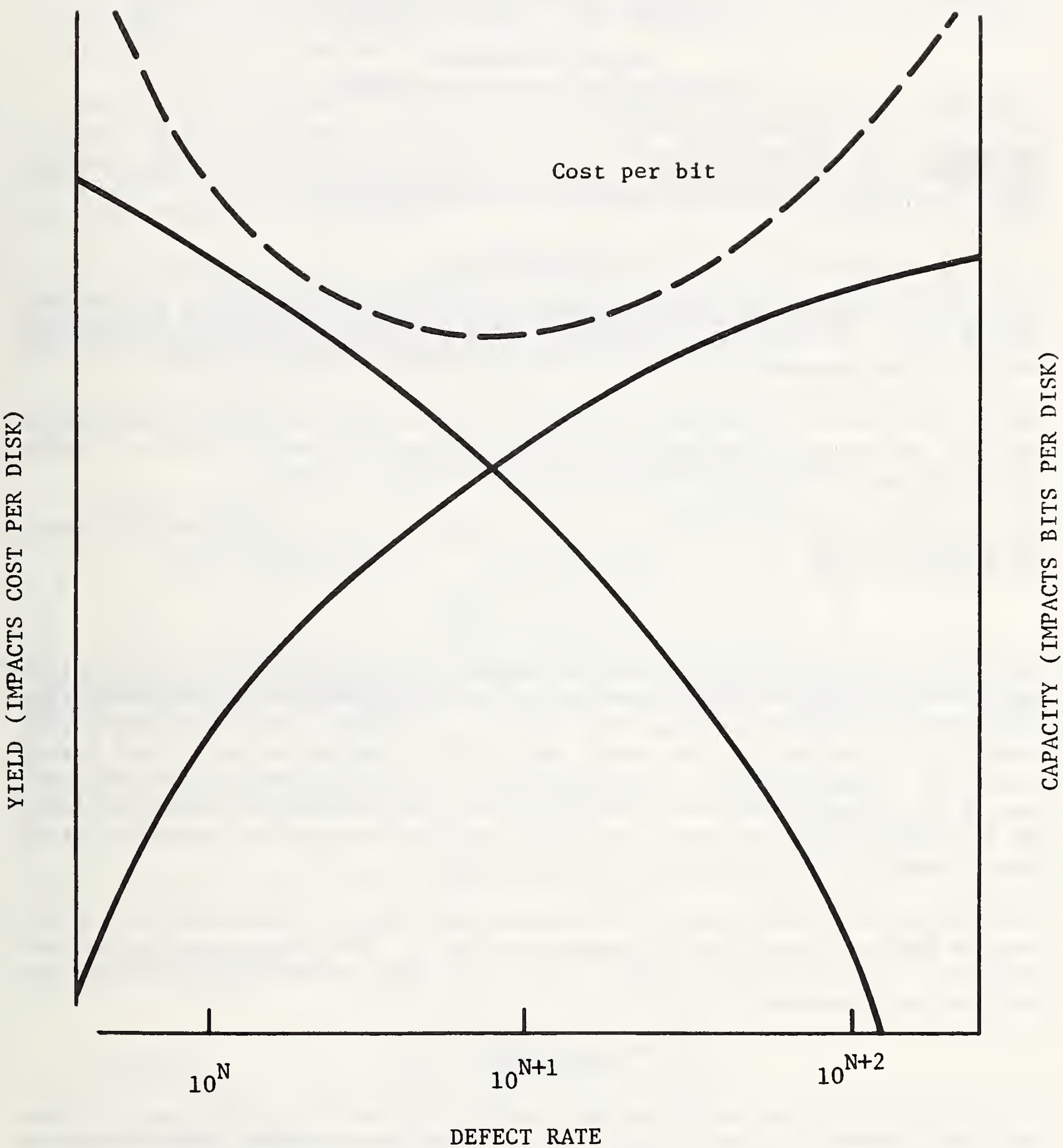



Figure 4.
(Capote - OCLI)

## 1.1.5 QUALITY CHARACTERISTICS OF DIGITAL OPTICAL RECORDING MEDIA

**By Jan Verhoeven**
**Optical Media Laboratories (OML)**

Key words: data integrity; defect density; localized errors; media characteristics; media specification; media test bed; quality characteristics.

### Introduction

Dr. Verhoeven displayed a disk cartridge containing a 305 mm (12 in) double-sided optical disk. The disk is a composition of two circular glass disks (substrates) bonded to and separated by an inner and an outer spacer as shown in **fig. 1.**

On the inner side of the substrate a sensitive layer is deposited onto an intermediate layer in which are embedded prerecorded grooves that carry tracking, heading information, and in-track clock signals, as shown in **figs. 2 and 3.**

The beginning of each sector contains synchronization information, a sector number, and a track number.

### Characterization

Optical Media Laboratories performs testing and measurement of dimensional specifications such as disk inbalance and excentricity; **see fig. 4.** Testing of quality specifications included homogenity, flatness, sensitivity, signal-to-noise ratio, condition of pregrooving, bit error rate (BER), modulation depth, and ageing properties. Over a period of several years, hundreds of disks have been tested beyond the normal production inspection by computer-control-led media test beds, **fig. 5**, and other test equipment. This media test bed enables the localization of bit errors, defects, and servo errors on a disk, **see fig. 6.**

This enabled the investigation of the density distribution of the defects and of the relation between defects and bit errors, **see fig. 7.** The measurement of defects presents a non-destructive quality test of a disk, which may be useful for certification procedures.

### Discussion

Dr. Verhoeven felt that individual disk certification should be performed for disks which are intended for long-life applications. When asked if disks could be tested by means other than scanning, he stated that they could be tested on a track-by-track level in tens of minutes per disk by advanced equipment.

When asked about the relative merits of servo-written media versus pregrooved media, Dr. Verhoeven stated that this was a valid subject for further consideration. Regarding the possible influence on error rate due to pregrooving, he noted that few errors could be attributed to this source.

It was suggested that there might be performance limitations with the pregroove process since the replication procedure may contribute defects to the disk. Dr. Verhoeven did not consider this to be the case.

A question was raised as to whether print-through might occur to the apparent closeness of the two sensitive layers in a double-sided configuration. This was answered emphatically in the negative, since the actual spacing is an adequate 0.3 mm (0.001 in), and the hole formation is based on removing material to the edge instead of evaporation of material.

As to the measurement of the signal-to-noise ratio, Dr. Verhoeven explained that a test pattern was applied to the disk and that the signal and noise levels were measured in central aperture under specified conditions with respect to frequency, numerical aperture, rotation speed, and detection band width.

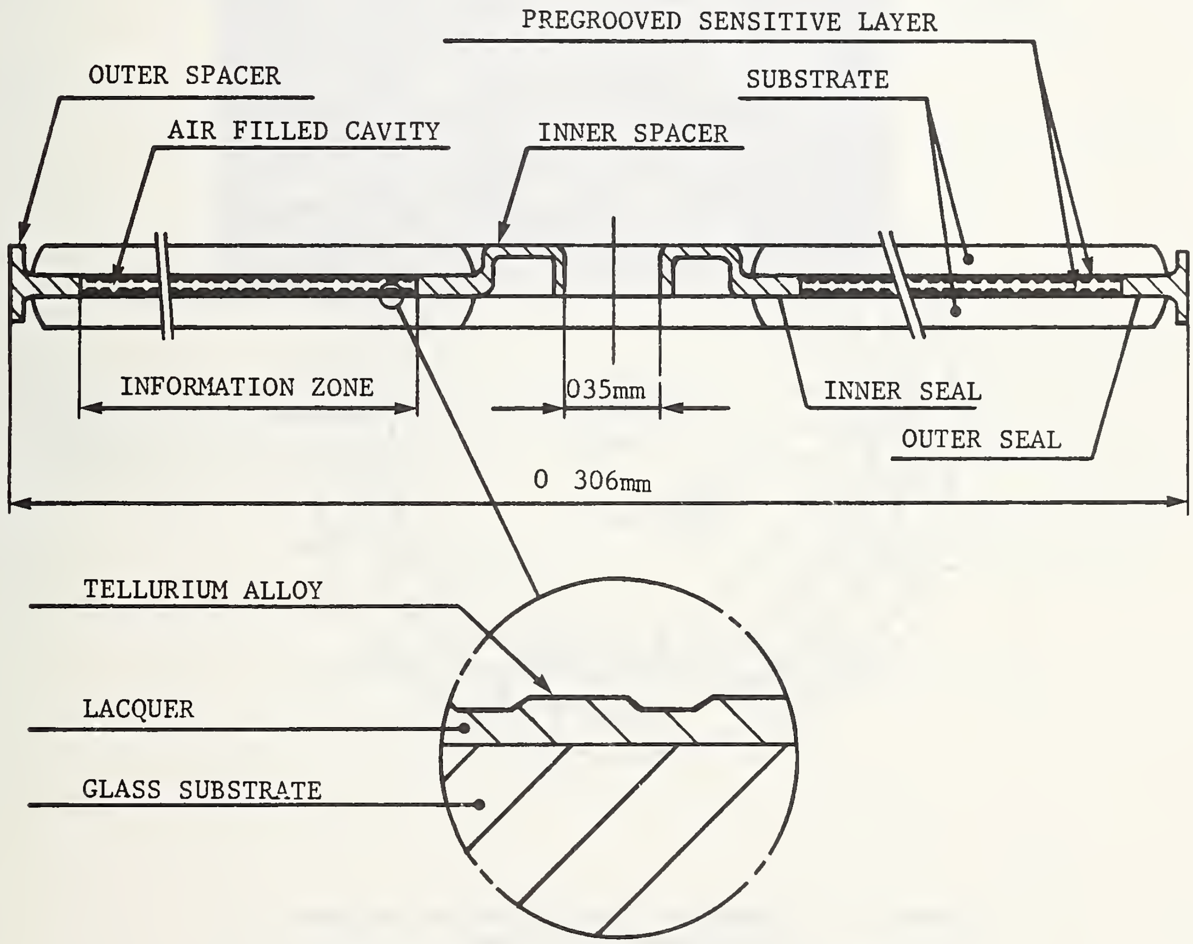



Figure 1. Schematic View of the Sandwich Structure of a TE-Based DOR Disk (Verhoeven - Optical Media Laboratories)

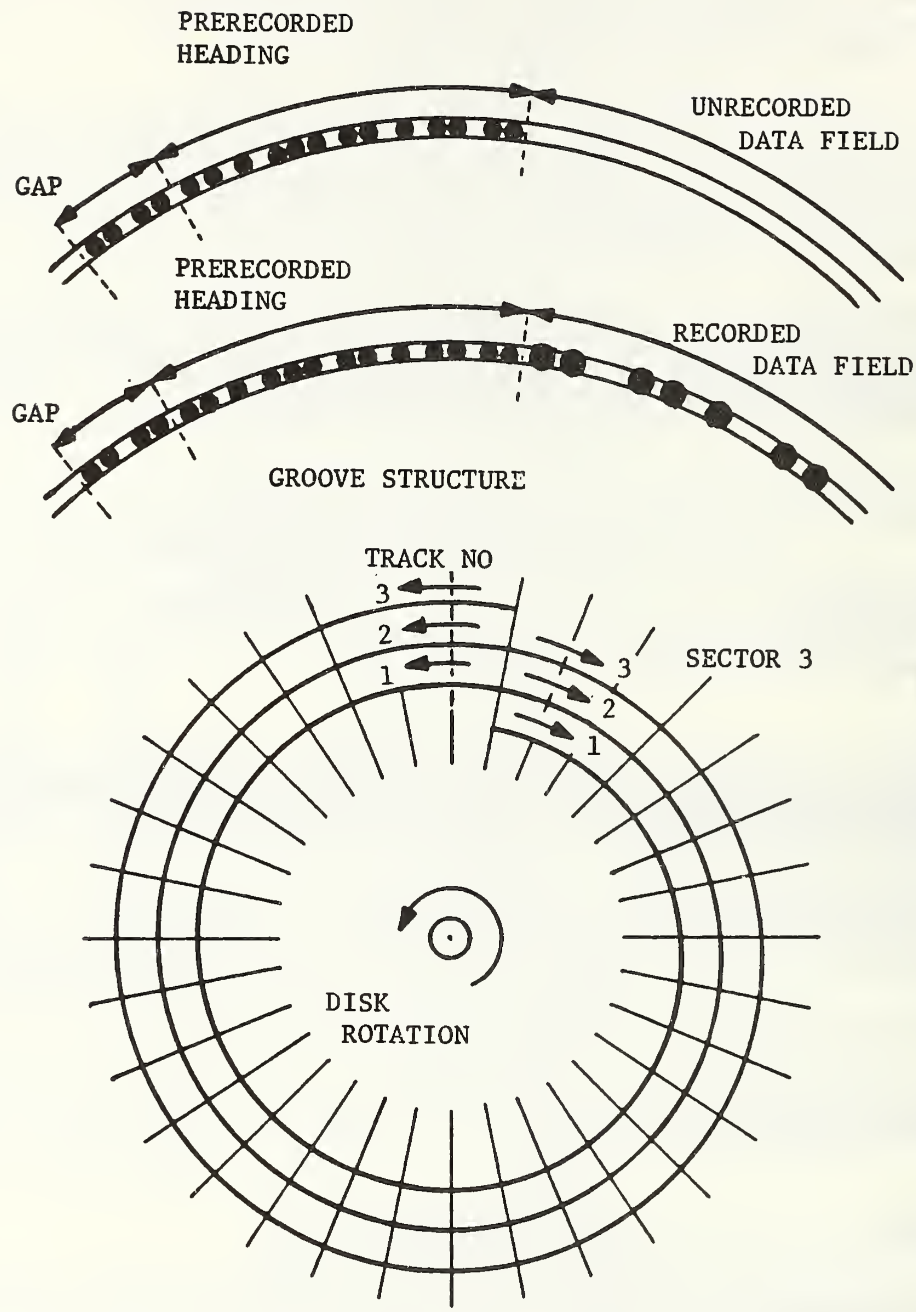
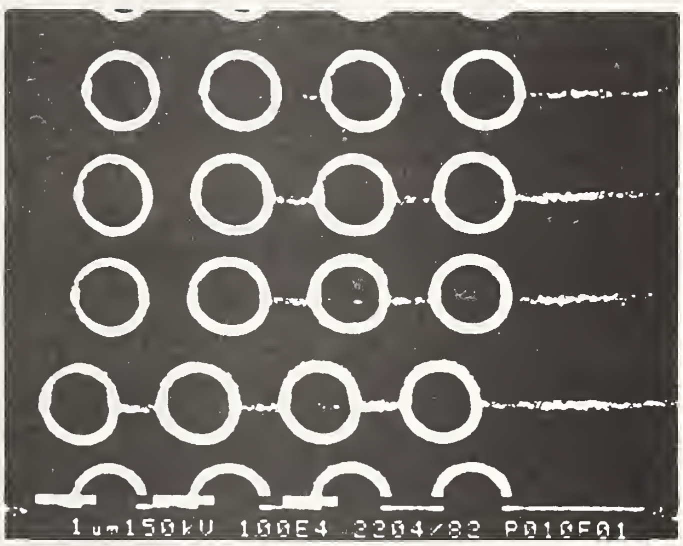



Figure 2. Schematic Showing the Sectorized Pregrooves of a Disk (Verhoeven - Optical Media Laboratories)




SEM photograph of the pregrooves with in-track clock with written holes.
The holes shown have a diameter of about 0.9um. The tracks are 1.6um apart.

Figure 3.
(Verhoeven - Optical Media Laboratories)

| | |
|---|---|
| DIMENSIONS | - INNER AND OUTER DIAMETER<br>- SUBSTRATE THICKNESS<br>- SANDWICH THICKNESS<br>- UNBALANCE |
| SIGNAL CHARACTERISTICS | - SIGNAL TO NOISE RATIO<br>- MODULATION DEPTHS<br>- PREGROOVE SIGNAL<br>- DATA SIGNAL CHARACTERISTICS<br>- HEADER RECOGNITION<br>- CLOCK REGENERATION |
| SERVO ASPECTS | - FLATNESS<br>- ECCENTRICITY<br>- ACCELERATION |
| DATA INTEGRITY | - BIT ERROR RATE<br>- DROPOUTS<br>- DEFECT DENSITY<br>- DEFECT DISTRIBUTION |
| HOLE FORMATION | - SENSITIVITY<br>- HOMOGENEITY<br>- MATERIAL COMPOSITION<br>- LAYER THICKNESS |
| AGEING PROPERTIES | - ACCELERATED<br>- LEAKAGE<br>- SHELF LIFE |
| CERTIFICATION | - TRACKING<br>- SEGMENT HEADERS<br>- READABILITY<br>- FLAGGING OF DEFECTS |

Figure 4. Summary of Media Characteristics and Media Qualifications (Verhoeven - Optical Media Laboratories)

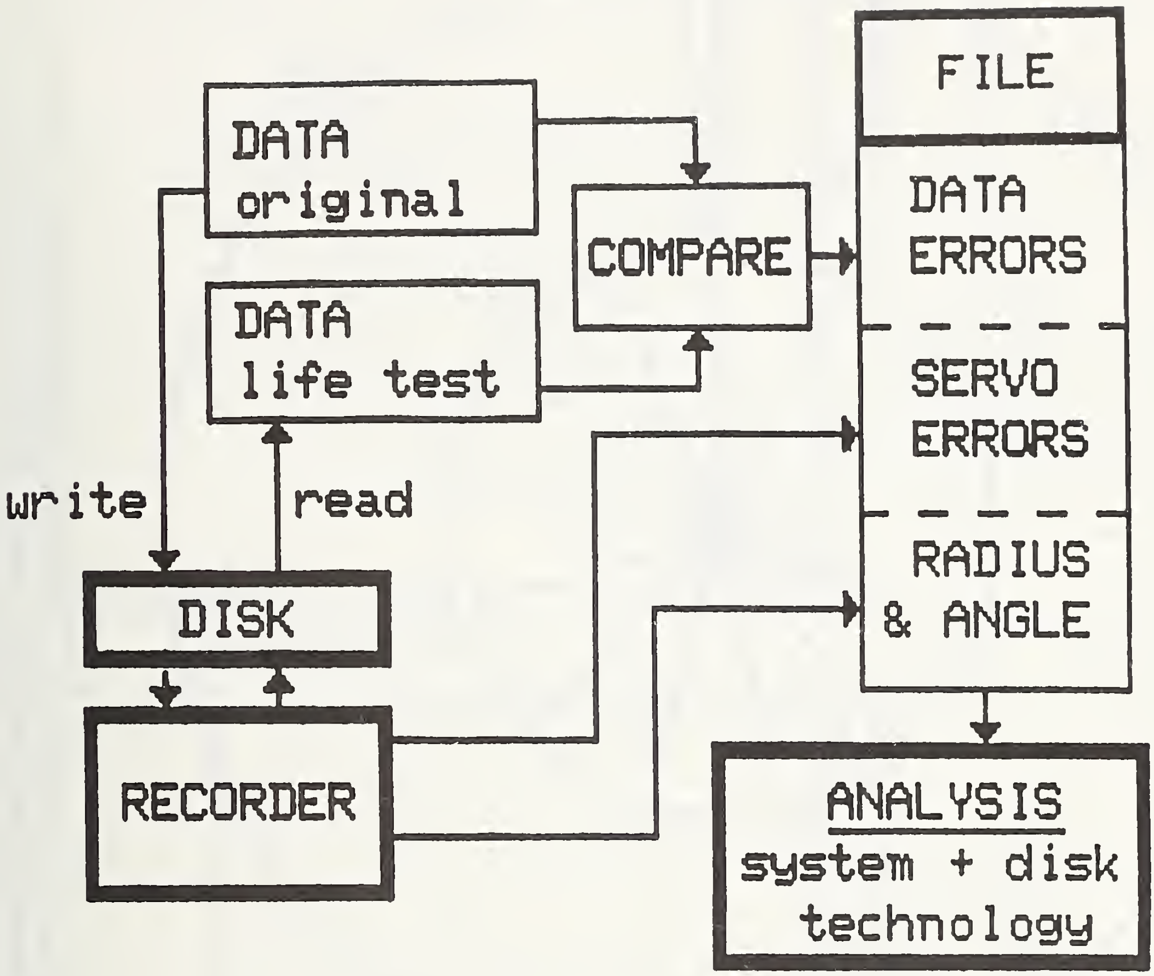



Figure 5. Blockdiagram of a Computerized Media Testbed
(Verhoeven - Optical Media Laboratories)

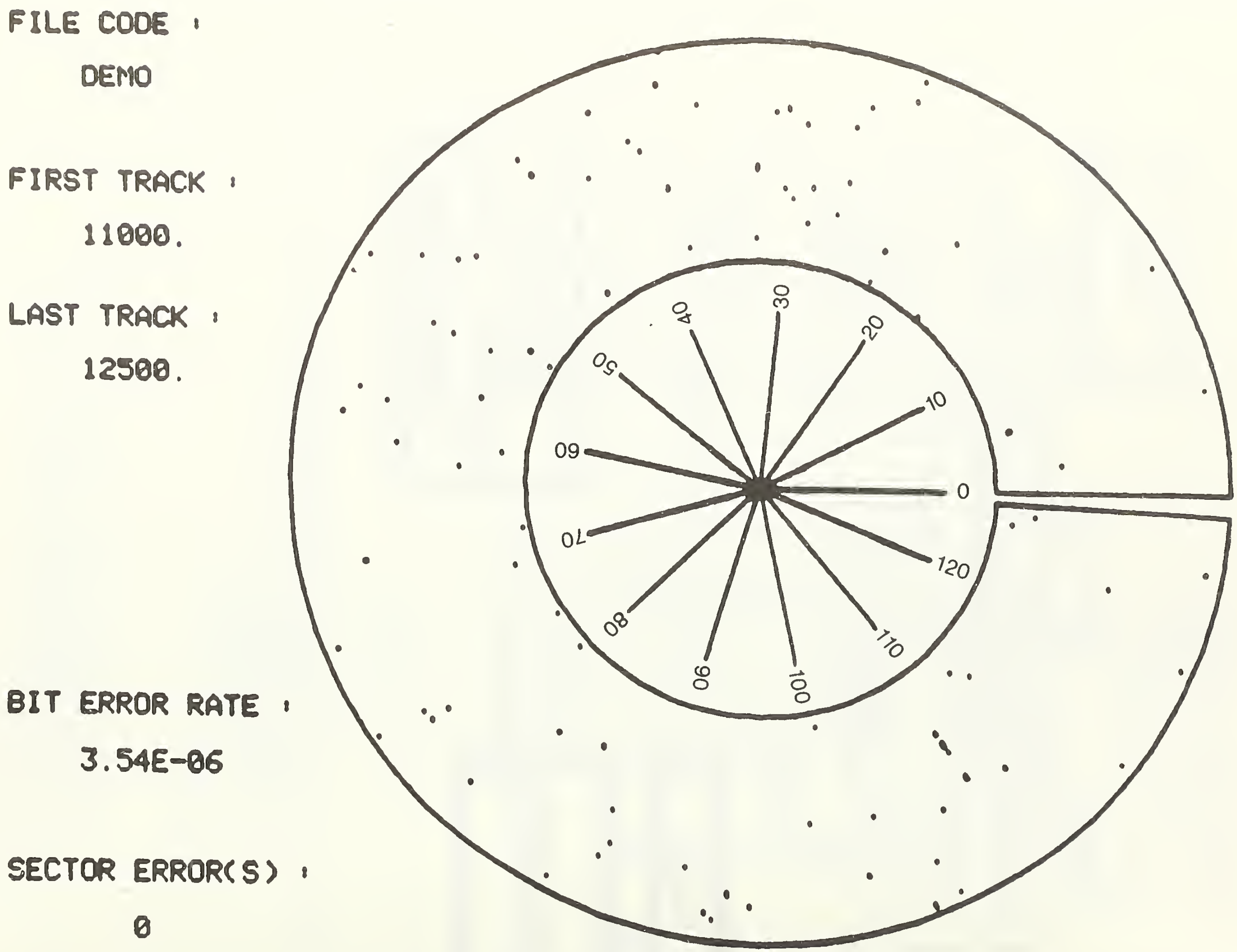
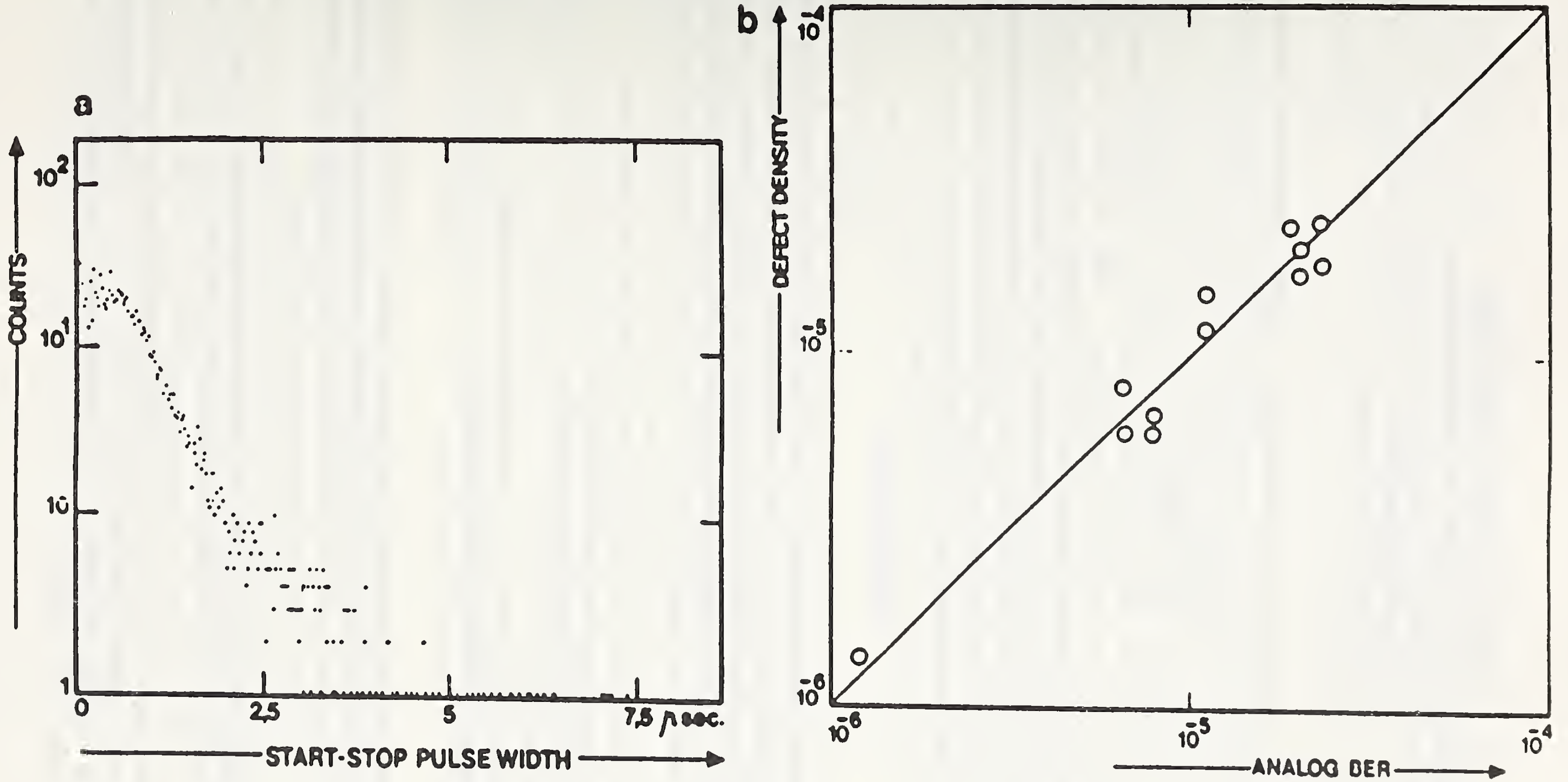



Figure 6. Localization of Defects on a Disk in the Area Between Track Number 11.000 and Track Number 12.500 as Measured by the Media Testbed (Verhoeven - Optical Media Laboratories)




A. DEFECT LENGTH HISTOGRAM OF 1500 TRACKS MEASURED AT A RADIUS OF 11 CM.

B. CORRESPONDENCE BETWEEN ANALOG BER AND DEFECT DENSITY.

Figure 7.
(Verhceven - Optical Media Laboratories)

## 1.1.6 OPTICAL DIGITAL DATA DISK
## Media Aims and Potential Standardization

**By Noel Proudfoot**
**Eastman Kodak Company**

Key words: definitions; media aims; parameters; quality assurance program, standardization.

### Introduction

The need for definition of terms and a common understanding of highly technical information is necessary in an emerging technology. This is true for media manufacturers involved in performance specifications or testing of optical disks; for the disk drive manufacturers; and for the users of both drives and media. The purpose of this paper is to put forward a plan for media aims and how these were developed; some definitions and understanding of the parameters selected; and suggested parameters that are appropriate for standardization.

### Media Aims

During the research and development effort on a new product much time is spent on getting the proper product characteristics. Some days the product requirements and the technical hurdles needed seem to be insurmountable. As the product proceeds toward reality, quality assurance plans must be made so that the required quality is achieved, unit after unit. Such a quality assurance program for Optical Digital Data Disks could have the following requirements:

(1) Assure optical disks meet or exceed specifications at minimum cost
(2) Document and maintain the specifications
(3) Maintain records for optical disk traceability
(4) Establish product audits
(5) Establish information systems to assess customer reaction
(6) Provide management reports of quality level
(7) Provide adequate training of work force

Under the item "Document and maintain the specifications" could be a relatively formal document outlining the customer's requirement for media sensitivity and bit error rate, two very important product parameters. The remaining discussion is limited to only part of this portion of the quality assurance program.

The data on curves and tables which follow are presented for example and discussion and may not be representative of any product or proposed product.

Typically, characteristic curves of power (P) in milliwatts on the disk versus carrier signal, noise level, and carrier-to-noise-ratio (CNR) could be generated for a specific recording and reading geometry. For purposes of this explanation only curves of carrier and noise will be used.

The first item needed is information that represents the ideal characteristics for customers within the capabilities of the product being developed. This could be called the customer reference. The customer reference can represent data from specially made test equipment or commercially available write-read equipment. Such data are shown in **fig. 1** including appropriate other necessary test information[1].

Data are also needed which represent the characteristics, at the time of manufacture in order to monitor production. This could be called the manufacturing aim. It should be based on a significant number of real production lots and the manufacturing aim could be representative of the means of those lots which meet product specifications. Tests are usually made on specially made write-read equipment **(fig. 2)**.

There is also a need to collect comparative data on the product at the average age from manufacture when customers start writing and reading the disks. This average age from manufacture could be 1 month, 3 months, 6 months, or 1 year depending on distribution systems and other arrangements. This information will indicate the expected characteristics of the disk at that time if tested on the specially made test equipment. It should include sensitivity and track changes with time, if any. This could be called the customer aim if based on manufacturing aim level product plus keeping factors **(fig. 3)**.

One additional set of curves and data are needed to complete the package. This is a customer aim specified in terms of the customer write-read equipment **(fig. 4)**. The customer write-read equipment could be identical to the specially made test write-read equipment but almost never is. The repeatability characteristics for the test equipment generally needs to be significantly better than customer equipment to assure appropriate media quality level for customers.

A comparison of the customer aim curves and the customer reference curves can readily show what more might be achieved in a product system.

Tabulated parameters are a convenient way to trace the manufacturing aim through keeping to the customer aim - customer reference **(table 1)**. Some definitions are included for understanding.

The aims will change and need to be updated as manufacturing methods change, distribution systems change, etc. The customer reference will not likely change unless the test equipment changes.

There is much more that needs attention to assure good product to customers. Some of these are keeping properties over more time, higher temperatures, etc. The overall program includes many other items. This is a plan for setting up a rather formal, documented set of critical parameters so that there can be management and organization agreement on product quality as manufactured fresh and when used by the customer.

## Definitions

Before standards can be written on media sensitivity or bit error rate, terms need to be agreed to which define the appropriate parameters. In **fig. 1** are shown Carrier, Noise, CNR, Noise Floor, 6 mw Carrier, Bit Error Rate, and curves of Carrier versus Laser Power and Noise versus Laser Power. Why were these selected; what are the definitions; and what about the curves and listed test conditions?

The Carrier is the root-mean-square value of the Carrier amplitude **(table 1 definitions).** This is reported in decibels relative to a 1 millivolt reference and the measurement can be made conveniently using a spectrum analyzer. Noise is also measured in the same way in the presence of the corresponding Carrier level. The Noise Floor is measured similarly except without any carrier signal present.

The Laser Output Power is available power on the disk and is plotted on a logarithmic scale which makes for convenience in comparing curves of different media. Ideally, the power versus carrier curve should look like that in **fig. 5**, where there is no sensitivity below a certain power threshold and very high and unchanging signal above that threshold. This ideal situation would mean that the write laser could be used for reading with reduced power without concern for causing changes in the written marks. Noise level should be unchanging and low over the whole range of power.

The listed carrier and noise parameters were measured at a power level which places the carrier signal on the high, flat portion of the curve **(fig. 1).** This will yield the maximum CNR value and the flat response here provides "ruggedness" to laser power variations. The 6 mw Carrier value is a measure of the sensitivity of the media and this can be used on a closely controlled product. A more universal media sensitivity measurement could be defined as the power needed to achieve a signal level 10 dBm below carrier maximum.

The test conditions and test equipment need to be specified in order to be able to compare useful data from different sources. Some of the needed information is listed in **fig. 1** for recording and reading. This is a start on a specification where the intent is to get the same results on the same media with test equipment made by two manufacturers.

The definition of bit error is necessary in order to communicate satisfactorily on the subject of bit error rate for media. One proposed definition is:

> Bit Error - A single transition signal read from a written track which is displaced by more than 50 percent of the code bit synchronizer window width from its correct location, when such displacement is due to non-functional areas in the recording layer.

Now, if you agree on this definition, then bit error rate is easier.

> Bit Error Rate - The ratio of bit errors detected upon read-out of pseudo-random data to the total number of bits measured in the form $Y \times 10^{-Z}$.

These definitions are for "raw" bit errors for media.

## Standardization

The need for definitions of terms and parameters for optical disks is readily apparent. A most important and difficult project in standardization is to achieve agreement on the definition of a wide range of technical terms in this growing technology. Otherwise, media and disk drive manufacturers, and users of both will become confused because of the lack of uniform definition. For instance, CNR numbers are published in technical reports without defining carrier or noise. Yet using "peak-to-peak" carrier signal instead of rms carrier compared to rms noise results in a 9 dB higher CNR number for the same carrier signal. Work has begun to define technical terms for optical disks in the American National Standards Institute, Optical Digital Data Disk Study Group.

I would like to propose three parameters for inclusion in a standard.

(1) CNR - The definition is shown in **table 1.** Values for CNR are routinely reported in the technical literature. G. J. Ammon et al.[2] have reported CNR values in excess of 70 dB measured in a 30 KHz slot. K. Yamada et al.[3] reported a maximum CNR value of 69 dB. R. P. Freese et al.[4] reported a maximum CNR of 68 dB measured in a 30 KHz bandwidth.

(2) Threshold Sensitivity - Power in mw, 10 dBm below the carrier maximum for a specified radius (mm) and a specified rotational speed (rpm).

(3) Bit Error Rate (uncorrected) - The definition is shown in **table 1.** Values for BER are also routinely reported in the technical literature. D. Y. Lou[5] reported $5.7 \times 10^{-5}$ bit error rate for a Miller modulated signal recorded at 1.8 $\mu$m per bit. G. J. Ammon et al.[2] reported raw BER of $3 \times 10^{-5}$.

There is need only for a lower limit for CNR. Threshold sensitivity needs a high power limit if semiconductor lasers are to be used for writing; a low power limit is also needed for those systems using the same laser for write and read. The bit error rate needs to be as low as possible consistent with the tradeoffs in media manufacturing cost, drive manufacturing cost, error detection and correction costs, and the users' application.

## Conclusion

The standardization of optical disk media measurement information is important to the continued progress of the commercial application of optical disks and optical disk drives. Definition of the technical terms in this emerging technology is the first need. This would be a great help in communicating among the media suppliers, drive manufacturers, and customers for both.

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3. Yamada, Koichi; Wantanabe, Isao; Ito, Osamu; Kubo, Takahiro. "Evaluation of Optical Disk Surfaces," SPIE Vol, 329, Optical Disk Technology (1982), pp. 242-243.

4. Freese, R. P.; Willson, R. F.; Wald, L. D.; Robbins, W. B.; and Smith T. L. "Characteristics of Bubble-Forming Optical Direct-Read-After-Write (DRAW) Media," SPIE Vol. 329, Optical Disk Technology (1982), pp. 174-180.

5. Lou, David Y. "Characteristics of Optical Disks," Applied Optics, Vol. 21, No. 9, 1 May 1982, pp. 1602-1609.

## Discussion

A workshop participant challenged Mr. Proudfoot's use of the carrier-to-noise ratio measurements as opposed to signal and noise level measurements. Mr. Proudfoot noted that carrier-to-noise ratio was an established measure for which measuring equipment was available; it could be extended by performing the measurement at several carrier levels. The audience commented that the bit error rate does not have a simple relationship to carrier-to-noise ratio, and hence the latter is not directly useful to the systems engineer. It was noted that the equipment for measuring carrier-to-noise ratio was designed with a different application in mind and used a 30 kHz bandwidth. When used with optical disks, it does not give useful information about the frequency distribution of noise components. The systems engineer needs to know about the noise behavior over the entire relevant bandwidth.

This session concluded with a brief floor discussion relative to disks which are enclosed in a cartridge versus removable disks. Martin Levene, of RCA, noted that an unconfined rotating disk acts as a pump and that the aerodynamic drag could be reduced by keeping the disk in confinement. He further suggested that removal and insertion of the disk could create an increased opportunity for admitting dust into the cartridge.

(Although not stated as part of this session's discussion, an even more compelling argument for the enclosed disk is that, in an automated access multidisk system where disk access time is desired to be as short as possible, operation of the disk within its cartridge is a significant time saver. Experience with the RCA developmental jukebox systems has shown "worst case" disk access times as short as 5 to 6 seconds. If additional time were taken to remove the disk from the cartridge, then that extra time would adversely affect disk access time.)

These arguments favor keeping the disk within the cartridge. This was countered by the observation that an unconfined 356 mm (14 in) disk requires only about 8 watts to rotate it at speeds up to 1800 revolutions per minute, and that there is only a 2 to 1 ratio in the drive power which is required for a confined versus an unconfined disk. (Note that the same unconfined disk would require 57 watts at 3600 rpm.)

It was noted that if an enclosed disk has too low an air flow, eddies and pockets will form allowing dust to accumulate, while too fast a flow will create turbulence. These factors result in more stringent design constraints on confined disks.

It was then conjectured that there may be a need for standards for read/write processes both inside and outside of a cartridge.

Table 1
(Proudfoot - Eastman Kodak Company)

MANUFACTURING AIM

| dBm Noise Floor | dBm Noise | dB CNR | dBm Carrier | dBm 6 mw Carrier | Bit Error Rate |
|---|---|---|---|---|---|
| -78 | -78 | 70 | -8 | -25 | $Y \times 10^{-z}$ |

CUSTOMER AIM KEEPING FACTORS

| | dBm Noise Floor | dBm Noise | dB CNR | dBm Carrier | dBm 6 mw Carrier | Bit Error Rate |
|---|---|---|---|---|---|---|
| Mfg. Aim 1 | -78 | -78 | 70 | -8 | -25 | $Y \times 10^{-z}$ |
| 1 yr. 26°C/50% RH | +3 | +3 | -3 | 0 | 0 | 0 |
| Track Change (Six months 26°C/50% RH) | NA | 0 | 0 | 0 | NA | 0 |
| Customer Aim (Test equipment) | -75 | -75 | 67 | -8 | -25 | $Y \times 10^{-z}$ |
| Test equipment to customer W/R equipment | 0 | 0 | -3 | -3 | -3 | 0 |
| Customer Aim (customer W/R equipment) | -75 | -75 | 64 | -11 | -28 | $Y \times 10^{-z}$ |
| Customer Reference | | | | | | |
| | -75 | -75 | 64 | -11 | -28 | $Y \times 10^{-z}$ |

dBm - decibels referenced to one millivolt.

Noise Floor - measure 1 MHz above the carrier signal with no writing on disk.

Noise - measured 1 MHz above the carrier signal in a fully formed track at R = 100 mm at 1800 rpm at about 8.6 MHz carrier.

Carrier - The RMS carrier level in dBm in a 30 KHz bandwidth centered at the fundamental (carrier frequency) of a monotone recording. The input is a 50% duty cycle square waveform.

Table 1, continued
(Proudfoot - Eastman Kodak Company)

Carrier-to-Noise Ratio (CNR) - The ratio of the Carrier to the CNR Noise level in dB.

6 mw Carrier - The carrier signal level for the 6 mw track (about 8.6 MHz).

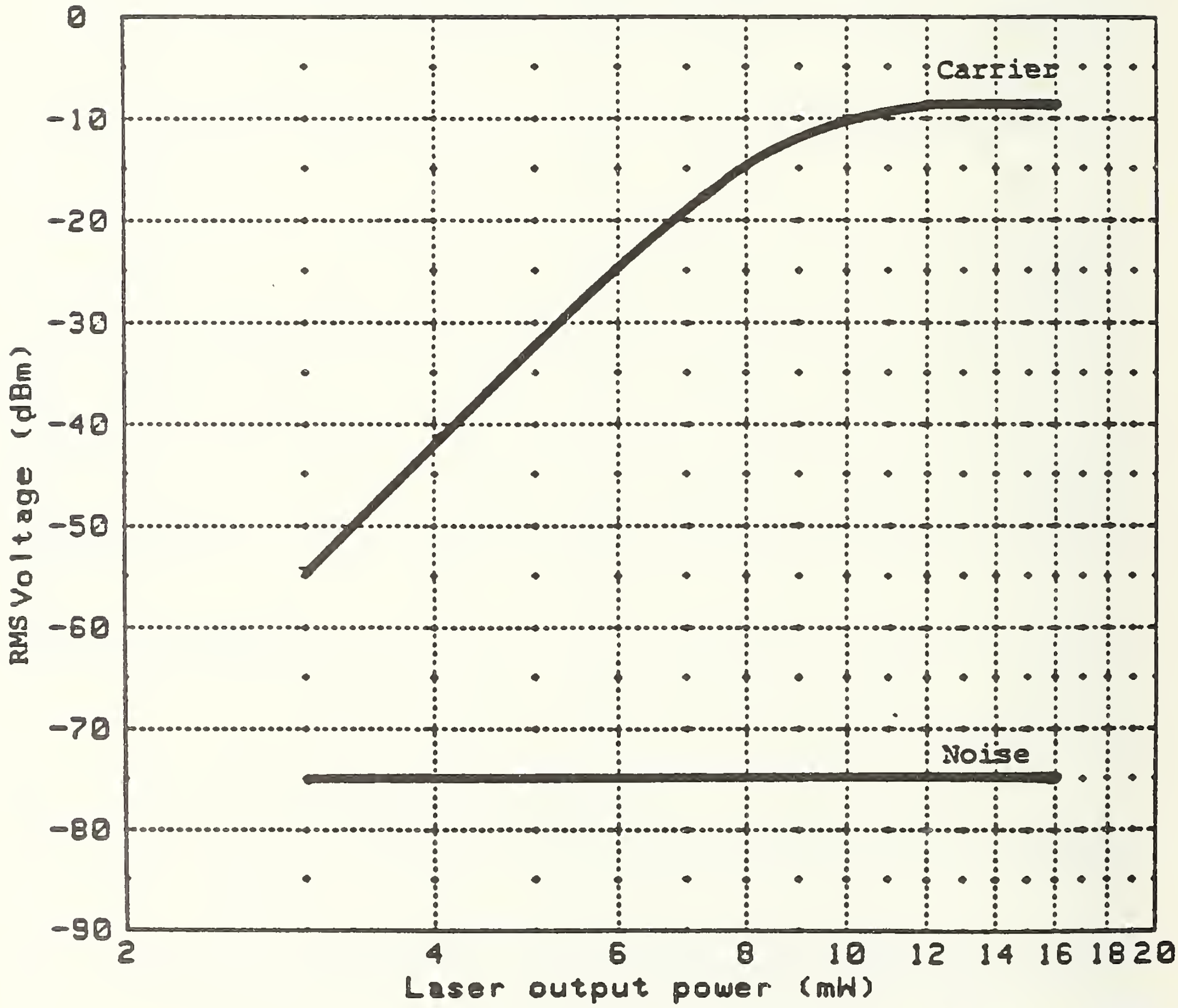
Bit Error Rate - The ratio of errors detected upon readout of a pseudo-random data to the total number of bits measured in the form $Y \times 10^{-z}$.

TEST CONDITIONS:

Recording: Laser at 830 nm, 1800 rpm, R = 100 mm
Elliptical spot in track 1.0 x 1.13 $\mu$m FWHM

Reading: Laser at 633 nm Circular spot 0.72 $\mu$m FWHM
Split detector HP Spectrum Analyzer #3585A

| Parameters | Aim |
|---|---|
| Carrier | -8 dBm |
| Noise | -75 dBm |
| CNR | 67 dB |
| Noise Floor | -75 dBm |
| 6 mW Carrier | -25 dBm |
| Bit Error Rate | y x $10^{-z}$ |




FOR EXAMPLE ONLY

Figure 1. Customer Reference for a "Standard Optical Digital Data Disk" (Proudfoot - Eastman Kodak Company)

TEST CONDITIONS:

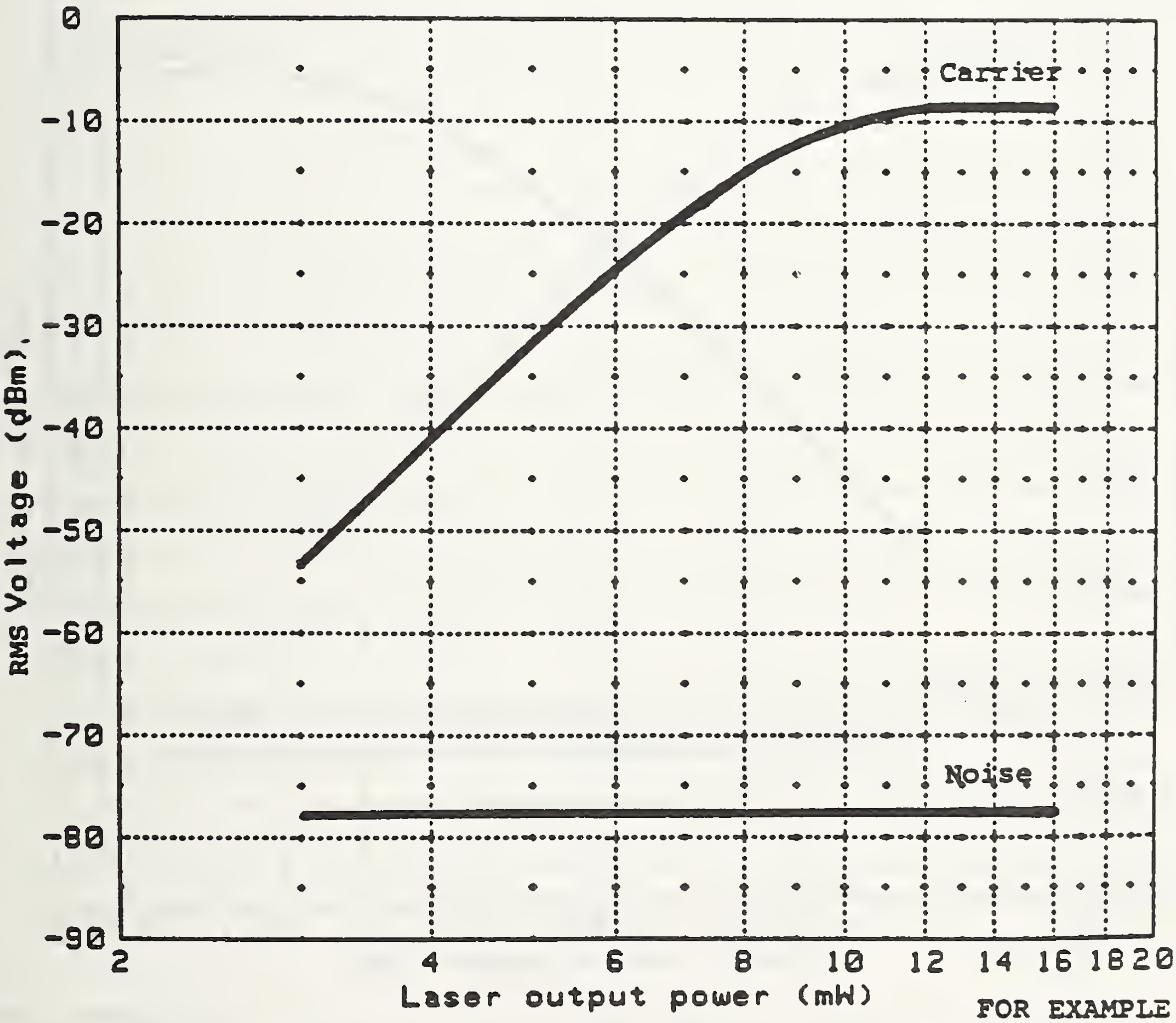
Sample Preparation:

Recording: Laser at 830 nm, 1800 rpm, R = 100 mm
Elliptical spot in track 1.0 x 1.13 $\mu$m FWHM

Reading: Laser at 633 nm; Circular spot 0.72 $\mu$m FWHM
Split detector HP Spectrum Analyzer #3585A

Parameters

| | Aim | Conformance Limits |
|---|---|---|
| Carrier | -8 dBm | -7 to -11 dBm |
| Noise | -78 dBm | -76 to -80 dBm |
| CNR | 70 dB | 66 to 72 dB |
| Noise Floor | -78 dBm | -76 to -80 dBm |
| 6 mW Carrier | -25 dBm | -22 to -30 dBm |
| Bit Error Rate | Y x $10^{-z}$ | Y x $10^{-z}$ |




FOR EXAMPLE ONLY

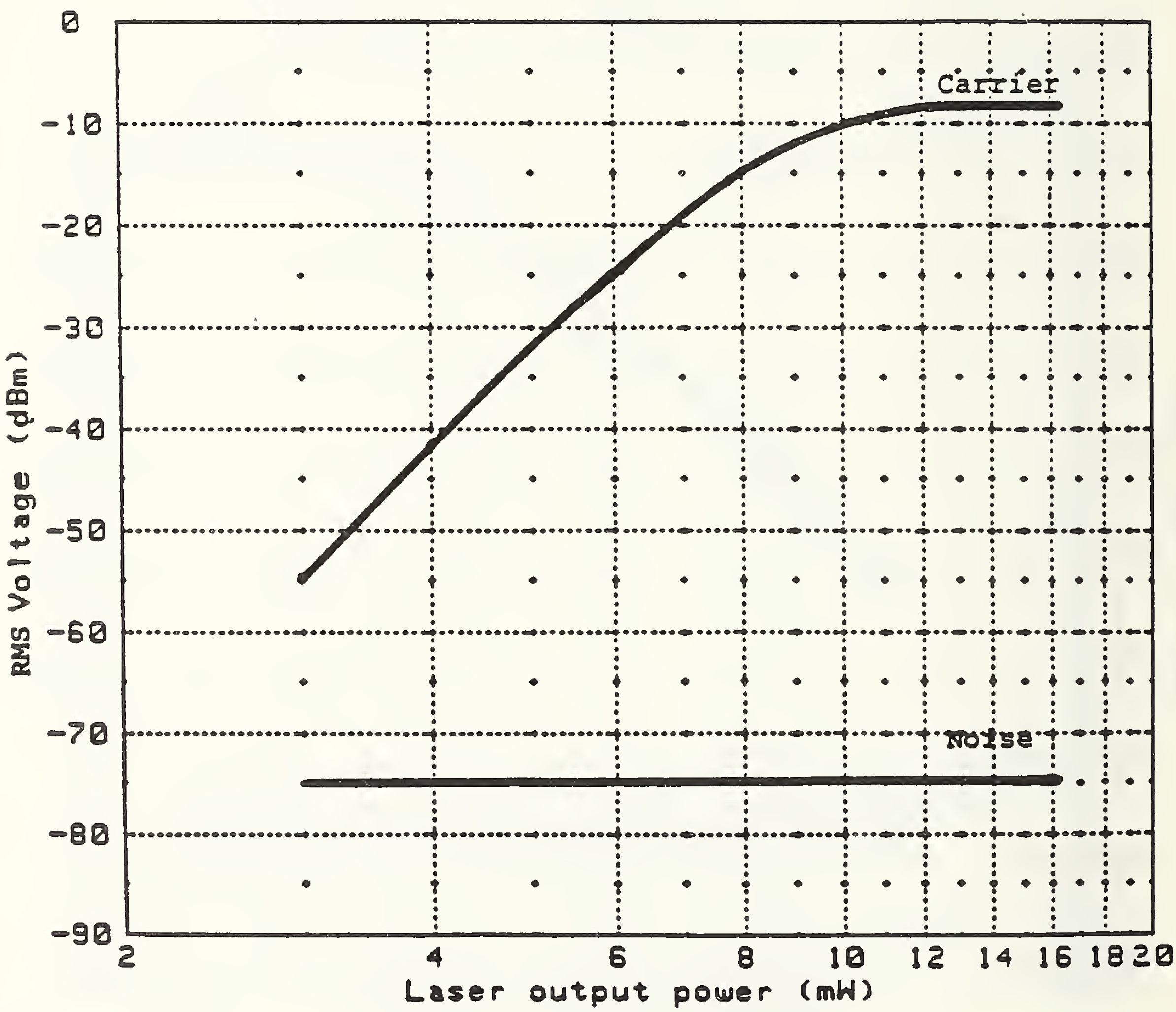
Figure 2. Manufacturing Aim for a "Standard"
Optical Digital Data Disk
(Proudfoot - Eastman Kodak Company)

TEST CONDITIONS:

Recording: Laser at 830 nm, 1800 rpm, R = 100 mm
Elliptical spot in track 1.0 x 1.13 μm FWHM

Reading: Laser at 633 nm Circular spot 0.72 μm FWHM
Split detector HP Spectrum Analyzer #3585A

| Parameters | Aim |
|---|---|
| Carrier | -8 dBm |
| Noise | -75 dBm |
| CNR | 67 dB |
| Noise Floor | -75 dBm |
| 6 mW Carrier | -25 dBm |
| Bit Error Rate | $y \times 10^{-z}$ |




FOR EXAMPLE ONLY

Figure 3. Customer Aim for a "Standard"
Optical Digital Data Disk
(Proudfoot - Eastman Kodak Company)

TEST CONDITIONS:

Recording: Laser at 830 nm, 1800 rpm, R = 100 mm

Reading: Laser at 633 nm
Split Detector HP Spectrum Analyzer #3585A

Parameters

| | Aim |
|---|---|
| Carrier | -11 dBm |
| Noise | -75 dBm |
| CNR | 64 dB |
| Noise Floor | -75 dBm |
| 6 mW Carrier | -28 dBm |
| Bit Error Rate | $y \times 10^{-z}$ |

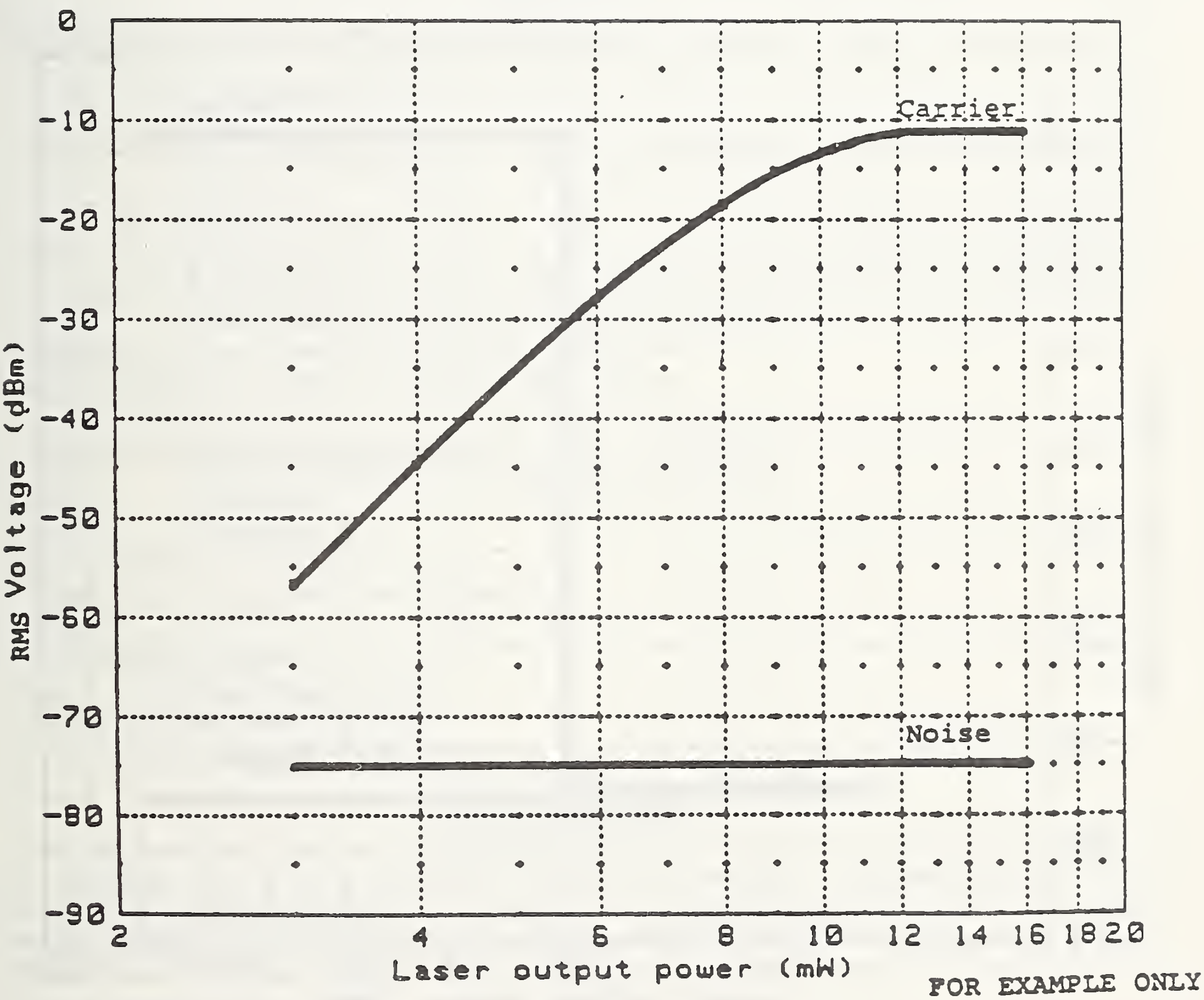



Figure 4. Customer Aim for a "Standard"
Optical Digital Data Disk
Tested on Customer Equipment
(Proudfoot - Eastman Kodak Company)

TEST CONDITIONS:

Recording: Laser at 830 nm, 1800 rpm, R = 100 mm
Elliptical spot in track 1.0 x 1.13 μm FWHM

Reading: Laser at 633 nm Circular spot 0.72 μm FWHM
Split detector HP Spectrum Analyzer #3585A

Parameters

| | Aim |
|---|---|
| Carrier | -8 dBm |
| Noise | -75 dBm |
| CNR | 67 dB |
| Noise Floor | -75 dBm |

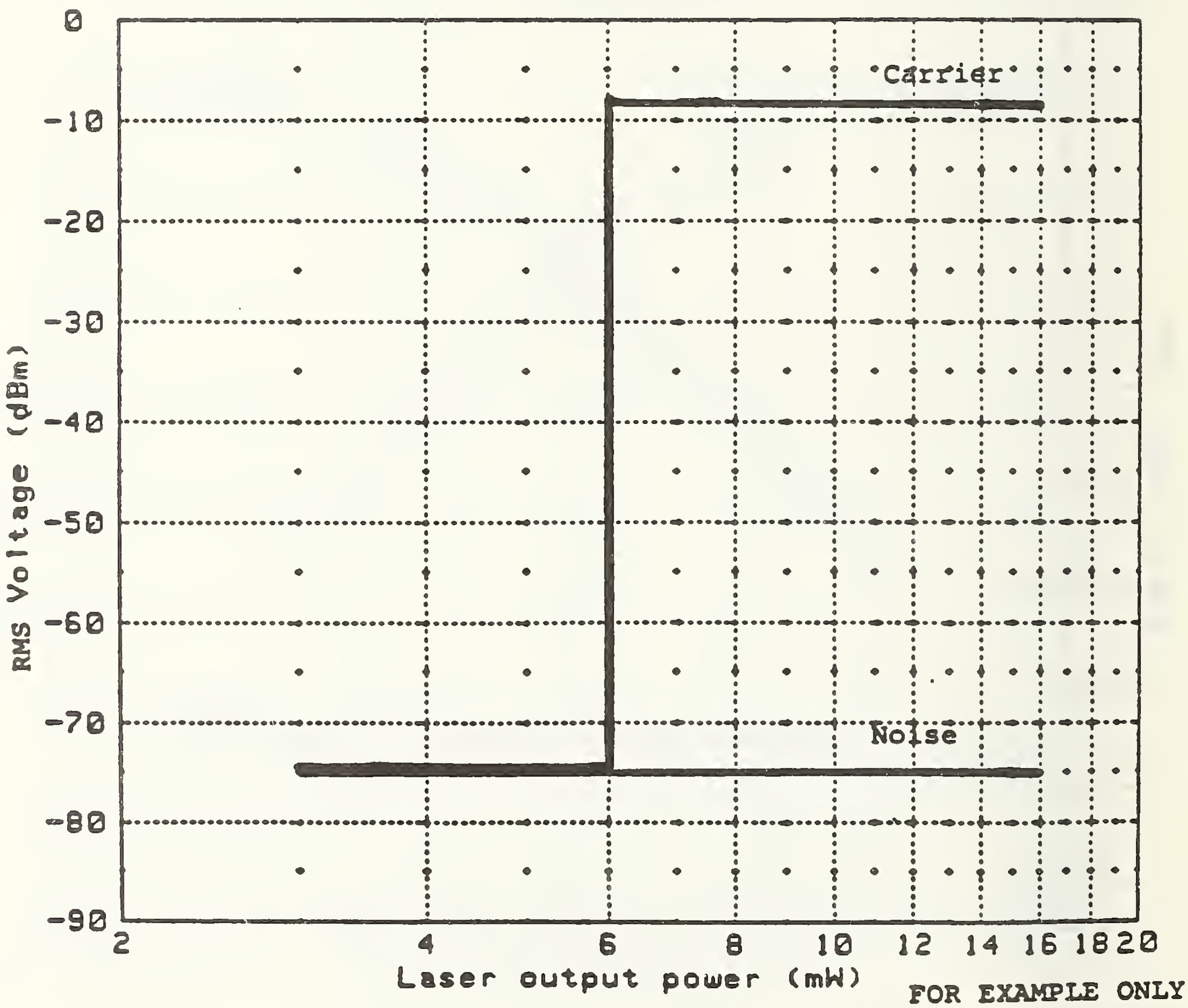



Figure 5. Ideal Sensitivity - Optical Digital Data Disk
(Proudfoot - Eastman Kodak Company)

## 1.2 SESSION II PRESENTATIONS AND DISCUSSION - RECORDED OPTICAL MEDIA UNIT CHARACTERISTICS

### 1.2.1 EFFECT OF DISK MECHANICAL RUNOUT ON DATA INTEGRITY

**By Edward LaBudde**
**LaBudde Engineering Corporation**

Key words: axial runout; focus error; hard error rate; mechanical runout; noise; radial runout; soft error rate; tracking error.

#### Introduction

Mr. LaBudde offered the following definitions:

(1) Error Rate Definition:

- (a) Initial defect density - Defects on unrecorded disk (non-destructive read).
- (b) Read error rate (soft) - Read bit error rate which can be cleared on reread.
- (c) Read error rate (hard) - Read bit error rate which is not clearable on reread (this could arise from initial defect).

(2) The soft bit error rate (BER) depends on:

- (a) Signal characteristics which are a function of
  - . Beam size (also a function of focus errors)
  - . Pit size
  - . Track error

(3) Noise characteristics depend on:

- (a) Pit noise
- (b) Read channel noise
- (c) Mechanical noise
- (d) Cotrack interference

#### Effects of Runout

Mr. LaBudde noted that mechanical runout can affect both the hard and soft error rates, which are reclearable on reread for small errors and not readable for large errors. There are two sources that cause mechanical runout: axial runout, which causes focus error, and radial runout, which causes tracking error.

Axial runout has the effect of increasing the focus error, which is also a function of the disturbance spectrum and the servo performance. Focus error causes an increase in spot size, a decrease in signal amplitude, an increase in pit edge noise, and an increase in cotrack interference. The error is expressed as follows:

$$\text{ERROR} = \frac{\text{Disturbance Spectrum}}{1 + \text{GH (servo bandwidth)}}$$

GH = Loop Gain

Radial runout produces an increase in track error, which is also a function of the disturbance spectrum and the servo performance. Track error causes a decrease in signal amplitude, a decrease in pit edge noise, and an increase in cotrack interference. (See the preceding error formula.)

The mechanical runout spectrum is usually limited to low frequencies. If the runout is large, it may blank out considerable spans (large portions) of the track. The effects may be repeatable on reread, requiring an offset on retry.

## Summary

In summary, a small mechanical runout will be within the error budget and will produce no system errors. A medium runout may degrade the soft error rate, but data may be recovered by retrying with offsets. A large runout can cause gross deterioration of the read error rate, and may not be correctable.

### 1.2.2 OPTICAL CHARACTERISTICS OF RECORDED MEDIA

**By Leonard Laub**
**Vision Three, Inc.**

Key words: information surface; locally written media; mass-replicated media; modulation; protective coating thickness; recording surface; resolution; wavelength specificity.

Mr. Laub reviewed the process by which optical disk media modulate light in terms of the optical path to the recording surface and the contrast offered by marks on the information surface. There may be a wavelength specificity. Slides of various recorded surfaces were shown. The types of modulation were characterized as deterministic redirection, absorption, scattering (non-deterministic), and polarization rotation. Mr. Laub noted that the optical reading process is not necessarily dependent on how the spots are formed.

Surface protection is needed against dust and scratches; however, such a protective coating can introduce aberrations in the optical path.

Requirements exist for compatibility between mass-replicated media and locally written media. These requirements should include reading in the absorption mode, the protective coating thickness must correspond to the set value, the reading wavelength and power should correspond, and the density should be limited to that achievable by the method having lesser resolution.

## 1.2.3 ELECTRICAL CHARACTERISTICS OF THE DISK Data and Servo Control

By Yoshito Tsunoda
Hitachi Ltd.

Key words: aberration of optics; noise characteristics; real time monitoring; recording layer; servo control; signal characteristics; subbing layer; tracking signal.

### Introduction

Mr. Tsunoda described a 305 mm (12 in) disk, two sided, with 2.6 gigabytes (2.6 x $10^9$ bytes) total storage capacity. The track spacing was 1.6 $\mu$m (64 $\mu$in), with 64 sectors per track. It was pregrooved, with preformed header information. The spot size was 1.2 $\mu$m (30.5 $\mu$in) to 1.6 $\mu$m (64 $\mu$in). A tellurium-selenium formulation was used which was found to be superior to tellurium alloy used alone. The pits formed in this surface were very clean and uniform.

### Electrical Characteristics

An evaluation of the electrical characteristics of the data should include both the writing characteristics and the signal and noise of the reading characteristics. A technique is available for monitoring the recorded signal during writing. Numerous slides of waveforms were displayed, showing signals during reading and writing.

Mr. Tsunoda indicated that the noise encountered during reading was influenced by both the recording layer and by the subbing layer (substrate). He described the reading characteristics of the signal as being influenced by the pit pitch, pit size, track runout offset, focus offset, and aberration of the optics.

The electrical characteristics of the servo control system should also be considered. This system consists of a tracking servo and a focusing servo.

Mr. Tsunoda described disk writing characteristics as determined by the following factors:

(1) Writing power versus signal level
(2) Writing power versus pit size
(3) Real time monitoring.

He suggested the following variables and associated tests be standardized:

(1) Media recording surface sensitivity:

   (a) measuring method (device, pulse)
   (b) specifications

(2) Signal characteristics:

  (a) signal type (bright or dark)
  (b) measuring method (device, etc.)
  (c) specifications

(3) Noise characteristics:

  (a) measuring method
  (b) specifications

(4) Servo control signal characteristics:

  (a) TR signal (groove, etc.)

## 1.2.4 DATA FORMAT, INITIALIZATION, AND ERROR MANAGEMENT

By Di Chen
Optical Peripherals Laboratory (OPL)

Key words: data format; direct read after write (DRAW); error correction; error correction code (ECC); error detection and correction (EDAC); modulation scheme.

### Introduction

Dr. Chen described an optical storage system consisting of optical digital data disk and optical disk drive subsystems. He then described $OD^3$ data formatting techniques:

(1) $OD^3$ Format

- (a) labelling: Human Read/Machine Read (HRMR)
- (b) addressing: sector and track mark
- (c) tracking: tracking servo signal
- (d) focusing: focusing servo signal
- (e) clock: timing window for read/write

(2) Data

- (a) modulation scheme: considers the laser duty cycle, user data capability, and encoder/decoder electronics by which the data is interchanged with the user
- (b) error detection and correction (EDAC): to improve BER
- (c) post field: for data correction/update within a sector
- (d) vector field: for pointing to correctly written sector
- (e) write verify: uses Direct Read After Write (DRAW)
- (f) write protect flag: flag to prevent overwrite

(3) Formatting Techniques: Formatting techniques for preformed material consist of stamping replication or bit-by-bit formatting (servo writing); the latter takes longer.

(a) Stamping Replication:

- Format information is embossed in depth from disk surface. Reading of format information is by optical interference.

- Dr. Chen illustrated a typical replication process, in which a master is formed, called a "father," from which a "mother" is formed, and which in turn is used to form a "son" which becomes the stamper (see fig. 1). Layers of plating are used to obtained a metalized surface.

(b) Bit-by-Bit Formatting:

- Format information is written on an unrecorded disk bit-by-bit. Reading of format information is the same as reading written data bits.

## Recording Geometries

The two basic recording geometries are the spiral and concentric track configuration. The spiral track geometry is widely used for entertainment material where continuously moving displays are desired, although the spiral track has also been adapted for use in digital data storage. The concentric track geometry corresponds closely to conventional track layouts on magnetic disks. In either case, the reading method must be capable of jumping by one groove at the end of a track. That is, if the data are to be reread repetitively from a spiral groove, it is necessary to jump back at the end of the groove to the start of the same groove. If data are to be read sequentially from concentric grooves, it becomes necessary to jump to the next groove at the end of the current groove. It is immaterial to the track servo as to whether it is following a spiral groove or a concentric groove, because the track spacing is so small compared to the possible radial runout of the disk that the servo is designed to accommodate.

There are two versions of track servo techniques. One uses a single spot which is kept centered over the pregrooved track in push-pull fashion. The other uses two spots, one following each edge of the track **(see fig. 2)**.

A. Review of Recording Geometries:

(1) Geometrical Format:

(a) Spiral
(b) Concentric

(2) Track Servo Techniques:

(a) Push-Pull
(b) 2-Spot

If the disk rotates at a constant speed, and the data are written at a constant rate in bits per second, the bit density within a track will increase with decreasing track radius. This is the constant angular velocity (CAV) recording. An alternate approach is to adjust the writing rate as a function of the track radius so as to maintain a uniform bit density or constant linear velocity (CLV) on each track. This approach offers a potential doubling of the disk capacity, but is avoided because of the difficulty in implementation.

B. Review of Disk Speed Factors

(1) Constant Rotational Speed or constant angular velocity (CAV):

(a) Angular bit density is constant

(b) Linear bit density varies, and is limited by the bit density on the innermost track
(c) Easy to implement
(d) Low data areal density

(2) Constant Linear Density or constant linear velocity (CLV):

(a) Rotational speed varies, lowest speed when addressing outermost track
(b) High data areal density
(c) Rotational speed change from track to track increases access time
(d) Difficult to implement

## Error Management

Error management involves the choice of the modulation scheme and the use of Error Detection and Correction (EDAC) techniques. In addition, write verification can be employed, in which data are reread and checked against the original. This may be done in real time using the Direct Read After Write (DRAW) technology. Write protection can be achieved through the use of a write-protect flag. Correction and updating of previously written data can be done by flagging the data and appending a jump to the location of the new data.

One method of performing the DRAW operation is to use two laser beams, one slightly behind the other. The second beam reads the information written by the first, allowing a 10 nanosecond decision time for detecting errors. The second method (one beam) utilizes the trailing edge of a read signal obtained during the writing process. The read signal shows a characteristic excursion as the result of writing a bit (mark) **(see fig. 3).**

C. Review of Error Management

(1) Modulation Scheme

(2) EDAC

(a) Degree of sophistication depends on the media raw error rate and the desired bit error rate

(3) ECC requires

(a) Disk real/estate
(b) Encoder/decoder and error generation/correction electronics

(4) Write Verification/Protection

(a) Real time verification by DRAW
(b) Write-protect flag to protect written field

(5) Data Correction/Update

(a) Post field for correction/update within the sector
(b) Vector field for pointing to correctly written new sector

## Summary

(1) The disk determines the drive design.

(2) The disk must provide format (disk firmware):

- (a) Tracking information
- (b) Addressing information
- (c) Clock information

(3) Data error management (disk software) includes:

- (a) Modulation scheme
- (b) EDAC
- (c) Write verification/protection
- (d) Update and correction capability

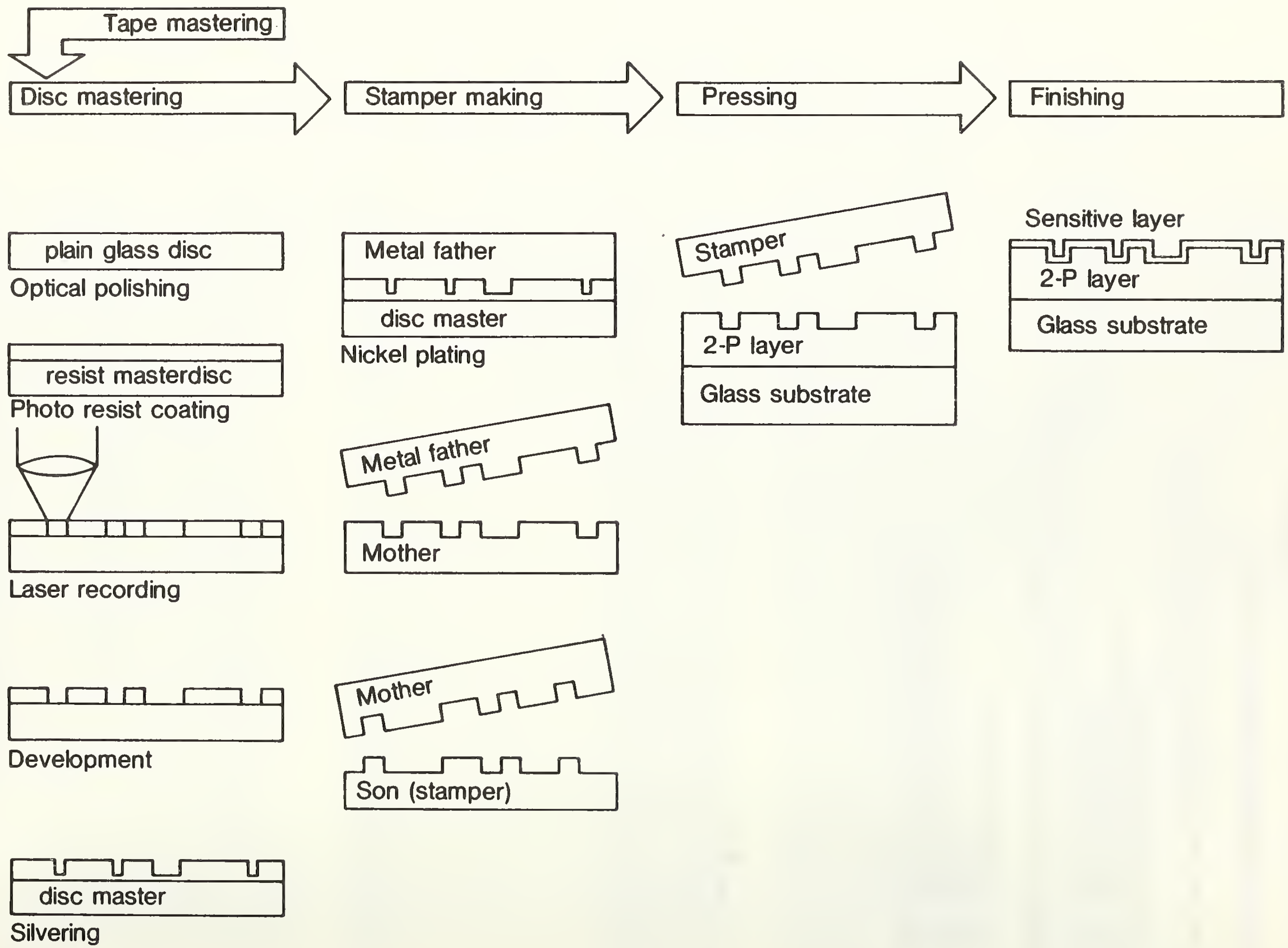
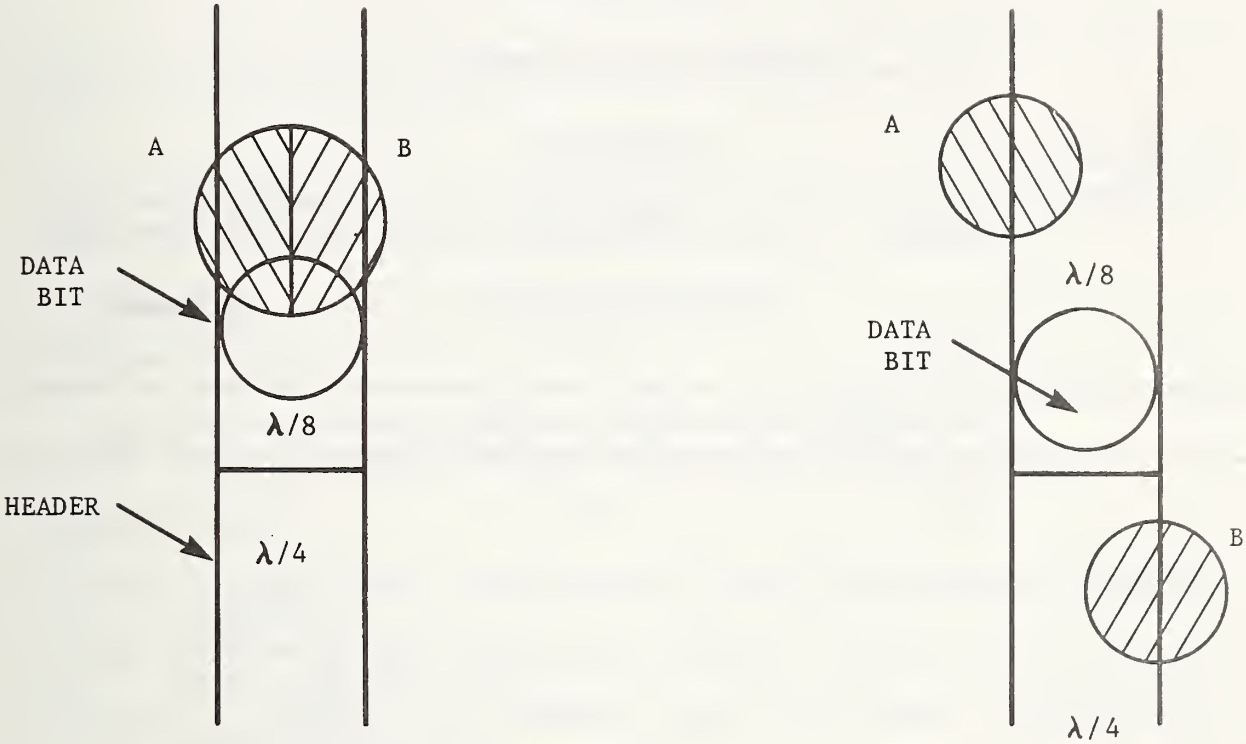



Figure 1.
(Chen - Optical Peripherals Laboratory)




TRACKING TECHNIQUES

Shaded area indicates beam position. The pregrooved track depth is $\lambda/8$ in the data field with the depth of the header bits at $\lambda/4$ depth.

Figure 2.
(Chen - Optical Peripherals Laboratory)

DRAW

DIRECT-READ-AFTER-WRITE

(1) TWO BEAM

(2) ONE BEAM

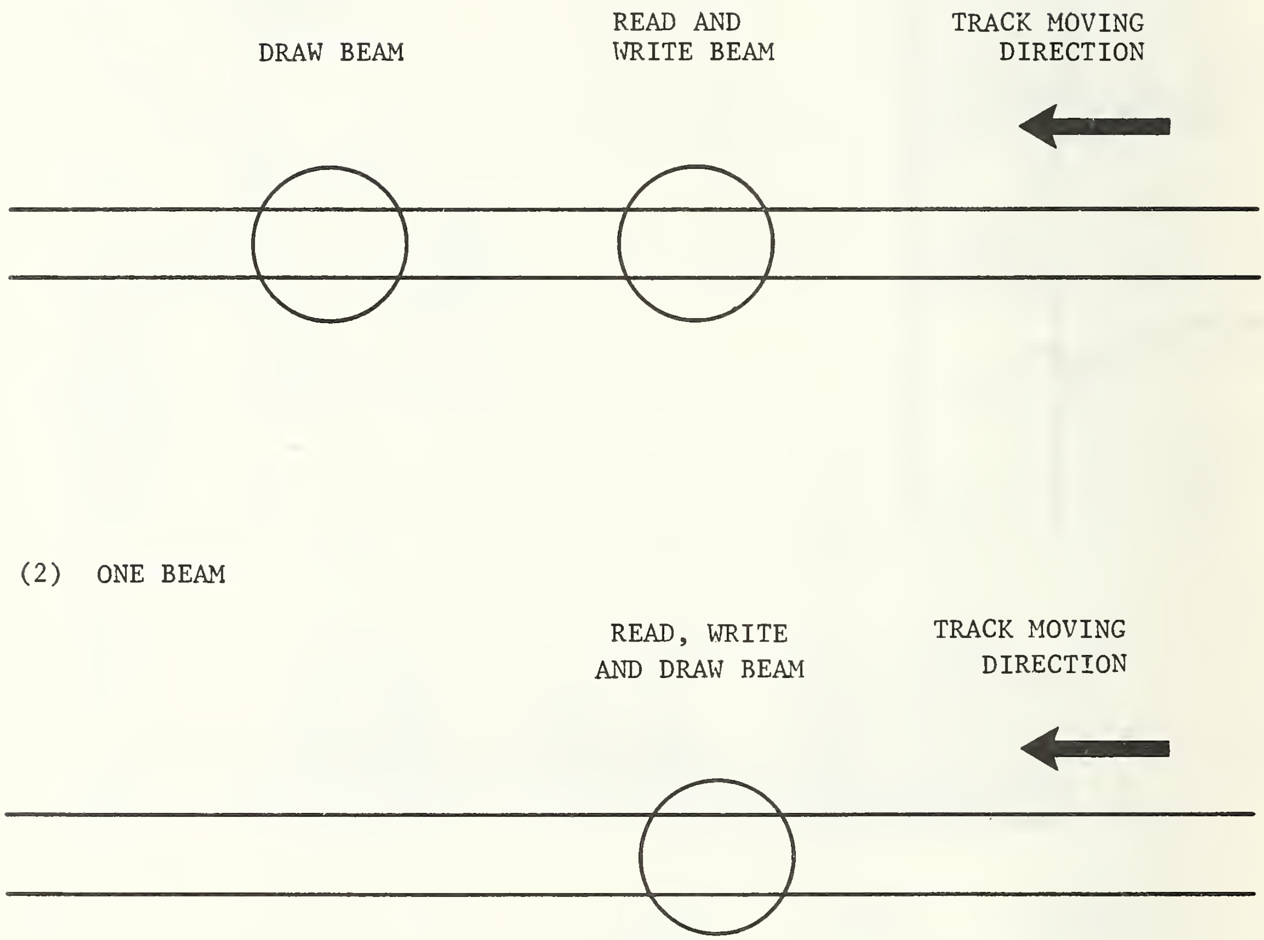



Figure 3.
(Chen - Optical Peripherals Laboratory)

## 1.2.5 RECORDED CHARACTERISTICS - FILE STRUCTURE AND LABELLING

**By Kenneth Nolan**
**IBM Corporation**

Key words: architecture; compatibility; files; interchange; software.

### Introduction

Mr. Nolan described a set of architectural layers related to the use of traditional magnetic direct access storage devices and their media.

### Architectural Layers

(1) System-related

- (a) Disk Drive Operation (Physical and Mechanical Properties)
- (b) Adapter/Controller Protocols (Bus Interface, Commands, etc.)

(2) Media-related

- (a) Unrecorded Media Characteristics (Physical, Mechanical, and Electrical Properties)
- (b) Recorded Media Characteristics (Encoding, Density, Track Layout and Format, CRC/ECC, etc.)
- (c) File Structure and Labelling (Volume ID, Space Allocation, Data Management, etc.)
- (d) File Content (Actual Data Exchange)

Mr. Nolan pointed out that the boundaries between these layers were, in some cases, arbitrary, but that they provided a useful way of viewing such devices for standardization. He showed that this view was equally relevant for discussions of $OD^3$ standards.

He pointed out that standardization of any particular architectural layer of the optical media was only useful for data interchange if the lower-numbered layer was also standardized. He also observed that the 'File Content' layer was essentially media independent and should not be considered specifically for $OD^3$.

Mr. Nolan discussed a number of technical considerations for the 'Recorded Media Characteristics' and 'File Structure and Labelling' layers and gave his view on the following compatibility issues.

### Compatibility Issues

(1) Software compatibility with traditional storage devices
(2) Consistent architecture for various sizes of optical media
(3) Media independence (architecture not tied to drive/media geometry)
(4) Potential functional enhancements

He began by emphasizing that compatibility of $OD^3$ with traditional storage devices would be very desirable from the standpoint of software architecture. Such compatibility would work to minimize software modifications for attachment of new devices.

He pointed out that a consistent architecture for various sizes of optical media would allow a given system to attach a number of different devices without significant incremental software expense.

He discussed the classical tradeoff between media-independent architectures, such as fixed-block architecture, and those using self-identifying data recorded in terms of cylinders, tracks, and sectors. He concluded that, for standardization of removable storage media, the latter provided a more reasonable approach.

He described functional enhancements such as automatic audit trails suggested by the non-erasability of the media and observed that these techniques would be difficult to standardize. Data interchange would likely be encouraged by a relatively simple architecture.

## 1.2.6 QUALITY CHARACTERISTICS OF OPTICALLY RECORDED DATA

**By Miguel Capote**
**Optical Coating Laboratory, Inc. (OCLI)**

Key words: bit error rate; inverse power plots; media performance; media testing; reflectivity; signal to noise ratio.

### Introduction

Mr. Capote presented his topics

(1) Delta $\Delta$R and Inverse Power Plots **(see fig. 3)**
(2) Noise - Four Types **(see fig. 4)**
(3) Resolution **(see fig. 5)**
(4) Drop-outs and Drop-ins **(see fig. 6)**

### Delta $\Delta$R and Inverse Power Plots

Mr. Capote discussed the absolute change in reflectance, $\Delta$R **(see fig. 1 and definitions fig. 2)**, which occurs when the data are recorded on an optical disk. He proposed the use of the inverse power plot as a more useful characterization, rather than the traditional plot of detector output versus writing power **(see fig. 3)**. This is obtained by plotting $\Delta$R in percent against the reciprocal of the write power P. He pointed out that $\Delta$R and $P_{threshold}$ are useful design parameters **(see definitions fig. 2)**. $\Delta$R is independent of the gain of the system. $P_{threshold}$ is the point where the inverse power plot intercepts the horizontal axis **(see fig. 3)**.

### Noise

Mr. Capote identified four types of noise **(see fig. 4)**:

(a) Low frequency peak noise - observed during prolonged peak output signal.
(b) Low frequency trough noise - observed during prolonged zero-level signal.
(c) High frequency peak noise - observed as amplitude variation of peaks among closely spaced bits.
(d) High frequency trough noise - observed as amplitude variation of troughs among closely spaced bits.

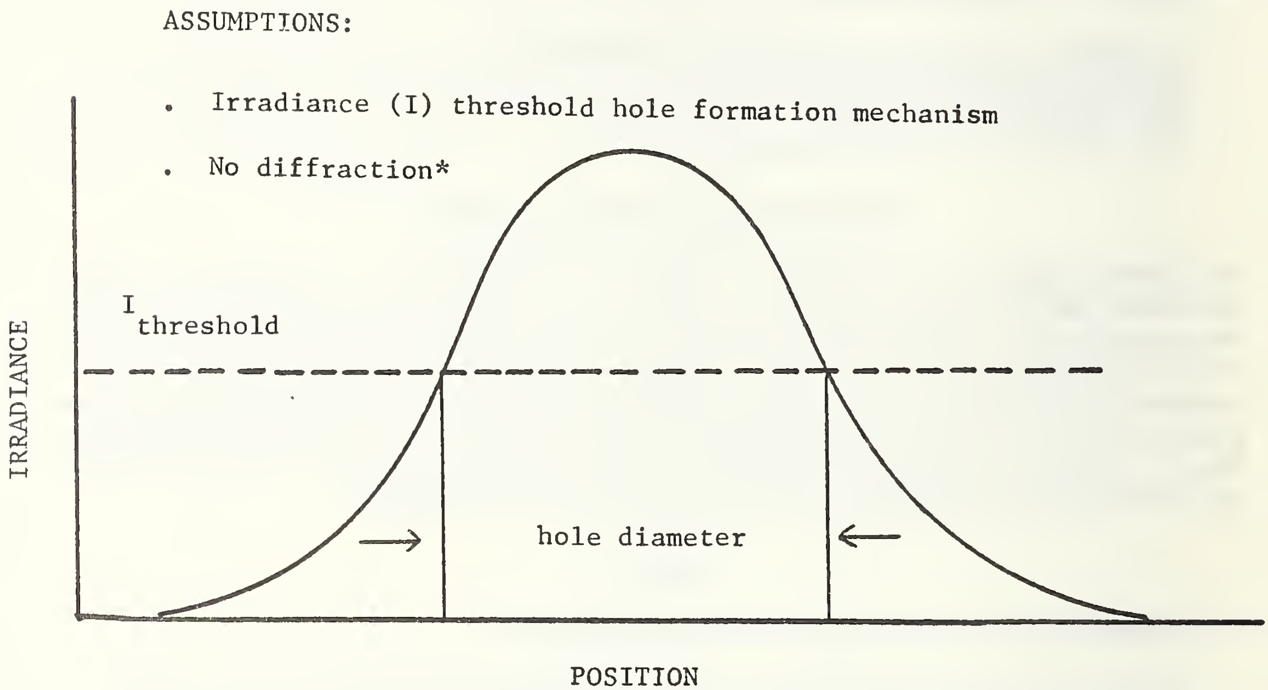
All noise types are evaluated in the same way, namely:

$$SNR = -20 \log (\sigma / \Delta R)$$

This parameter can be directly related to error performance from the user standpoint.

## Resolution, Drop-Ins and Drop-Outs

Mr. Capote used waveforms of closely-packed signals to illustrate the effects of overburn and underburn during writing. Overburn causes the baseline amplitude level to shift upward; underburn causes a decrease in peak amplitude. In either case, there is a loss of useful signal amplitude (see fig. 5). He also used waveforms to illustrate dropouts and dropins. He noted that most errors are small and widely separated (see fig. 6).




Most media behave this way.

*For discussion of diffraction effects, see C. Carneglia, Applied Optics, to be published.

Figure 1.
(Capote - Optical Coating Laboratory, Inc.)

It can be shown that the following approximation holds*

$$\Delta R = \Delta R_{\infty} \left(1 - \frac{P_T}{P}\right)$$

Where:

$\Delta R$ ≡ Measured change in reflectance upon writing and reading with a gaussian beam

0% = Perfect Absorber
100% = Perfect Reflector

$\Delta R_{\infty}$ ≡ Measured change in reflectance for an infinitely large hole

$P$ ≡ Write Power

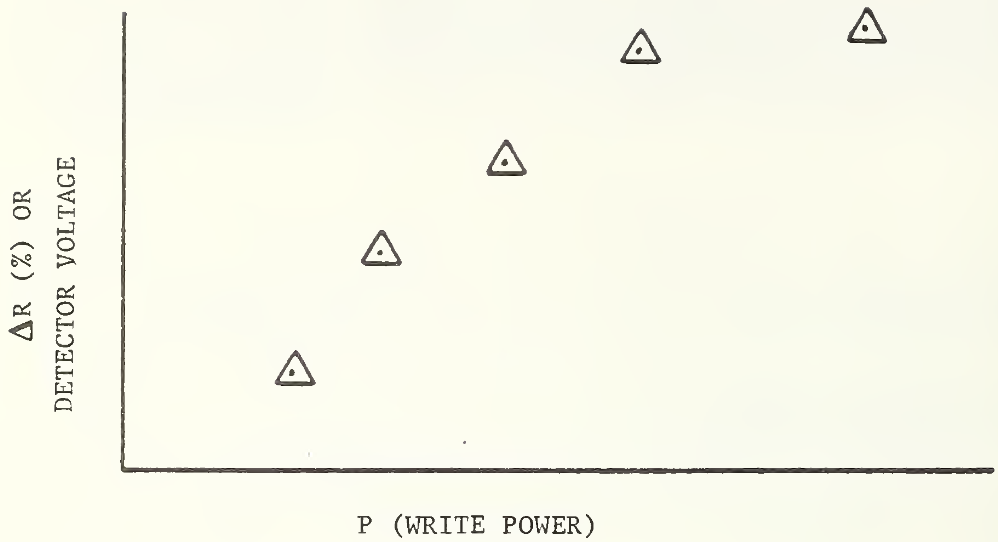
$P_T$ ≡ Apparent threshold Write Power

Constant exposure time and linear velocity is assumed.

*Reference: E. V. LaBudde, C. M. Shevlin, and R. A. LaBudde, Proceedings Topical Meeting on Optical Data Storage, Optical Society of America, January 1983.

Figure 2.
(Capote - Optical Coating Laboratory, Inc.)

INSTEAD OF THIS . . .




YOU HAVE THIS . . .

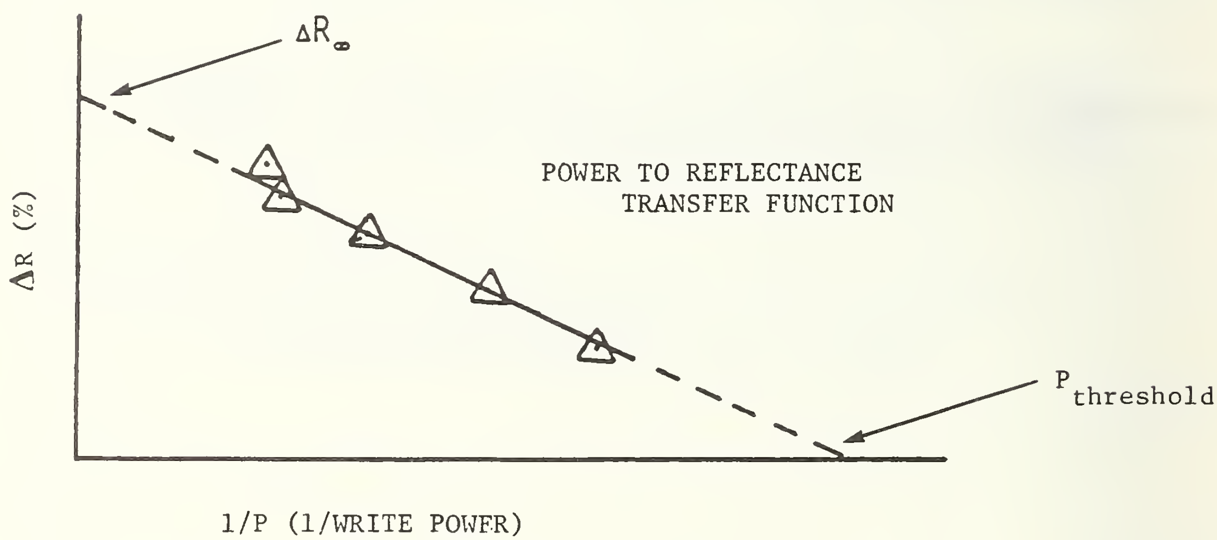



Figure 3.
(Capote - Optical Coating Laboratory, Inc.)

FOUR TYPES OF NOISE

$$SNR = -20 \ LOG \frac{\sigma}{\Delta R}$$

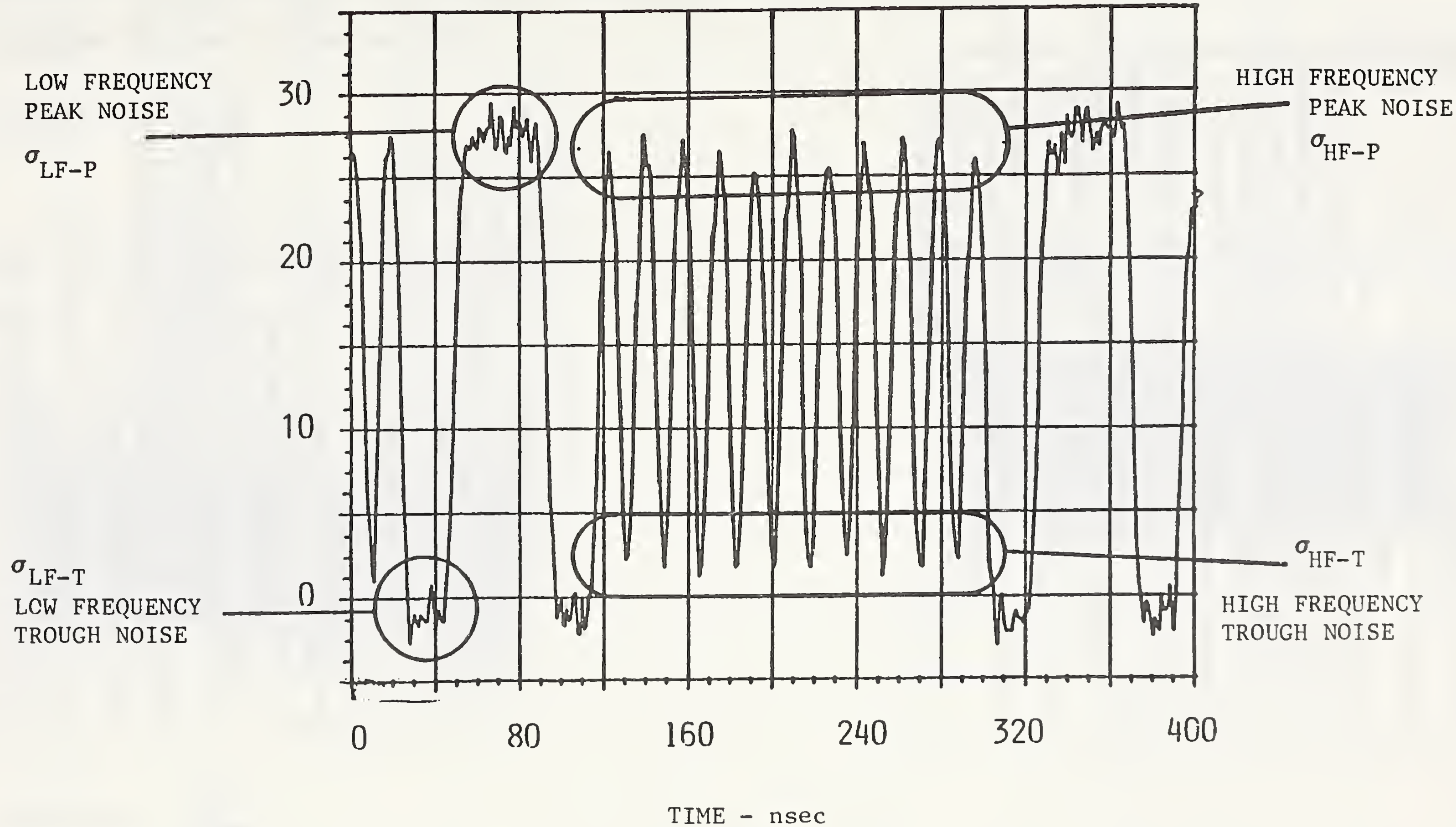
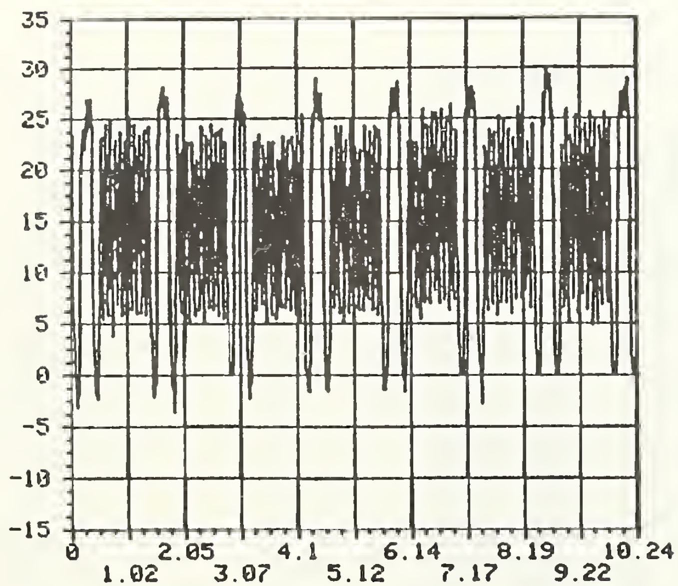


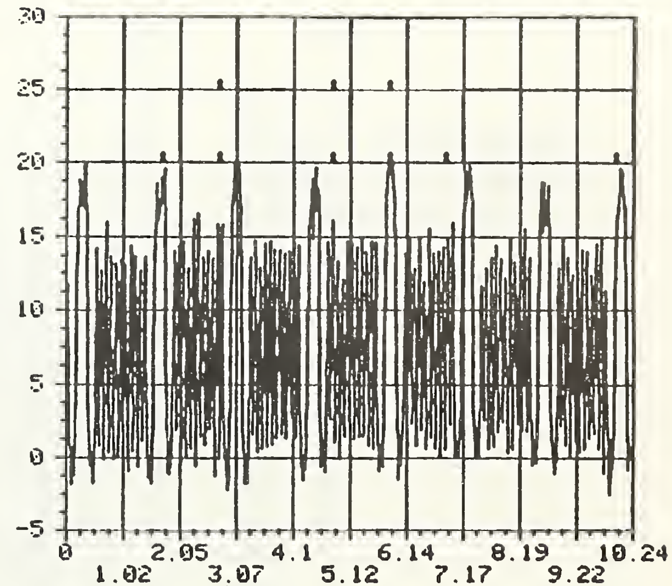

Figure 4.
(Capote - Optical Coating Laboratory, Inc.)

$$\text{RESOLUTION} = \frac{\Delta R_{HF}}{\Delta R_{LF}}$$




RESOLUTION = 67.5%

OVERBURN CAUSING HF BASELINE SHIFT




RESOLUTION = 73.1%

UNDERBURN CAUSING HF LOSS OF AMPLITUDE

RESOLUTION IS IMPORTANT FOR FREQUENCY COMPENSATION AND A - D CONVERSION.

Figure 5.
(Capote - Optical Coating Laboratory, Inc.)

BIT ERRORS -

HARD (REPEATED READING WILL NOT CORRECT)

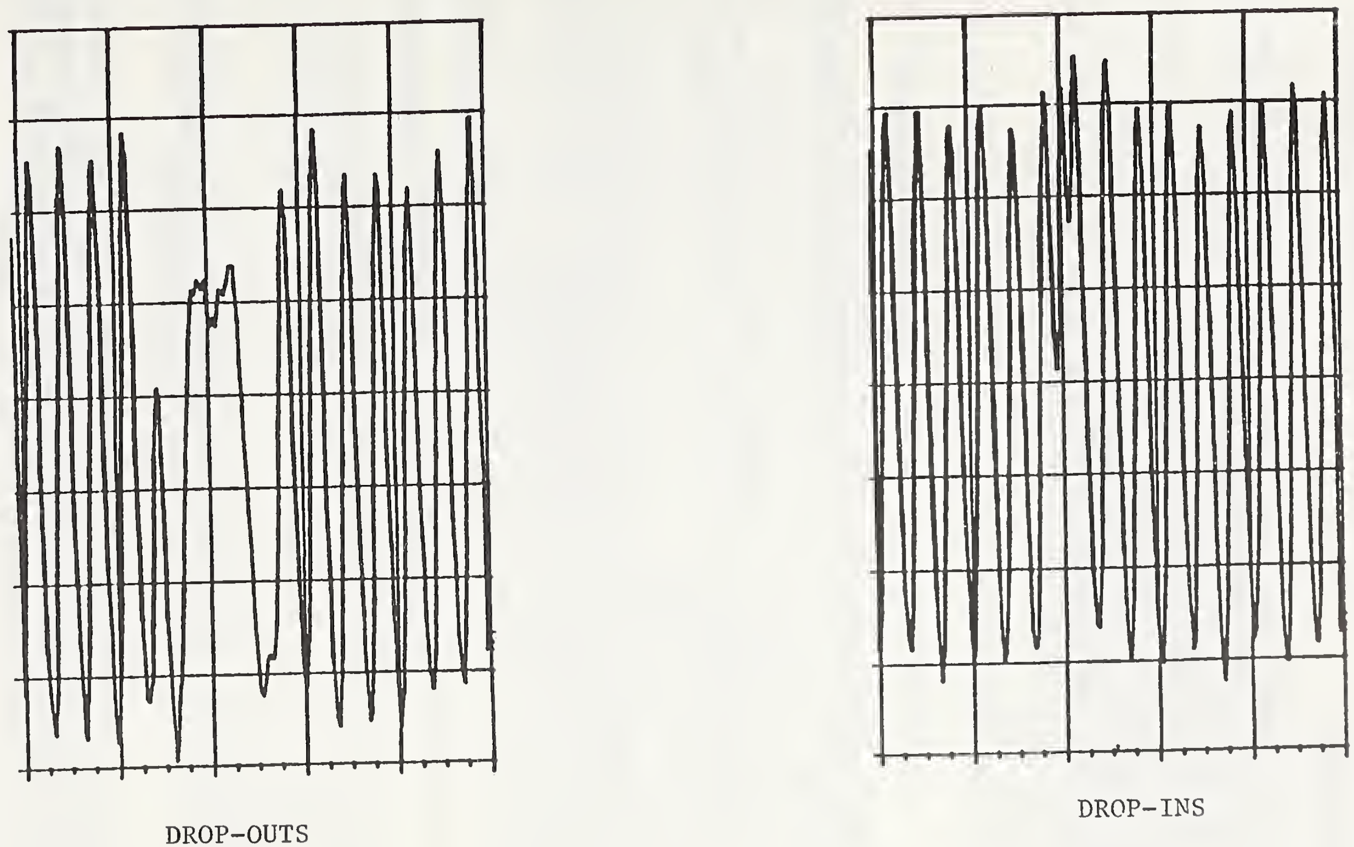



Figure 6.
(Capote - Optical Coating Laboratory, Inc.)

## 1.2.7 Panel Discussion: Recorded Optical Media Unit Characteristics

**Panel Participants:**

John Bray, NCR Corporation
Miguel Capote, Optical Coating Laboratory, Inc.
Di Chen, Optical Peripherals, Inc.
Mike Deese, Storage Technology Corporation
John Dove, United States Air Force
Mark Goldberg, National Security Agency
Edward LaBudde, LaBudde Engineering Corporation
Leonard Laub, Vision Three, Inc.
Kenneth Nolan, IBM
Yoshito Tsunoda, Hitachi Ltd.

(These Comments are not Transcribed Verbatim.)

**Floor:** Is there any possibility of format standards, such as for data encoding, error correction, etc.?

**K. Nolan:** There certainly is a possibility of format standards and these will be necessary to permit actual interchange of data. At this time, however, most of the interest is with the technology.

**L. Laub:** The subject of format standards is receiving more attention among those who are adopting video disks for digital applications. There is some question as to whether these are needed for computer applications.

**Floor:** While carrier-to-noise ratio is easy to measure, it is not very meaningful.

(M. Capote was asked about the ease of using his waveform measurements.)

**M. Capote:** This is simply a matter of using an oscilloscope and a ruler.

**Floor:** A device was once designed for making this measurement by means of a pattern display.

**L. Laub:** This is in contrast with the eye pattern used in telegraphy which readily shows whether any signal excursions occur in the wrong places.

**M. Capote:** The reflectances I refer to are based on 0 for a perfectly absorbing medium and 100 for a perfectly reflecting medium. The problem with using contrast ratios is that they are very deceptive. It is possible to have very high contrast ratios but signal levels which are not detectable reliably.

**M. Deese:** What about the relative accuracy of pregrooved media versus servo-written media?

**D. Chen:** The raw error rate is in the range of $10^{-5}$ to $10^{-6}$ for either process. However, for one-spot servo-tracking, the media must be pregrooved.

**Floor:** Would pregrooving reduce the options and deprive a user of possible economies?

**D. Chen:** The mastering machine for preparing pregrooved media operates in a manner similar to that encountered in servo writing.

**M. Goldberg:** Is format standardization sensible, even if different media were used?

**K. Nolan:** Yes, especially for manufacturers who produce a number of different systems. Format standardization permits common software to be used for different media.

**J. Bray:** Would it be difficult to arrive at a standard sector length?

**Floor and Panel:** Yes!

**K. Nolan:** There could be different sector sizes for the media, but a standard anchor sector might be used to characterize these sectors. An example of this is the case of 8" (inch) floppy disks. Track 0 is always recorded in 128-byte sectors and a volume label on track 0 indicates the size of the sectors on the other tracks.

**J. Dove:** All speakers have been referring only to holes and pits in optical disks as the means of storing information. While that ablative method is the most used, it is not the only way of recording digital and video information. There is the technique of recording information by forming blisters or bubbles on the surface of the media. This technique usually involves a thin metallic surface layer placed on a gas forming sub-layer that forms bubbles when heated by the laser beam. This technique has significant potential as a laser recording method and should be discussed explicitly and separately from ablative recording.

**Panel:** These terms were intended to encompass all technologies.

**M. Capote:** For panel members responses: Where would you begin to standardize if you were the only designer?

**E. LaBudde:** Start with the center hole and the mechanical configuration of the disk. This is important to the manufacturer for tooling purposes, and because of the related learning curve for each size of disk.

**L. Laub:** Examine the video disk standards and build on these.

**Yoshito Tsunoda:** A good point to start with standards would be the direction of disk rotation, then add the coding scheme, sectoring, and addressing.

**Floor:** Support for the suggestion for standardization on the direction of disk rotation was received from those who were concerned with reading both sides of a disk. Since the ability to read both sides adds greatly to the complexity of the drive design, one scheme is to remove the disk and turn it over. This could lead to a requirement for being able to read backwards.

**L. Laub:** It is very difficult to achieve a double-sided reading capability, and this could lower the disk yield. There isn't much user requirement for this.

**Floor:** Two-sided disks are valuable for mapping requirements.

**K. Nolan:** There has been little demand in the marketplace for magnetic "Flippies" which are floppy disks that are turned over to be read on the reverse side.

**D. Chen:** Regarding $OD^3$ data format standardization, it is important to start with a good set of $OD^3$ definitions. Then work on standardizing the data format, addressing the use of spiral or concentric tracks; whether to use pregrooved or servo-written tracks; and the sector size.

**K. Nolan:** To gain perspective on $OD^3$ data format standardization, refer to the architectural hierarchy as it was described in my earlier presentation, **1.2.5, Format Labelling and File Structure Concepts.** A range of requirements exists for various $OD^3$ applications. These differing requirements may result in a number of different standards. For instance, there may be a need for different standards for the "high and low" ends.

**Floor:** The comment was made that users needn't care about mechanical details if the device works well. This was challenged by users who felt a strong need to be involved and to participate in the standardization process.

## 1.3 SESSION III PRESENTATIONS AND DISCUSSIONS - OPTICAL DIGITAL DATA TRANSFER AND COMMAND INTERFACES

### 1.3.1 CHARACTERISTICS OF THE HOST COMPUTER I/O INTERFACE

**By William Burr**
**National Bureau of Standards (NBS)**

Key words: backplane bus; bus; bus structure; device; device interfaces; peripheral bus; subsystem.

#### Introduction

Mr. Burr used a variety of computer configurations to illustrate storage and peripheral device interfaces within computer systems of various sizes. In the typical mainframe computer, the memory controller is the central element of the system and there are often multiple parallel paths to the banks of main memory and to the peripherals **(see fig. 1).**

In the mini or micro multicomputer system, the backplane is the nexus of the system. Various components of the system interface to the backplane bus via Direct Memory Access (DMA) ports **(see fig. 2).** In the small personal computer, the mother board bus is the central interconnecting element **(see fig. 3).**

Where are the opportunities for standards?

#### Memory and Backplane Buses

In the mainframe computers, the memory bus is ruled out as a potential standard, since memory buses are peculiar to each mainframe computer and, individual memory buses do not necessarily connect to all memory modules; it is therefore necessary to work with controllers through peripheral buses. In small systems, the backplane bus is the traditional interface point.

There are many candidate backplane buses **(see fig. 4).** These range from 8 to 64 bits in width and are listed below:

(1) S100 - IEEE 696
(2) VME - IEEE P1014
(3) Versabus - IEEE P970
(4) STD bus - IEEE P961
(5) Multibus - IEEE 796
(6) Unibus
(7) Q bus
(8) Eurobus

Peripheral buses are generally 8 or 16 bits wide **(see fig. 5).**

## Device Interfaces

Device interfaces are specific to the associated devices, and many device characteristics show through the device interface. Devices have a range of capability and are characterized as dumb, semi-intelligent, or intelligent. The architectural levels involved in interfacing a device to a peripheral bus are as follows (starting from the bus): DMA, Control, Formatter, Data Separator, Device. The degree of intelligence in the device determines where in this path the separation occurs between the device and the controller **(see fig. 6).** While device level interfaces are important in magnetic disks, they are difficult for users to deal with, and imply a separation of device and controller, which may not be appropriate in the emerging world of VLSI technology.

## Peripheral Buses

Peripheral buses have a broader usefulness than either backplane or device level interfaces, and are the traditional interface type available on mainframe computers. The FIPS PUB 60-1, I/O Channel Interface is a peripheral bus which offers an excellent opportunity for the optical digital data disk. It has a comparatively high transfer rate, is available in 80 percent of the world's mainframes, has existed for a very long time, and probably will not change substantially for the remainder of the decade. Mr. Burr felt, however, the traditional "count, key, and data" technique described in FIPS PUB 63, Operational Specifications for Rotating Mass Storage Subsystems, a variable block structure, is probably not appropriate for optical disk systems. A fixed block structure is also available and is described in FIPS PUB 97, Operational Specifications for Fixed Block Rotating Mass Storage Subsystems. He strongly urged consideration of a fixed block structure **(see fig. 7).**

In the future, Mr. Burr sees the Intelligent Peripheral Interface (IPI) as a mainstream interface for $OD^3$ systems, which, since it uses a 16-bit transfer path, is basically twice as fast as the I/O channel, and uses half as many signal lines. IPI should soon be an ANSI standard. **See fig. 8.** Another candidate interface for smaller systems is the Small Computer System Interface (SCSI), previously having the proprietary name "SASI" **(see fig. 9).** The SCSI is already used by at least one early optical disk product.

For related terminology, **see table 1.**

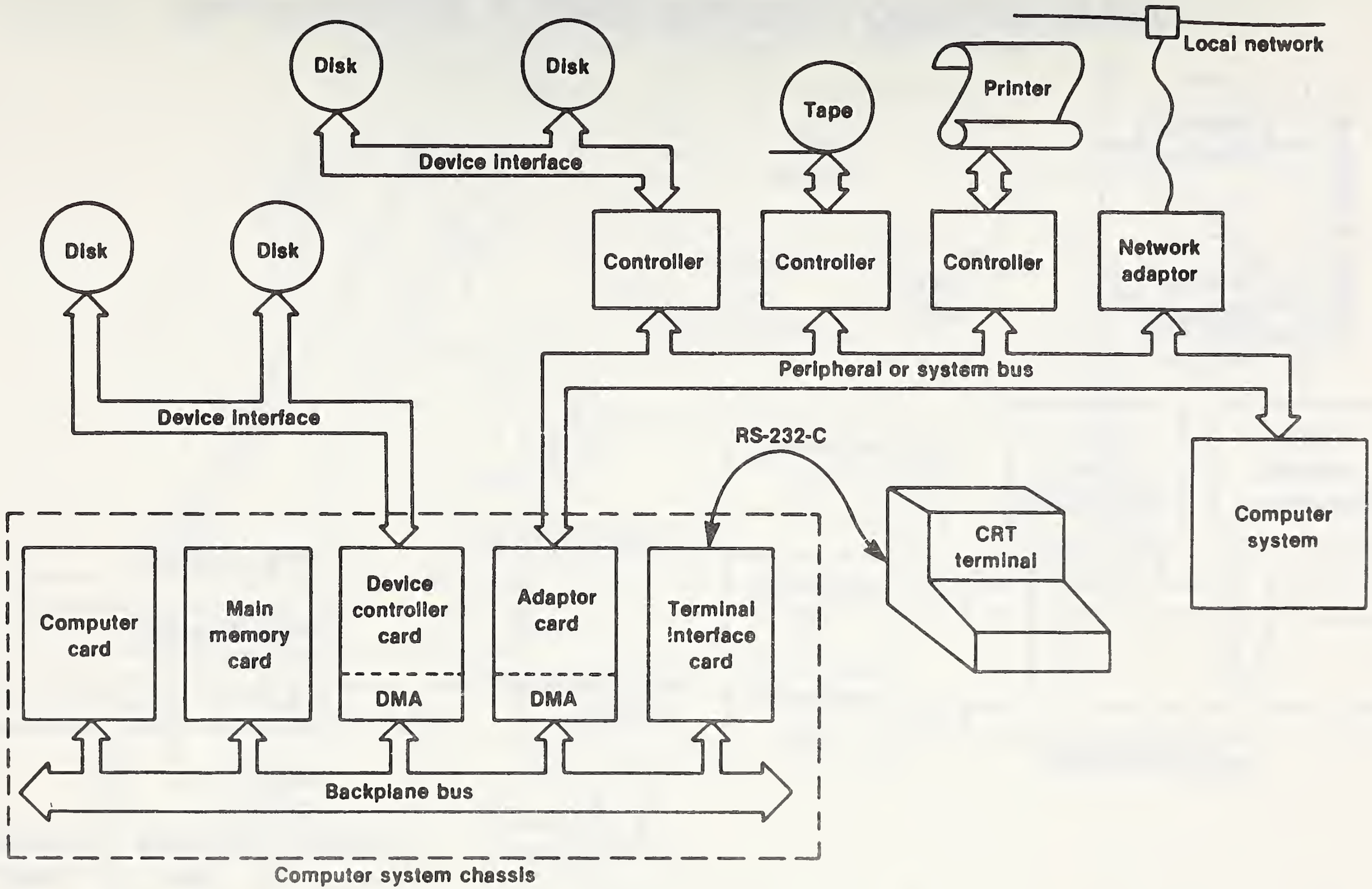



Figure 1. **Bus Structure of a Large Microcomputer or Minicomputer System**

(Burr - National Bureau of Standards)

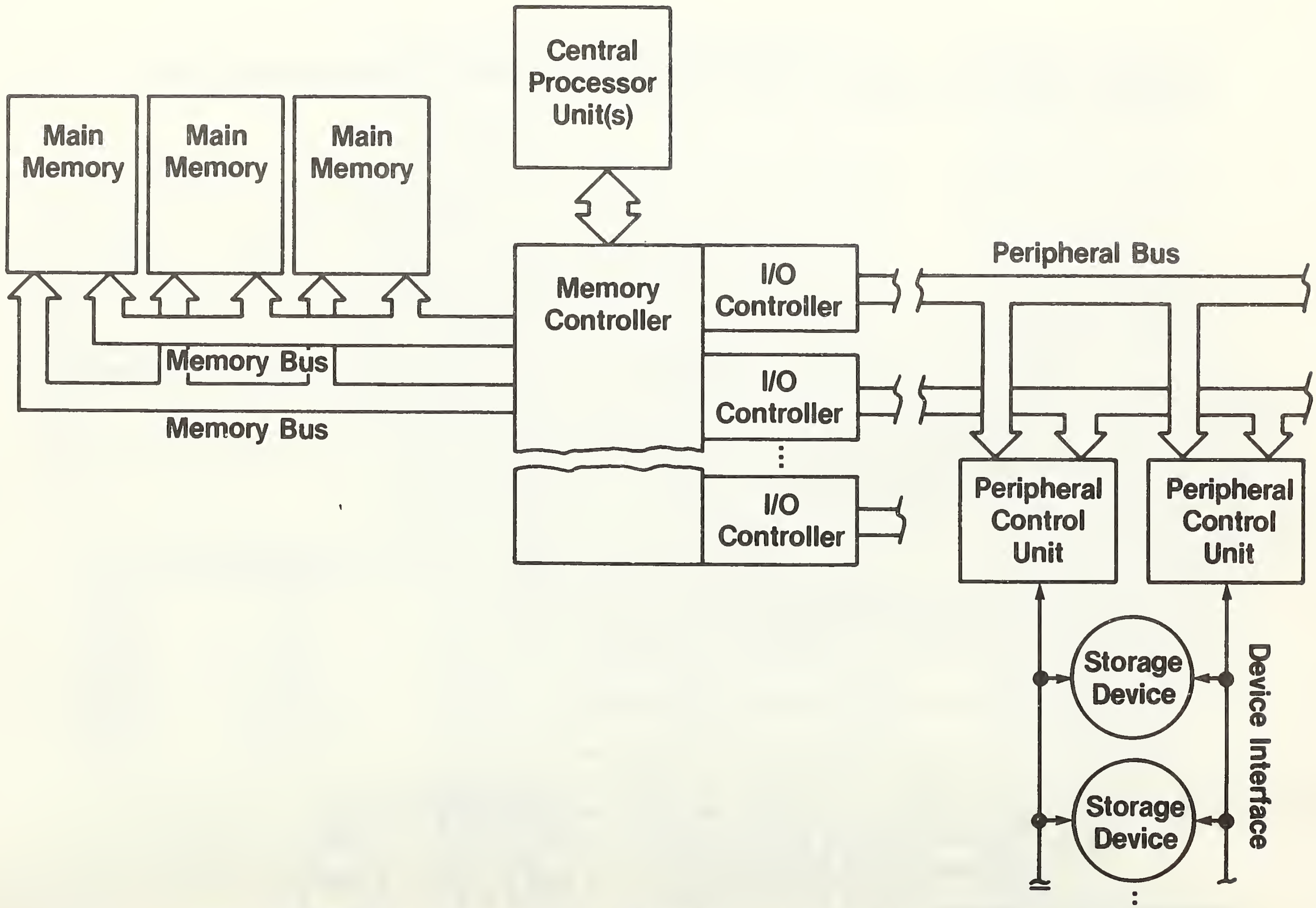



Figure 2. **Bus Structure of a Typical Mainframe Computer System**
(Burr - National Bureau of Standards)

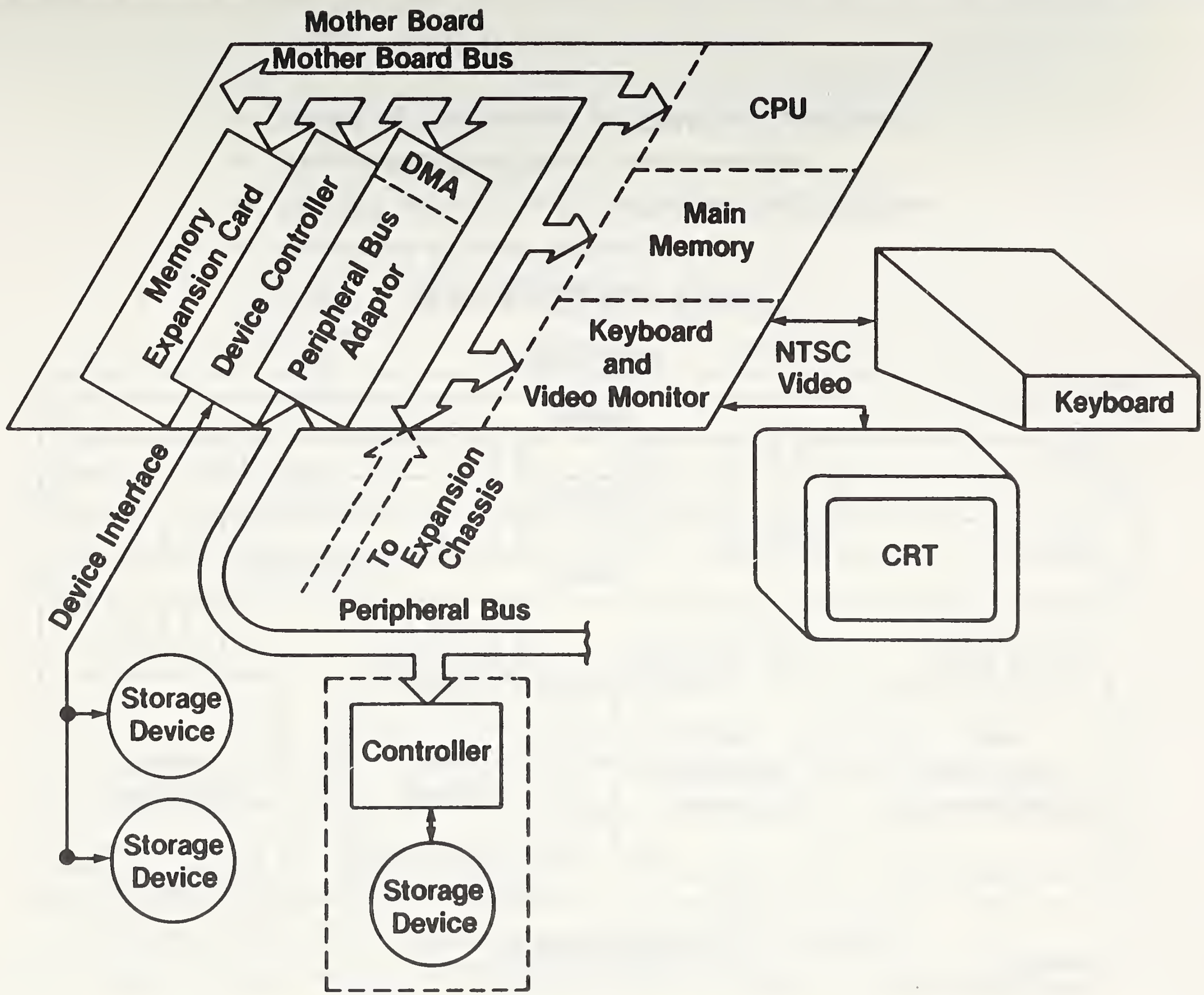



Figure 3. **Bus Structure of a Typical Small Personal Computer**
(Burr - National Bureau of Standards)

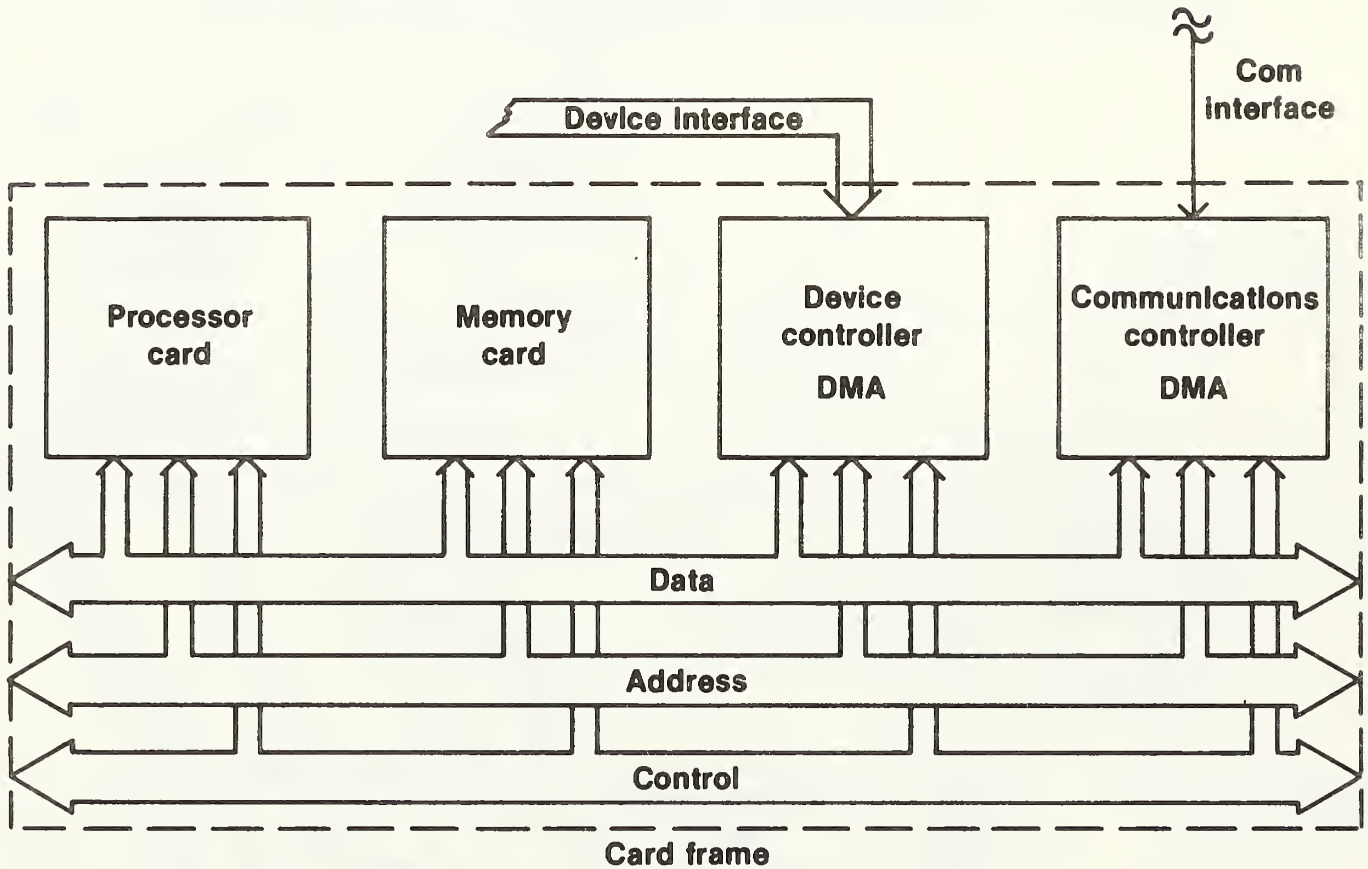



Figure 4. **Backplane Bus**

— Processor to main memory bus
— Permits word by word instruction/data fetches
— Always includes circuit card standard
— Hooks up peripherals via DMA and controller

(Burr - National Bureau of Standards)

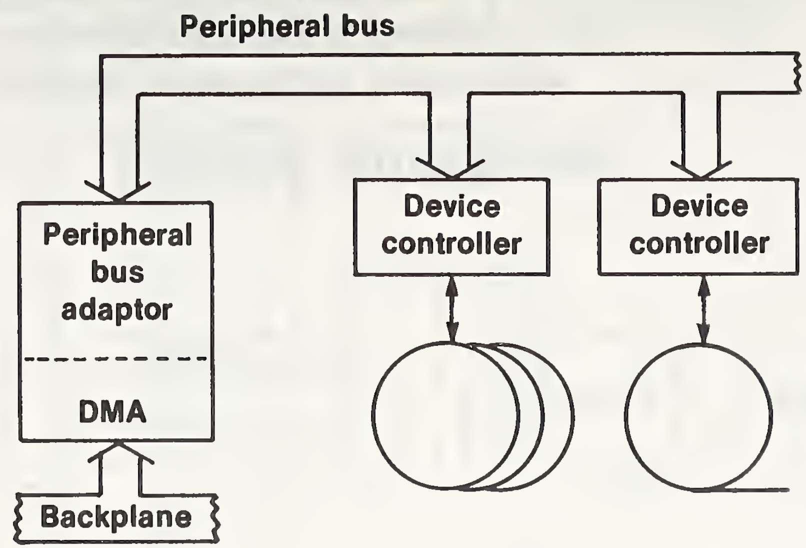



Figure 5. **Peripheral Bus**

(Burr - National Bureau of Standards)

- Connects computer to peripheral controllers of different kinds
- Block transfer rather than word transfer orientation
- No provision for memory address on bus
- Longer distances than backplane
- Interface hides many device characteristics from software
- If peer to peer, multi-master protocol may be called a ''system bus''

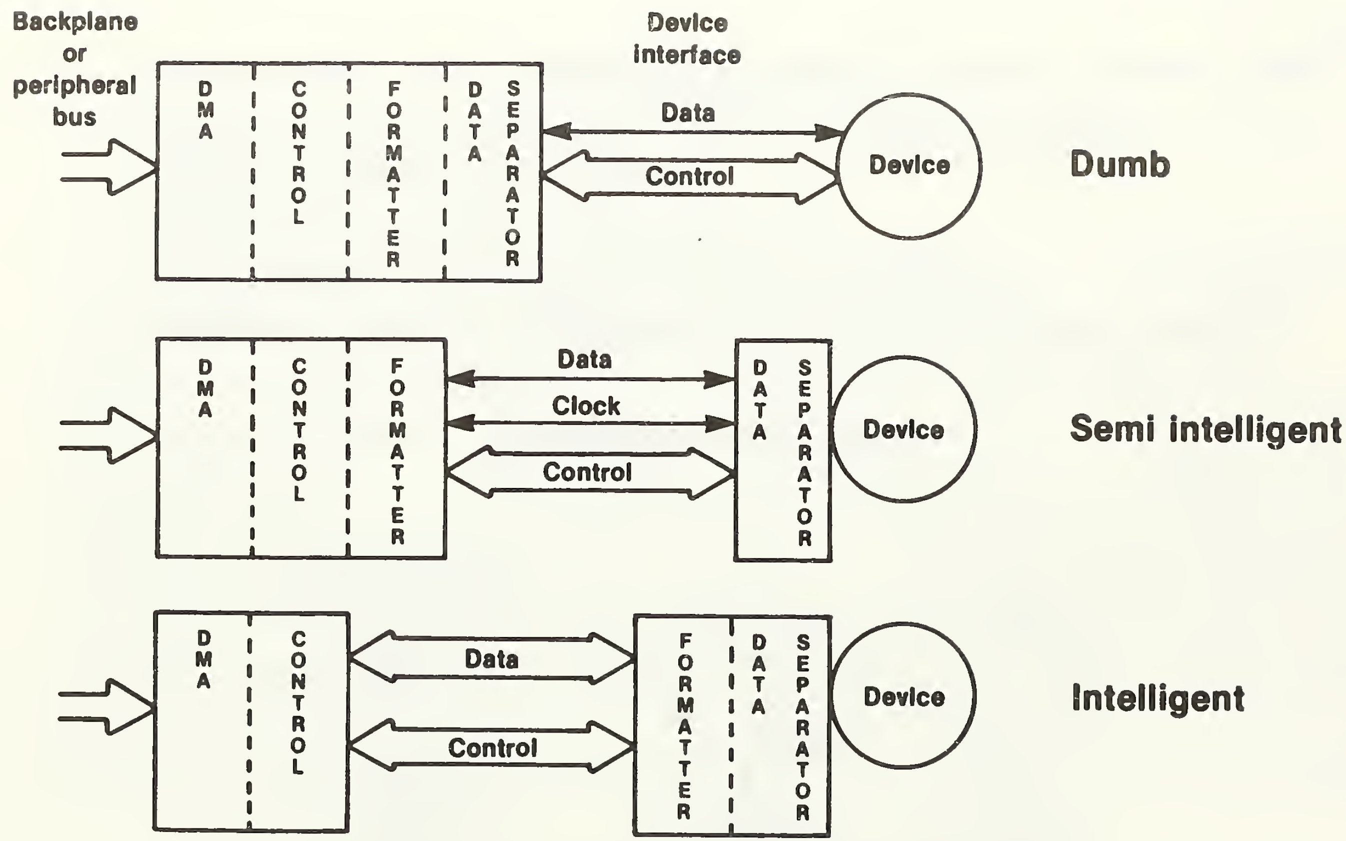
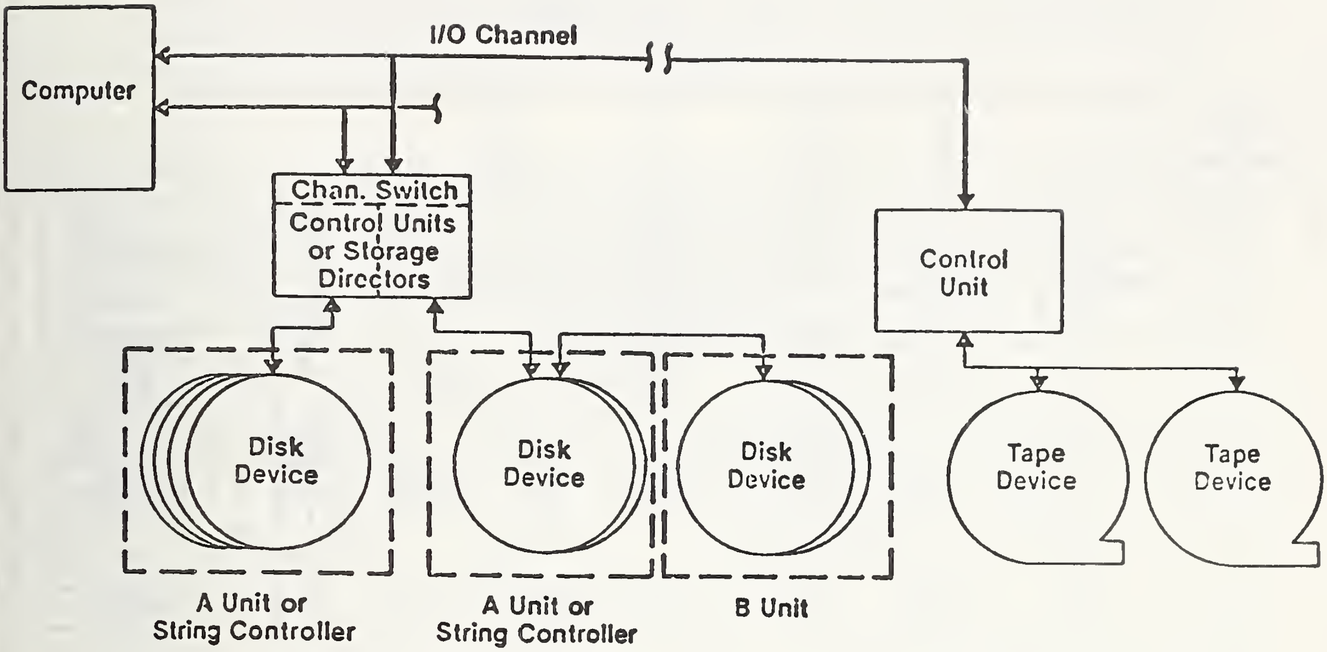



Figure 6. **Device Interfaces**
(Burr - National Bureau of Standards)

- Specific to particular device type
- Between controller & device
- Often serial data transfer
- User device interchangability not always certain
- Very widely used by industry




- Not an ANSI standard, developed by X3T9 but rejected by X3, however has been adopted as a Federal Information Processing Standard (FIPS 60).

- Companion "Operational" specs give Count, Key, and Data command set for disks (FIPS 63) and tape command set (FIPS 62). There also is a companion power control interface (FIPS 61). A fixed block disk command set has been adopted as FIPS PUB 97.

- All signal lines go out from computer or in to computer; there are no bidirectional lines.

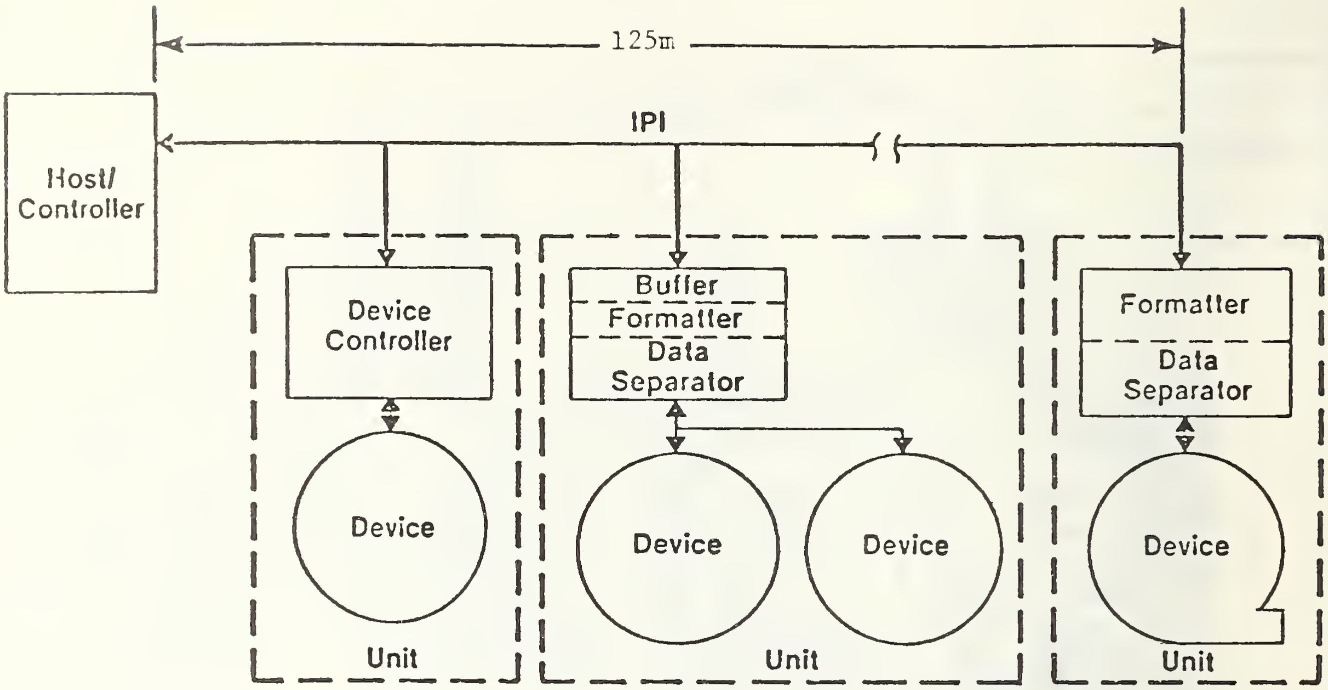
- Single ended open emitter signals.

- With "Data Streaming" feature, can transfer at up to 3 Mbytes/s.

- "Normal" version uses 2 cables, each with twenty-four 92 ohm coaxial lines, and 38 signals.

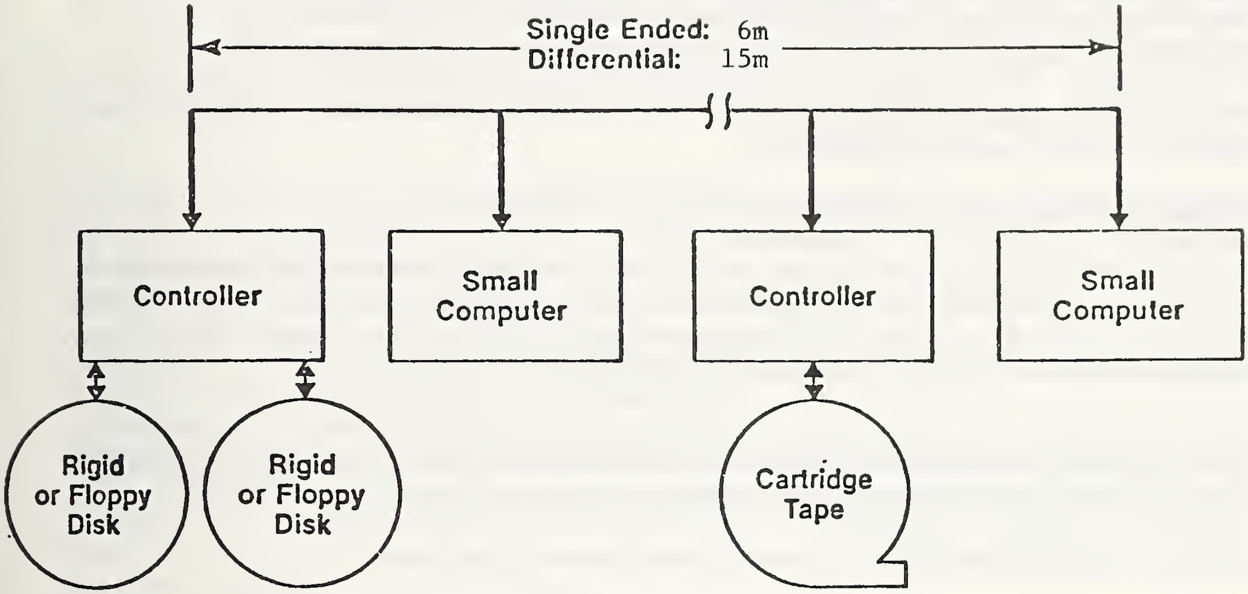
- Lockout chain arbitration of interrupt requests.

**Figure 7.** FIPS 60 I/O Channel Interface
(Burr - National Bureau of Standards)




- Connects host to up to 8 units in master/slave mode.
- Eight or sixteen bit bus for data transfer.
- Two 8-bit buses (in and out) for commands and status speed protocol and status presentation for fast path switching.
- High transfer rate (up to 5 Mbytes/s) over relatively long cables allows use with high performance 14" disks.
- Four proposed electrical/cable configurations, all single ended, with 24 mA tristate and open collector, 100 mA open collector, and 100 mA open emitter drivers and maximum cable lengths of 3, 15, 5, and 125 m (meters).
- 24 Signals
- Central, prioritized arbitration of interrupt requests.
- Includes command sets for common peripherals.

**Figure 8.** Intelligent Peripheral Interface
(Burr - National Bureau of Standards)




- Connects up to 8 computers and peripheral controllers.
- 8 x 8 connectivity
- Max rate up to at least 2 Mbyte/s asynchronous, 5 Mbytes/s synchronous: suitable for floppy disks, all 5-1/4" and 8" winchester disks, medium performance (e.g., SMD) 14" disks, and streaming tapes.
- Relatively high level peripheral command set.
- Single ended version: 50 conductor flat ribbon cable, up to 6 m, 48 mA drivers.
- Differential version: 50 conductor flat or twisted pair cable, up to 15 m, EIA RS-485.
- Distributed bus arbitration
- Includes command sets for common peripherals.

**Figure 9.** Small-Computer System Interface
(Burr - National Bureau of Standards)

Backplane Bus - A bus connecting main memory CPU's, single board computers, other processors, and DMA controllers. Backplane buses make provision for addressing each memory word with each transfer cycle. Backplane bus standards also invariably include mechanical printed circuit board standards as well.

Bus - A linear signal path connected to three or more attachments. Distinct from radial or point-to-point connections.

Computer - The central processor and its main memory.

Control Unit - Presents the I/O bus with a relatively high level logical interface to the storage subsystem and connects to devices through a lower level Device Interface. CU's are typically microprogrammed units and may contain significant amounts of buffer memory. Also called Controller.

Device Interface - A relatively low level interface, usually peculiar to a particular type of device between a control unit and a device. With intelligent peripheral device interfaces, becoming more similar to peripheral buses.

Device - A single storage unit such as a disk drive or tape drive.

Data Encoder - When writing, the data separator combines separate clock and data signals to create a serial pattern of flux reversals which contains both the clock and data, i.e., a "self clocking code."

Data Separator - Data and clock signals are stored together in the form of flux reversals in a magnetic surface. When reading, the data separator breaks the recorded pattern of flux reversals into separate data and clock signals. The data separator may be in either the device or the control unit.

Formatter - Data are ordinarily recorded in a predetermined format typically including gaps, synchronization fields, ID fields (often containing flags for bad recording areas), the data to be stored, and error detecting or correcting codes. The formatter adds these needed fields when writing data and removes them when reading data. The formatter has generally been a control unit function in existing subsystems; however, newer "intelligent" devices may contain the formatter.

Intelligent Peripheral - In the past, the tendency has been to remove most electrical logic from individual devices and put it in a controller. This allowed the expensive logic to be shared between several devices. With the advent of LSI, it is now practical to move some logic formerly in controllers into devices. Very high recording densities require that the data separator be in the drive. At a minimum, intelligent peripherals have the data separator and formatter at the device, and may also have buffering and error detection/correction logic as well as relatively high level command sets.

Table 1. Terminology
(Burr - National Bureau of Standards)

I/O Bus - Connects the computer to peripheral subsystems. In some computer systems, the I/O bus is also a backplane bus (e.g., UNIBUS of the PDP-11) which also connects the processor to its main memory. In other systems, this is a separate bus with a separate memory port (e.g., the FIPS 60 I/O Channel). For the purpose of this discussion, backplane buses, peripheral buses, and system buses may all function as an I/O bus.

Peripheral Bus - A bus which connects a single host/computer to several peripheral devices, with an interface which is broadly applicable to a range of peripherals. Unlike backplane buses, a peripheral bus does not carry memory addresses. Unlike a system bus, a peripheral does not facilitate host-to-host communications.

Subsystem - The combination of a control unit plus one or more attached devices. Synonymous with "unit" in the IPI terminology.

System Bus - A bus which directly connects hosts and peripherals and allows direct host-to-host, host-to-peripheral, and peripheral-to-peripheral transfers. Unlike a backplane bus, a system bus does not carry memory addresses. Unlike a peripheral bus, any bus port can "talk" to any other port thus facilitating host-to-host communications.

Unit - The term "unit" is widely used in various interfaces with rather different meanings. Although unit is not used in FIPS 60, it is in common usage in I/O channel compatible systems to mean a single physical box containing one or more peripheral devices. In the IPI proposal, unit is used to mean the combination of a controller and one or more devices. In the SCSI, a "logical unit" is a peripheral device.

Table 1. Terminology (continued)
(Burr - National Bureau of Standards)

## 1.3.2 OPTICAL DEVICE LEVEL CHARACTERISTICS Which can Help Determine Interface Selection

By Robert Bender
Storage Technology Corporation (STC)

Key words: device control; host computer; interface; optical storage unit (OSU); storage controller.

### Introduction

Mr. Bender began with an illustration showing how a bank of Optical Storage Units (OSU) might interface to a pair of host computers through a pair of storage controllers. The OSU's and controllers would be dual ported in this configuration **(see fig. 1)**. He visualized an interconnection consisting of the host computer, a storage controller, a device control, and the OSU **(see fig. 2)**. The device control would incorporate the intelligence to perform such functions as read/write, ECC, data buffer, band index memory, and band index look-up **(see fig. 3)**.

### Optical Device Characteristics

(1) High density/capacity
(2) Long media storage life
(3) Removable media
(4) Permanent, non-erasable storage
(5) High data reliability
(6) Random access

Mr. Bender felt that $OD^3$ would be most attractive in those applications which require: large file sizes, a moderate rate of data additions, both good random and rapid sequential access, long data retention, and high data integrity. He conjectured that these characteristics would foster the development of a variety of new applications.

Mr. Bender felt that the inclusion of intelligence at the device level would allow for a multiple choice of interfaces, permit direct attachment to a host, and maximize product characteristics.

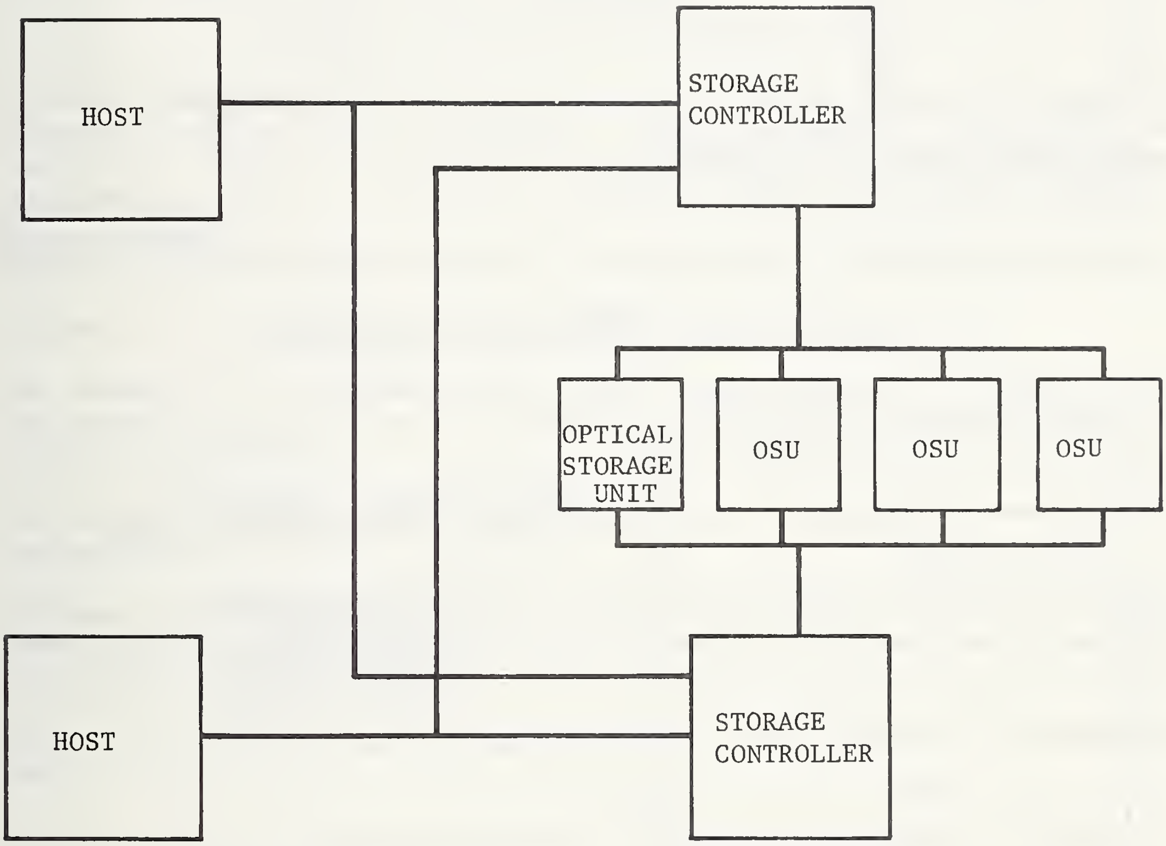
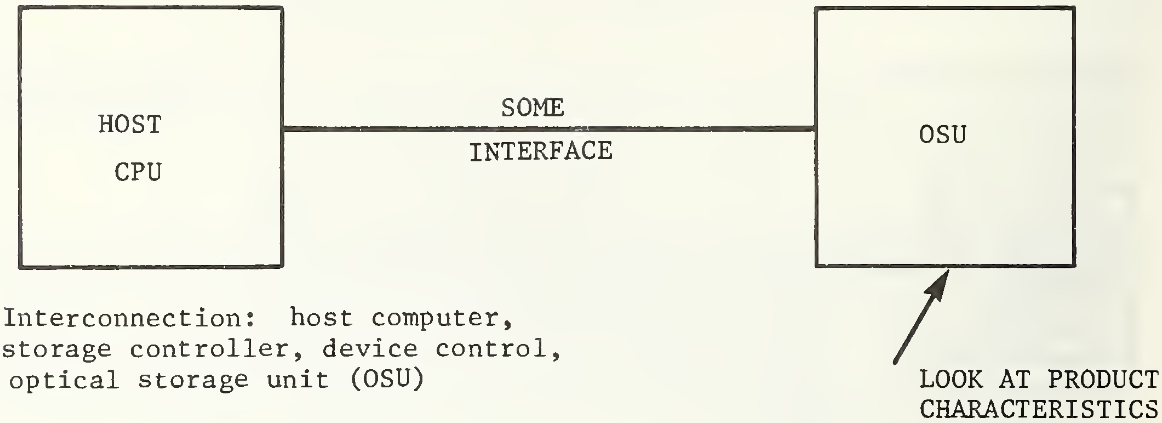



Figure 1. Optical System Configuration
(Bender - Storage Technology Corporation)




Interconnection: host computer, storage controller, device control, optical storage unit (OSU)

Figure 2.
(Bender - Storage Technology Corporation)

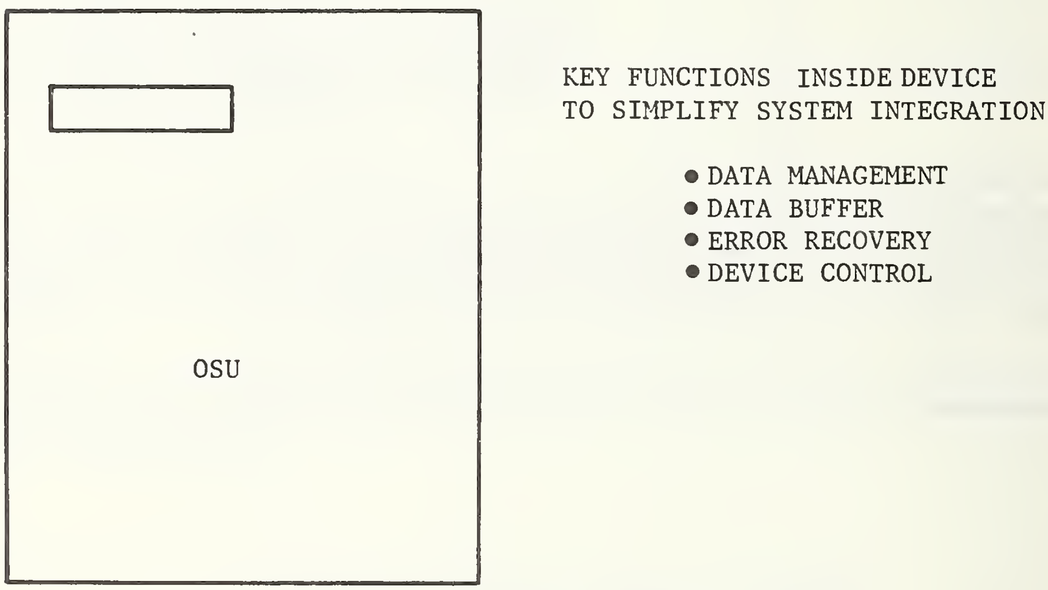



Figure 3. Optical Storage Unit
(Bender - Storage Technology Corporation)

### 1.3.3 Panel Discussion: OD$^3$ Transfer and Command Interfaces

**Panel Participants:**

Robert Bender, Storage Technology Corporation
William Burr, National Bureau of Standards
Leonard Laub, Vision Three, Inc.
Kenneth Nolan, IBM

(These Comments are not Transcribed Verbatim.)

**L. Laub:** A hierarchy of devices would be present. Off-loading device management functions from the CPU is preferable. Storage Technology's VSS product was designed to reduce CPU loading and permit the use of unconventional storage peripherals.

**Floor:** Storage management should be off-loaded, but data management should not.

**R. Bender:** Only a portion of the data management will be in the device.

**M. Goldberg:** Is it important, when using optical disks in a magnetic tape environment, to be backward compatible with the existing magnetic tape data management systems?

**R. Bender:** Optical storage is complementary to magnetic, not a complete replacement.

**K. Nolan:** An effort should be made to treat them (optical and magnetic storage) identically, as far as practical, but deviate as required. This would be influenced by the random access characteristic.

**Floor:** How would the interface requirement for OD$^3$ be affected by the high data rate?

**W. Burr:** CPU's are capable of rates up to 24 megabits per second, which would not be exceeded by OD$^3$.

**Floor:** What is the current status of erasability of OD$^3$?

**K. Nolan:** OD$^3$ erasability is not sufficiently advanced for consideration with regard to standards.

Mr. Nolan portrayed the following architectural structure of a storage control system:

(1) Application
(2) Data Management
(3) I/O Control System
(4) Storage Controller

(5) Device Control
(6) Device
(7) Media

He pointed out that if the data on the media is as self-identifying as possible, then it can most readily be exchanged among systems with varying degrees of sophistication.

## 1.4 Summary: Characteristics of an Optical Media Unit and the Digital Data Channel Interfaces as Related to Drive Performance

By Edward LaBudde
LaBudde Engineering Corporation

Mr. LaBudde reiterated the workshop objectives, namely, to examine technical issues, examine application issues, discuss standards possibilities, and determine directions for $OD^3$ standards. He noted that the workshop participants were drawn from among manufacturers, users, and technical experts and had come to realize that not everyone at the workshop had as much familiarity with $OD^3$ as had been anticipated. Therefore, he briefly reviewed the salient characteristics of $OD^3$ technology.

He stressed the close interrelationship between the media, the optical, and electromechanical aspects of $OD^3$ systems. He noted the recognized need for a disk container. Due to the minuteness of the detail on the disk, positioning cannot be accomplished in an absolute sense but must be done relative to the desired data; therefore, the disk must contain "road maps" to guide the positioning system.

Mr. LaBudde noted that the $OD^3$ technical issues include the cartridge for protection against dust and handling; the physics, the mechanical, and the optical aspects of the disk, the format, whether prerecorded or stamped, and the data channel. These factors have an impact on the $OD^3$ drives, systems, and applications.

The focus of the workshop is primarily on what standards are possible and desirable, and on their impact and their direction. The second and third days of the workshop emphasize this focus on standards.

The issues related to $OD^3$ standardization are complex because of the interrelationships between the cartridge, the disk, the data channel, the system interface, the file structure, and the environment.

According to Mr. LaBudde, a selection method for arriving at the characteristics of $OD^3$ that require standardization, could include the following three categories:

| Type of parameter | Philosophy | Performance |
|---|---|---|
| Number of parameters | Knowledge/Exercisers | Cost |
| Definition | Application | Reliability |
| Verification | | |
| Interrelation | | |
| Tolerances | | |
| Alternatives | | |

## 2. DAY 2: Thursday, June 2, 1983 - APPLICATIONS FOR DIGITAL OPTICAL STORAGE AND TEST METHODS FOR DETERMINING RELATIVE MEDIA & DATA LIFE

### 2.1 SESSION I PRESENTATIONS AND DISCUSSION - APPLICATIONS FOR DIGITAL OPTICAL STORAGE TECHNOLOGIES

#### 2.1.1 A LARGE CAPACITY MASS STORAGE SYSTEM (MSS) At the National Center for Atmospheric Research (NCAR)

**By Bernard O'Lear**
**NCAR**

Key words: mass storage system (MSS), network MSS node.

Introduction

Mr. O'Lear outlined his topics for discussion as follows:

(1) Characteristics of the TBM* system
(2) A Possible Future NCAR MSS
(3) Early stages of the next MSS
(4) Other MSS considerations
(5) MSS expectations

Mr. O'Lear noted that the NCAR computing center exists to support the computing requirements of the nation's atmospheric research community.

He then proceeded to describe the present TBM system and the proposed transition to a next generation MSS.

TBM System

The characteristics of the present TBM system are summarized below:

(1) 23-42, $10^9$ bit tapes mounted
(2) $0.8 \times 10^{12}$ bits of on-line storage
(3) 31,000 accesses per month (read and write)
(4) 1,250 accesses per day, on a peak day (growing)
(5) $1 \times 10^8$ bits average access dataset size
(6) 0.5 x 109 bits of new data written per day
(7) $1 \times 10^{11}$ bits average data flow per day between disks, tapes, and TBM
(8) $13 \times 10^{12}$ bits held by TBM in May 1983 (up from $3 \times 10^{12}$ in January 1980)
(9) $3 \times 10^6$ dollars spent for hardware
(10) $2.5 \times 10^5$ dollars spent for Ampex maintenance per annum

*TBM (Terabit Memory) is a registered trademark of the Ampex Corporation.

(11) NCAR personnel:
   (a) 2 systems programmers
   (b) 1 MSS librarian

## TBM Services

Among the services provided by the TBM are connections to two Cray-1A's, servicing of other nodes, and a repository for various data types, including archived weather data, mathematical model data, and program files **(see table 1 and figs. 1 and 2).** Mr. O'Lear showed the existing and proposed NCAR Network Configuration **(see figs. 3 and 4).** They expect to add NSC adapters and will have two file transport trunks, one trunk for peripheral devices, and one trunk for a special software package called Data Management Support Package (DMSP). Other plans include the addition of an advanced vector computer. **See fig. 5** for a schematic of a possible NCAR MSS (Mass Storage System).

## A Possible Future NCAR MSS

The transition to a next generation MSS (Phase 1) at NCAR could include installation of the new system using NSC HYPERchannel,* a dual connection utilizing a Cray-1A and IBM 4341. Extensive testing and software development will follow.

The transition to a subsequent generation MSS (Phase 2) at NCAR was described by Mr. O'Lear as: building the MSS "node" including the master file directory software, network access software, and utility software.

The early stages of the next MSS installation at NCAR would initiate building other software, such as node and network software: network high-level file transport JCL and network file transport monitor.

Mr. O'Lear called attention to other MSS considerations, including the longevity of data, noting that it outlasts both the creator of the data and the computer system that created it. Nineteen percent of bits stored at NCAR are read or written each month; 46 percent (total bits) are moved for backup and verification; and 35 percent (total bits) are moved for compress-purge of old files.

Data conversion and data archive planning for various current and future systems and processes are a major activity at NCAR.

## MSS Expectations

The expectations for a future MSS are a data flow of $10^{12}$ bits per day, a data collection of $10^{14}$ to $10^{15}$ bits, and a data flow rate of $5 \times 10^7$ bits per second. The MSS archive expectations progress from $3 \times 10^{12}$ bits in 1980 to $305 \times 10^{12}$ in 1993 **(see table 2).** The data flow rate over that period will progress from $0.5 \times 10^6$ bits per second to $21.2 \times 10^6$ bits per second **(see table 3).** An on-line storage requirement of $10^{12}$ to $10^{13}$ bits will exist in the 1985-1987 time frame, growing to as much as $10^{16}$ bits in the late 1980's to early 1990's. A media life of 2,000

*HYPERchannel is a registered trademark of the Network Systems Corporation.

retrieval/load/read/unload/replace cycles is required, with a cost goal of $.015 per $10^6$ bits of information. The unrecoverable bit error rate should not exceed 1 failure in $10^{11}$ bits. Therefore, for physical records consisting of $10^6$ bits, no more than one record in 100,000 records should fail **(see tables 4 and 5).**

## Discussion and Conclusion

Mark Goldberg who moderated the panel discussions in this session, entitled "Applications for Digital Optical Storage Technologies," noted that this session presented an opportunity for users to express themselves, and that the panel included individuals who could help assess the impacts of a particular user's requirements on the $OD^3$ system designs and the related standards.

**Panel Participants:** Di Chen, Optical Peripherals Laboratory; Mark Goldberg, NSA (Moderator); Edward LaBudde, LaBudde Engineering Corp.; Leonard Laub, Vision 3.

Mr. LaBudde noted that the NCAR application was well suited to optical disks, in that it required high capacity, relatively modest transfer rates, and a reasonable data access rate. The file usage exhibits a low duty cycle, lending itself to the loading and unloading of disks on spindles. He also noted that the key requirement with regard to standards is for media interchangeability among spindles.

Mr. O'Lear remarked that they mail out data sets (disks) to customers around the country and therefore would benefit from media transportability/compatibility.

| | CRAY-1 | CDC 7600 | TMS-4 |
|---|---|---|---|
| **Operational Software** | | | |
| Request Function | | | |
| User Level | 6500A* | 18500A | 0 |
| System Level | 550A | 4000A | 13000A |
| Directory Function | 0 | 0 | 5200A |
| Work Manager Function | 0 | 0 | 20000A |
| MSD Controller Function | 0 | 0 | 39600A |
| I/O Function | 1450A | 3000A | 5200A |
| **Support Software** | | | |
| MOVE/COPY and COMPRESS | 0 | 0 | 2100A |
| Directory Maintenance | 0 | 4500H† | 2500A |
| Diagnostics | 1700A | 2500A | 1500A |
| OPERATING SYSTEM | | | 17000A |
| | 10,200A | 28,000A<br>4,500H | 106,100A |

* = Assembly
† = High Level

Table 1
(O'Lear - National Center for Atmospheric Research)

TOTAL VSNs ON THE TMS-4 SYSTEM AND TOTAL BITS MOVED BETWEEN THE 7600, CRAY AND TMS-4 (total of bits read and written)

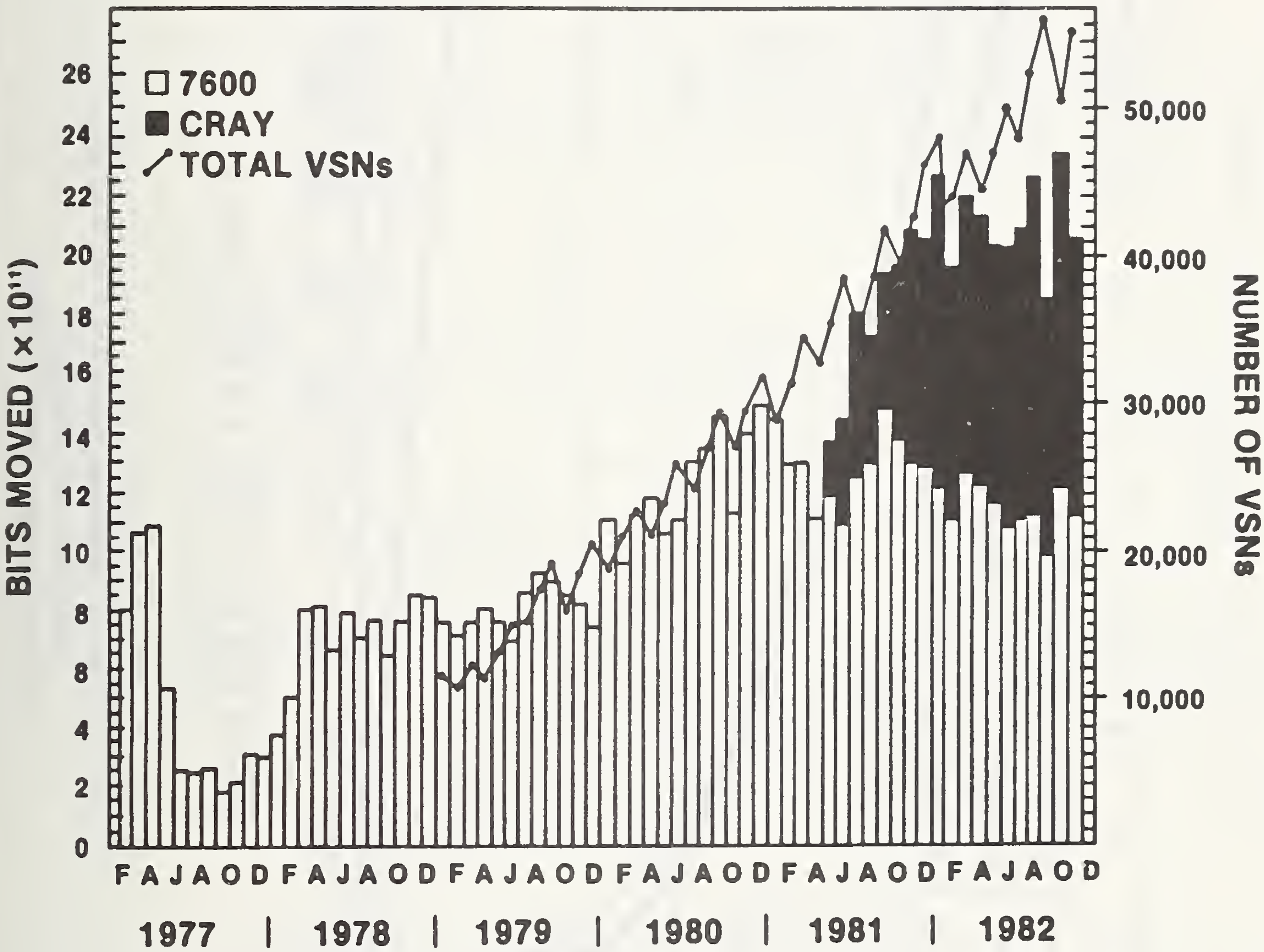



Figure 1.
(O'Lear - National Center for Atmospheric Research)

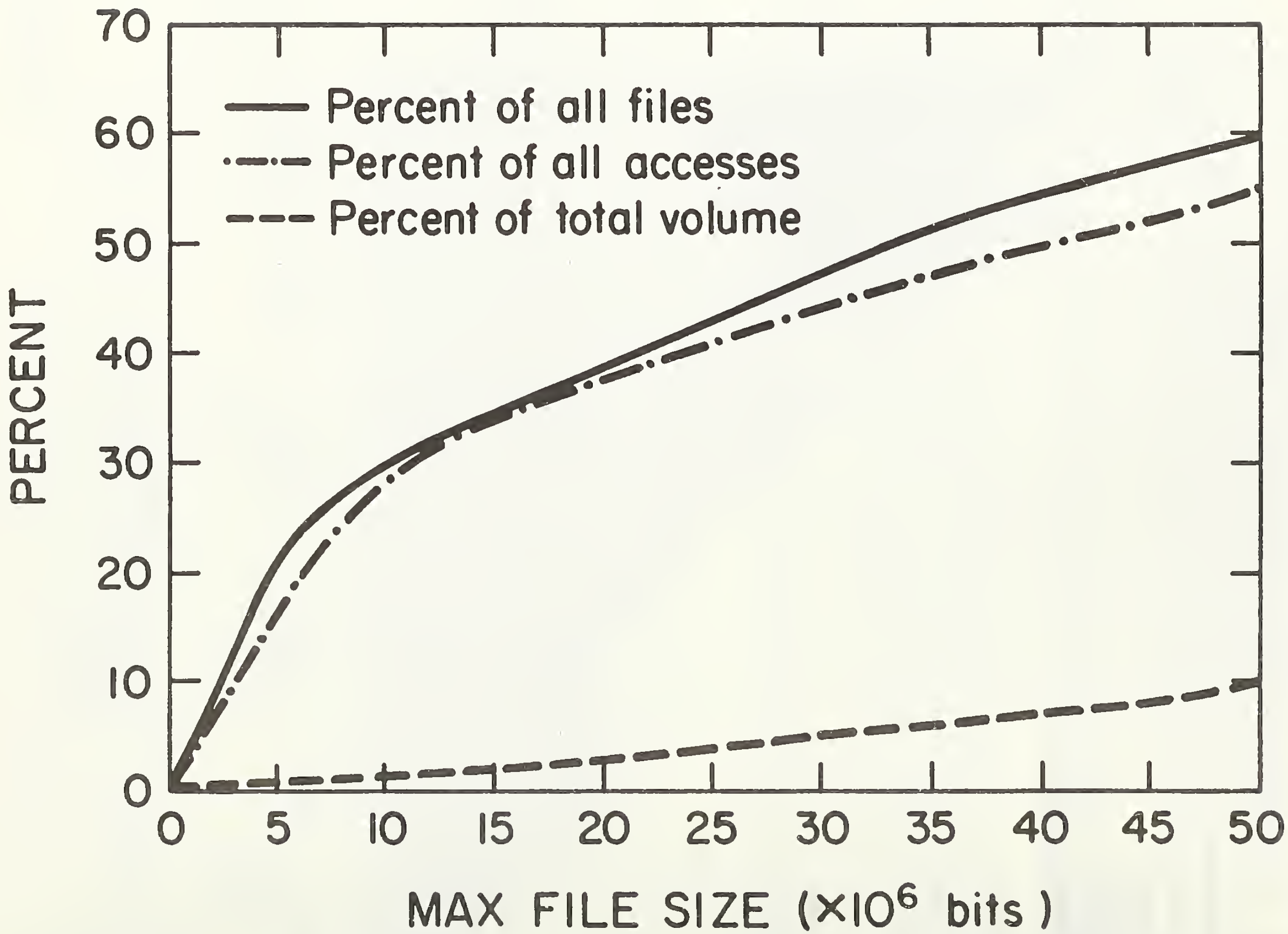



Figure 2.
(O'Lear - National Center for Atmospheric Research)

NCAR NETWORK CONFIGURATION
EXISTING AND PROPOSED
(September 1981)

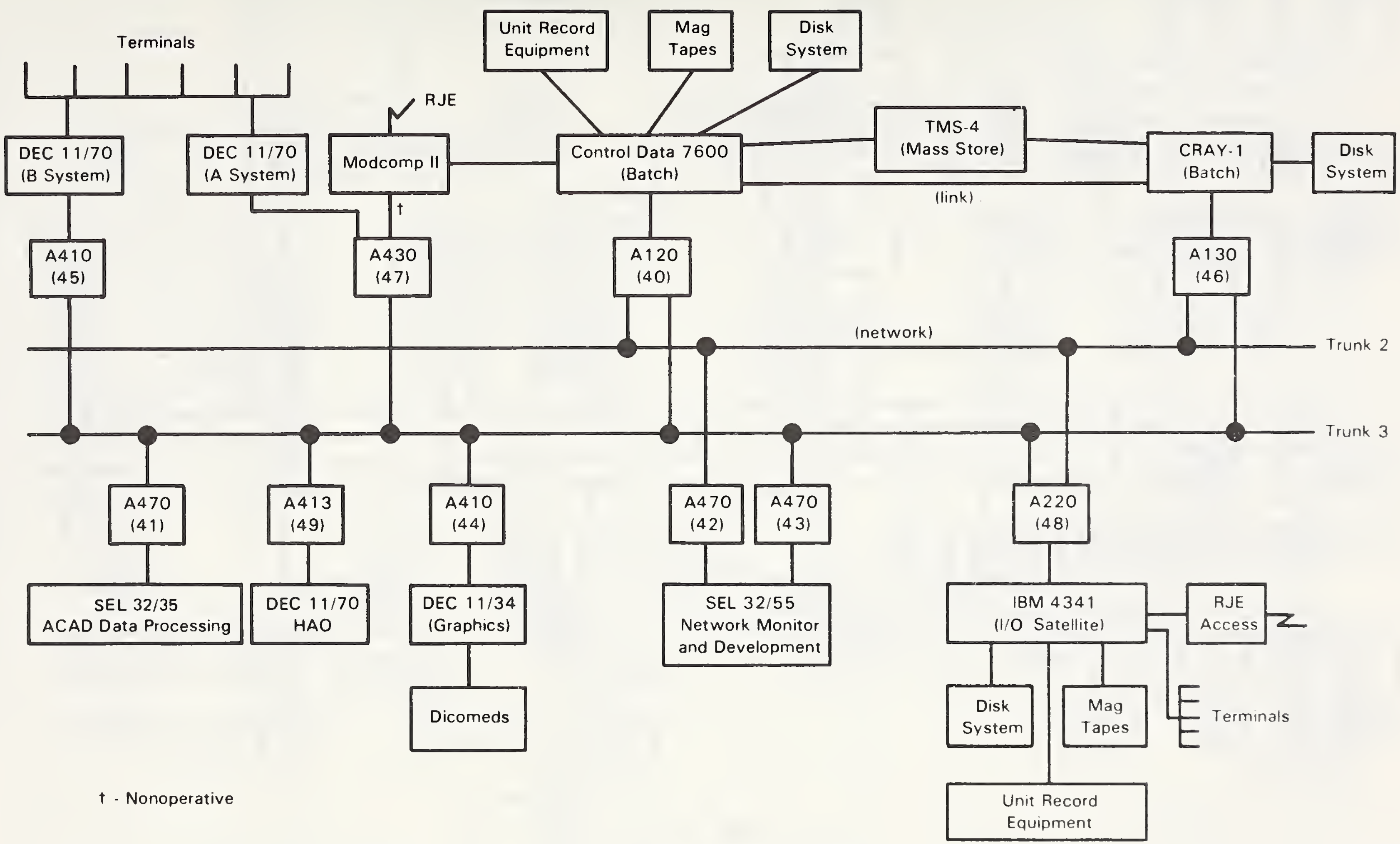



Figure 3.
(O'Lear - National Center for Atmospheric Research)

## NCAR NETWORK CONFIGURATION EXISTING AND PROPOSED

July 1983

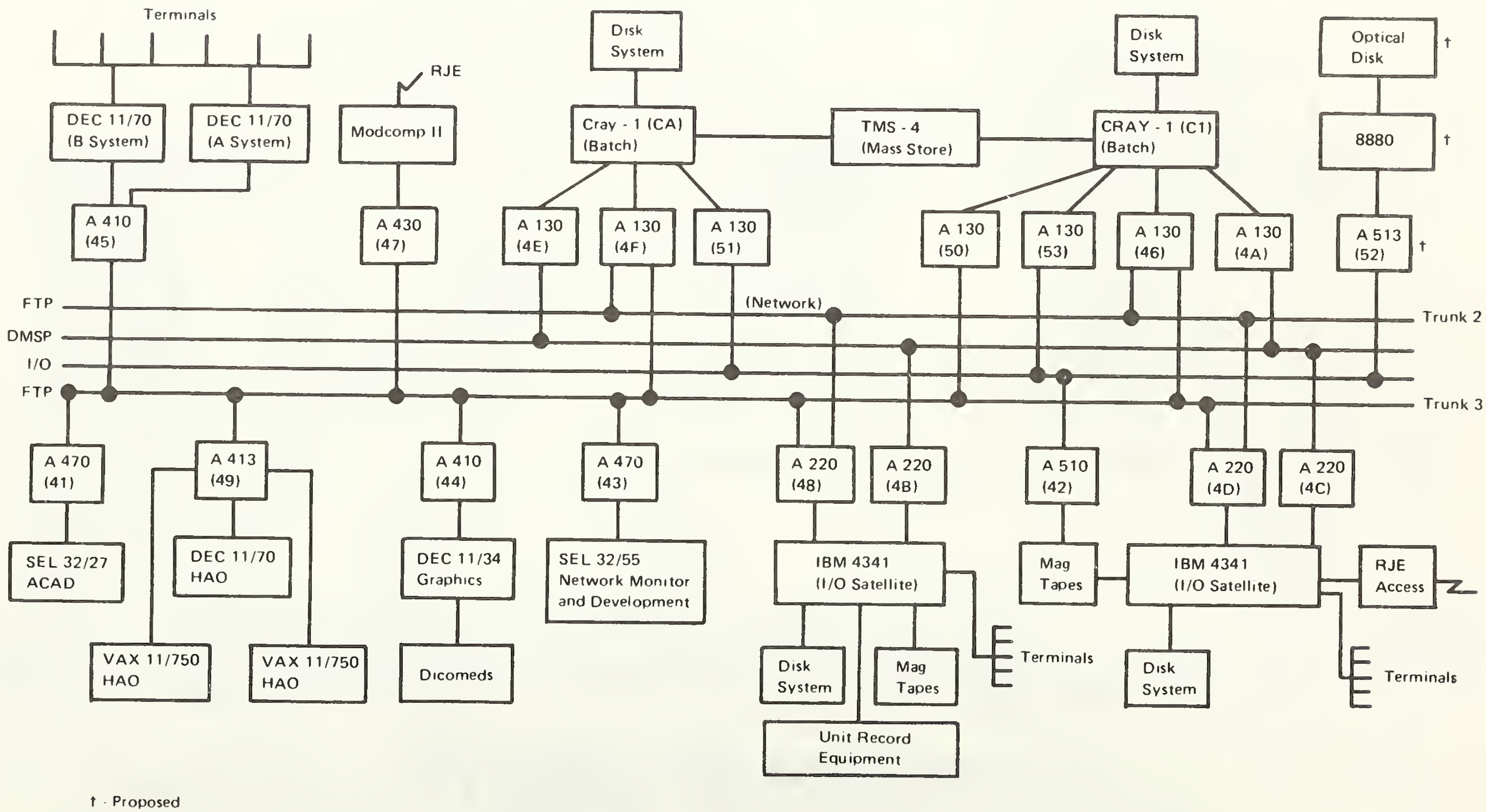
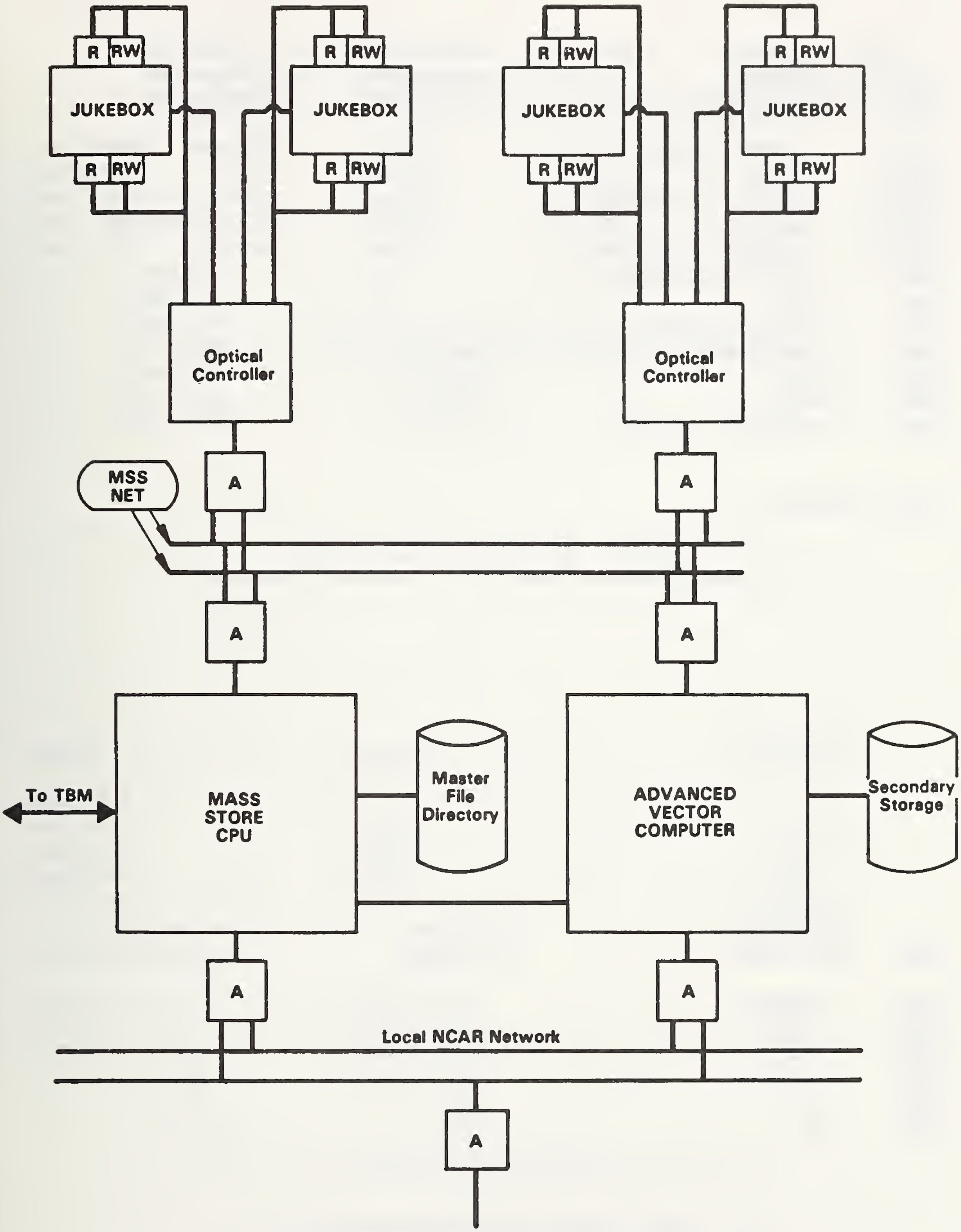



Figure 4.
(O'Lear - National Center for Atmospheric Research)




**A POSSIBLE NCAR ODMSS**

Figure 5.
(O'Lear - National Center for Atmospheric Research)

| Year | NCAR Compute Power | Net Rate of Archiving Data ($10^{12}$ bits/yr) | Data In Archive ($10^{12}$ bits) |
|---|---|---|---|
| 1966 | .3 (CDC 6600) | | (at end of year) |
| 1968 | .6 | E.08 | |
| 1971 | 3.3 (add CDC 7600) | | |
| 1976 | 3.0 | E.27 | 1.5 (tapes) |
| 1978 | 8.3 (add Cray-1A) | | |
| 1980 | 11.6 (Cray efficient) | 3.3 | 3.0 (MS*) |
| 1982 | 11.6 | 3.3 | 10.0 (MS) |
| 1984 | 20.0 (2 Cray's) | 5.7 | 20.0 (MS) |
| 1986 | 70.0 (Add AVC) | (19.9) 19.0 | 45.0 (MS) |
| 1987 | 100.0 | (28.4) 24.0 | 69.0 (MS) |
| 1992 | 100.0 | (28.4) 32.0 | 214.0 (MS) |
| 1993 | 400.0 (new machine) | (114.3) 90.0 | 305.0 (MS) |

*MS = Mass Store

Table 2. MSS Archive Expectations
(O'Lear - National Center for Atmospheric Research)

| Year | Net Rate of Archiving ($10^{12}$ Bits) | User Bits $10^{12}$/Year | Aver. Bit Rate $10^6$/Sec. |
|---|---|---|---|
| 1980 | 3.3/Yr | 15 | .5 |
| 1983 | 4.0 | 31 | 1.0 |
| 1984 | 5.7 | 44 | 1.4 |
| 1986 | 19. | 143 | 4.5 |
| 1987 | 24. | 182 | 5.8 |
| 1993 | 90. | 670 | 21.2 |

Table 3. MSS Data Rate Expectations
(O'Lear - National Center for Atmospheric Research)

| | No. Archive Datasets | Accesses/Mo. If Linear With Sets | Estimated Actual Accesses/Mo. | Average Accesses Per Hour | Peak Accesses Per Hour |
|---|---|---|---|---|---|
| Dec. 1982 | 58,000 | 22,600 | 22,600 | 30.9 | 309 |
| Dec. 1984 | 116,000 | 45,200 | 40,000 | 55.0 | 550 |
| Dec. 1986 | 261,000 | 108,300 | 130,000 | 178.0 | 1780 |
| Dec. 1987 | 400,000 | 155,900 | 165,000 | 226.0 | 2260 |
| Dec. 1993 | 1,769,000 | 689,000 | 610,000 | 834.0 | 8340 |

Table 4. Expectations (continued)
(O'Lear - National Center for Atmospheric Research)

| Actual | Datasets | Rate of Adding Datasets |
|---|---|---|
| Feb. 1977 | 0 | |
| Oct. 1978 | 9,300 | 7,000/Yr |
| Aug. 1979 | 15,000 | 10,000 |
| Aug. 1980 | 27,000 | 12,000 |
| Dec. 1982 | 58,000 | 15,000 |
| Projection | | |
| Dec. 1984 | 116,000 | 26,000 |
| Dec. 1986 | 261,000 | 86,000 |
| Dec. 1987 | 400,000 | 109,000 |
| Dec. 1993 | 1,769,000 | 409,000 |

Table 5. MSS Dataset
(O'Lear - National Center for Atmospheric Research)

## 2.1.2 A MODERATE CAPACITY MASS STORAGE SYSTEM (MSS)

**By Paul Allison**
**U.S. Army Materiel Development and Readiness Command**

Key words: aperture card scanner; CAD/CAM; graphics terminal; printer (high speed); plotter.

### Introduction

Mr. Allison described the emerging Digital Storage Retrieval Engineering Data System (DSREDS). According to Allison, "DSREDS" is a state-of-the-art system for digital storage, update, retrieval, dissemination, and duplication of engineering drawings and documentation.

### The DSREDS System

DSREDS is being developed by the U.S. Army Materiel Development and Readiness Command (DARCOM). DSREDS will store and provide access to a large and growing quantity of engineering drawings **(see fig. 1)**. The standard system will scan and digitize drawings which are currently on hard copy and aperture cards. Future drawings can be accepted electronically in digital form directly from weapon system contractors. Digitized drawings will be verified for quality and integrity, processed by a system controller and permanently stored on optical disk. When needed, they will be retrieved and output as aperture cards, provided as hard copy, or transmitted to remote graphics terminals for review and verification. DARCOM presently has 4.2 million aperture cards, containing 35 mm film images of engineering drawings. Without new storage technology, the current system capacity will be insufficient by 1986. The number of drawings are expected to approach 14 million by the end of this century **(see figs. 2 and 3)**. Much of the present equipment incorporates the early 60's technology, and it is feared that an irreparable breakdown of the system could occur in the next two or three years **(see fig. 4)**. The current system relies on mail and courier systems for transferring drawings among subordinate commands and other activities. Preparation of technical data packages is presently slow and inefficient.

DARCOM's technical data mission is to maintain archival drawings and technical documents, to assemble technical data packages for procurement, and to provide technical data support to engineering personnel.

The technical data mission is supported by technical data/configuration management systems and archival drawing/document storage and retrieval systems, including Mosler/Infodetics automated aperture card systems, Dare automated film chip system, and hard copy/mylar manual systems.

The equipment currently being used by DARCOM for this production has the following problems:

(1) It is based on early 60's technology.

(2) Some of this equipment is no longer supportable, with replacement parts becoming scarcer.
(3) Its maintenance costs are increasing 10-15 percent per year, as the older units are becoming increasingly less reliable.

The future plans include the scanning and digitization of all drawings which are currently in hard copy or aperture cards. Future drawings will be accepted electronically in digital form, directly from contractors, and will be stored on optical disks. They can then be output as needed on aperture cards, hard copy, or transmitted to remote graphics terminals for editing and subsequent storage. Design goals are for a peak input rate of 2,500 drawings per hour and a peak output rate of 9,600 per hour. Repositories at seven sites are planned, for redundancy.

## DSREDS Requirements

DSREDS requirements are summarized as follows **(see fig. 5):**

(a) Optical disk-based mass memory - stores 2 x $10^6$ expandable to 4 x $10^6$ digitized engineering drawings and documents averaging 1 x $10^6$ bits of data each.
(b) Optical read only - accepts manual load of disks from mass storage unit.
(c) Process controller - controls all system component functions.
(d) High speed printer - prints 1000 lines per minute on 378 mm (14.875 in) by 279 mm (11 in) paper.
(e) Magnetic tape storage - provides for dual-density 9-track digital magnetic tape recording and reproducing.
(f) Magnetic disk storage - provides for data management and temporary storage of digitized data.
(g) Master control operator console - provides for dialogue between the system operator and the DSREDS system. Provides hard copy output.
(h) Data integrity control - provides for data file analysis for document validation prior to commitment to permanent file.
(i) Data compression/decompression - compresses data for optimum storage and decompresses data for output to peripheral devices.
(j) Communications - permits interaction between process controller and a variety of external devices.
(k) Plotter - provides A-K engineering drawing hard copy with resolution equal to the original; accepts raster and IGES data.
(l) Aperture card scanner/duplicator - scans at 240 cards per hour with 8 points per mm (200 points per in) resolution.
(m) A-K drawing scanner/duplicator - scans D size drawing in 3 minutes with 200 points per inch resolution.
(n) Computer output microfilm - images digitized data with 8 points per mm (200 points per in) resolution.
(o) Aperture card output - contact prints negative silver roll microfilm to 35 mm diazo cards at 2500 cards per hour.
(p) Aperture card duplicator - reproduces/interprets 9,600 cards per hour.
(q) Graphics terminal - displays complete E size drawing with 1700 x 2200 pixels resolution; accepts raster and Initial Graphics Exchange Specification (IGES) data; provides hard copy output.
(r) Alphanumeric terminal - provides 16 inch screen with optional hard copy output.

## DSREDS Benefits

Anticipated benefits of the DSREDS system include the following:

(a) Capacity for projected increase in engineering drawings.
(b) Reduction of administrative lead time (ALT).
(c) Reduced maintenance costs/downtime.
(d) Disk storage at multiple sites for continuity of operations.
(e) Transmit drawings electronically.
(f) Drawings can be viewed electronically at remote sites.
(g) Less space requirements.
(h) Transmit technical data packages (TDP) electronically to contractors.
(i) Interface with CAD/CAM systems.
(j) Improved productivity for engineering changes.
(k) Transmit engineering change proposals.

## Conclusion

In summary, optical disk technology can avoid total system breakdown, by replacing aging systems and accommodate the increasing drawing storage needs in the mid and long term. According to P. Allison, the DSREDS acquisition program is cost effective and can pay back hardware/software costs in under 2 years.

## Discussion

Mr. Laub called attention to the possibility of storing digital data from a CAD/CAM process, rather that fully digitized images. This is a highly compressed representation of such data. He also foresaw the need for automated cartridge handling. He did not anticipate any unusual standards requirements for this (U.S. Army) application of $OD^3$.

He noted that there was a recognized need for transportable media which could be used for sending stored images to remote sites.

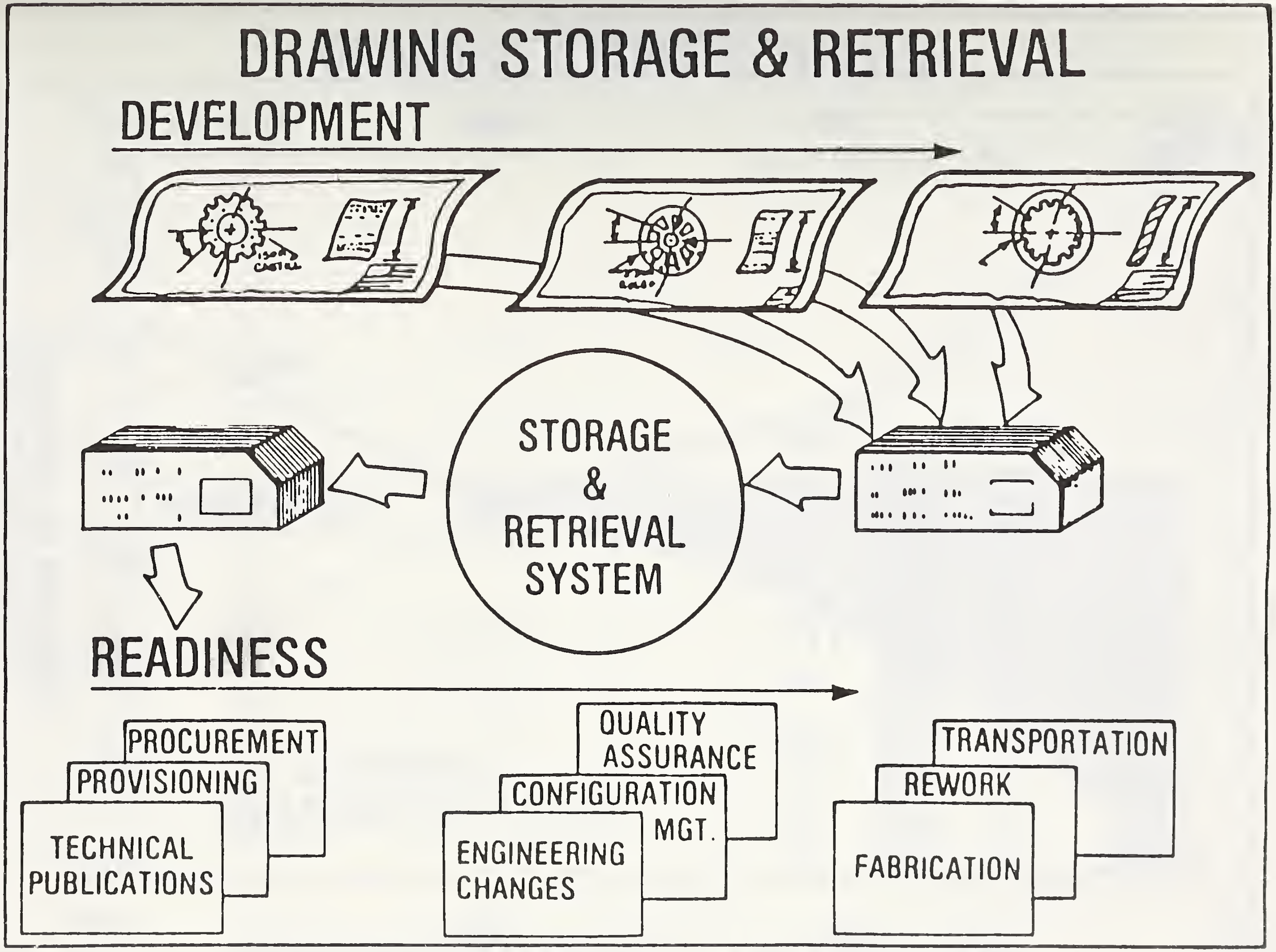



Figure 1.
(Allison - U.S. Army Materiel Development and Readiness Command)

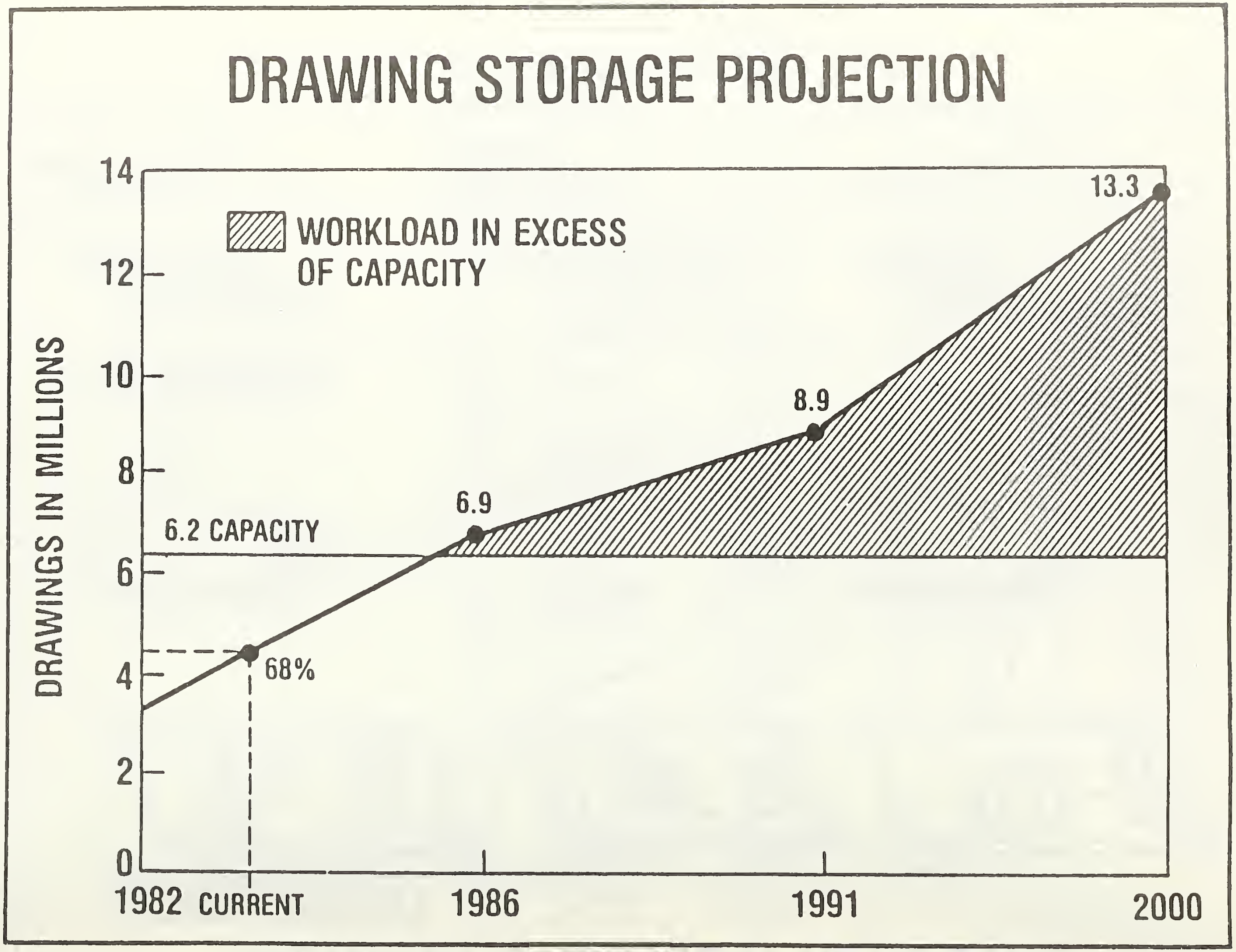



Figure 2.
(Allison - U.S. Army Materiel Development
and Readiness Command)

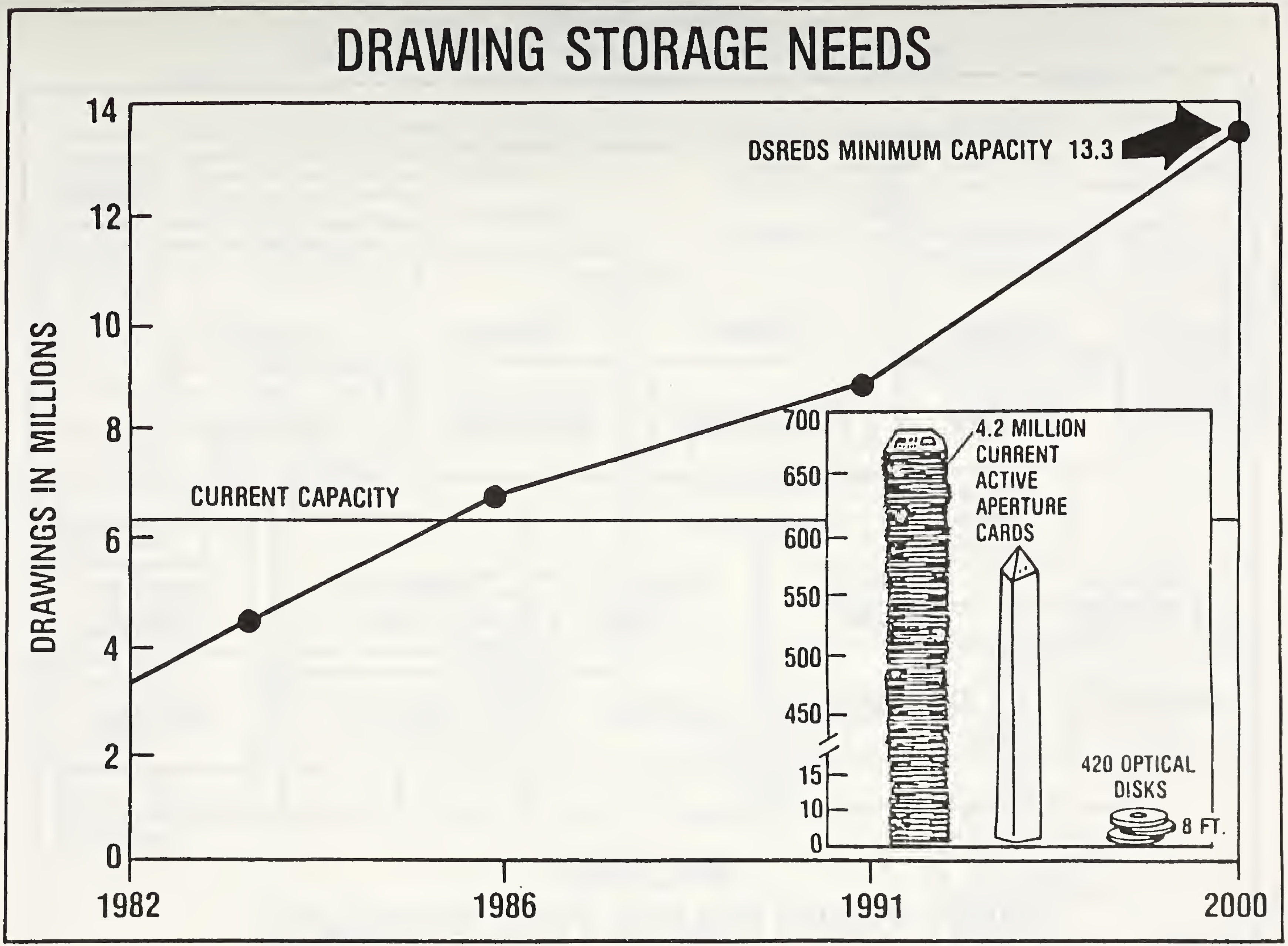
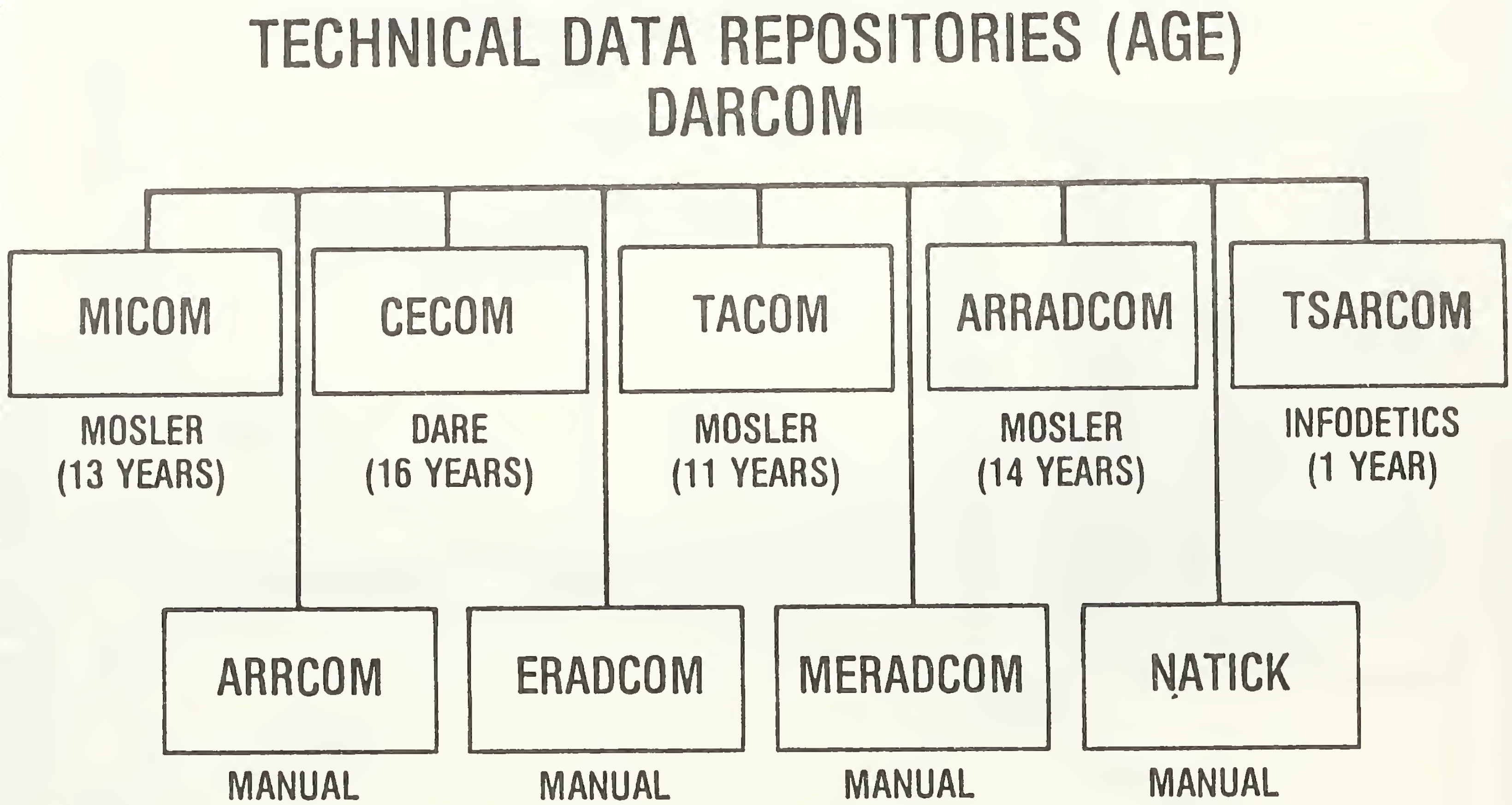



Figure 3.
(Allison - U.S. Army Materiel Development and Readiness Command)




Definitions

MICOM - Missile Command
CECOM - Communication and Electronic Command
TACOM - Tank Automative Command
ARRADCOM - Armament Res. and Dev. Command
TSARCOM - Troop Support and Aviation Materiel Command
ARRCOM - Armament Materiel Command

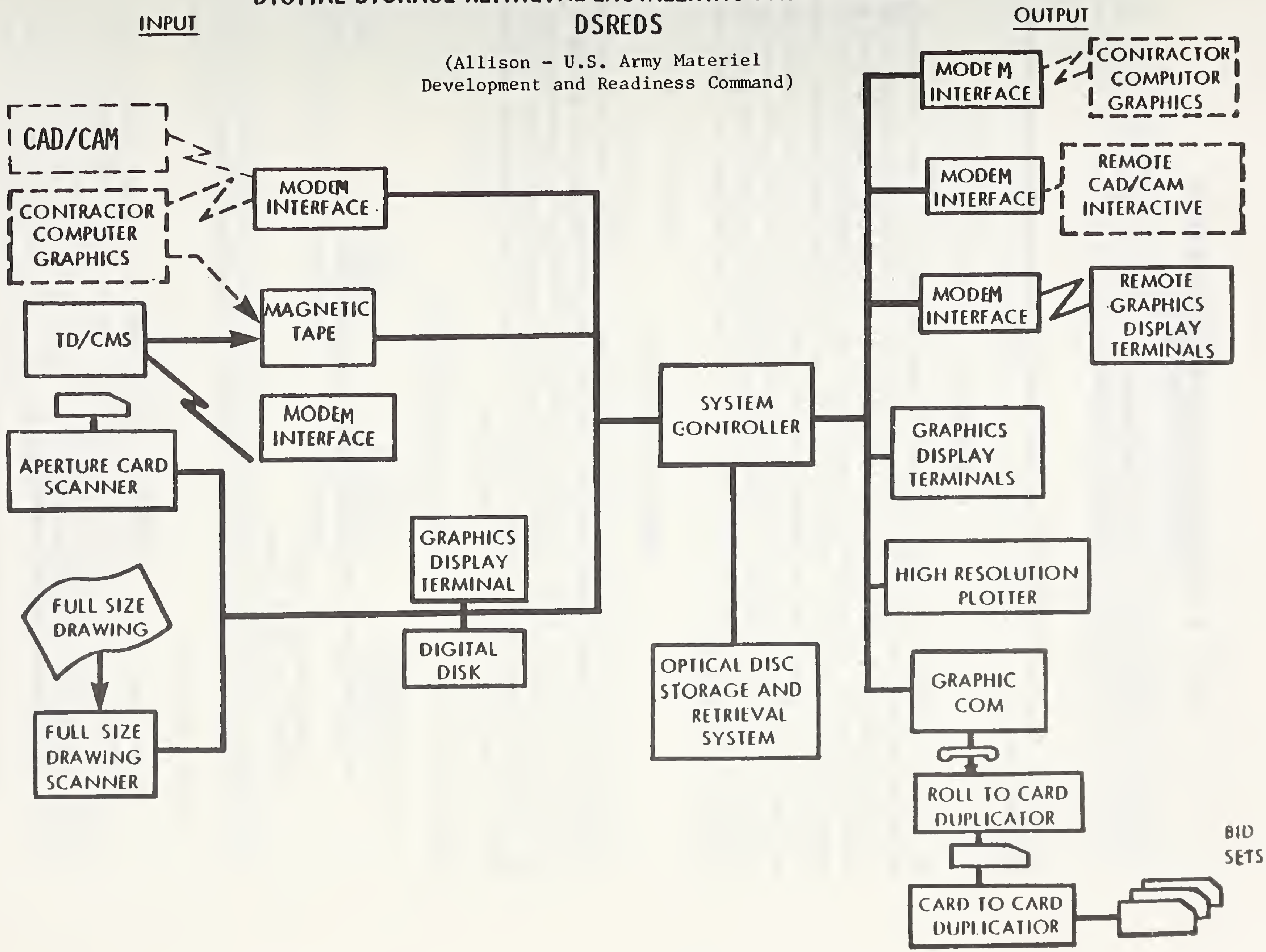
*ERADCOM - Electronic and Res. and Dev. Command
MERADCOM - Mobility Equip. R&D Command
NATICK - R&D Labs

*Includes MERADCOM and NATICK.

Figure 4.
(Allison - U.S. Army Materiel Development and Readiness Command)

Figure 5. DARCOM STANDARD
DIGITAL STORAGE RETRIEVAL ENGINEERING DATA SYSTEMS
DSREDS

(Allison - U.S. Army Materiel Development and Readiness Command)



## 2.1.3 A LARGE CAPACITY DISTRIBUTED MASS STORAGE SYSTEM (MSS)

By Pat Savage
Shell Oil Company

Key words: floating point operations; geophones; geophysical computations; seismic computation.

### Introduction

Mr. Savage described the typical procedure used for both land-based and marine geological exploration. On land, a "computer truck" is used to receive data from up to 240 geophones extending some 3660 m (12,000 ft). An explosive charge is fired in a test hole and the resulting shock waves are sensed at 3 millisecond intervals for approximately 7 seconds. This test yields some 600,000 data samples, each consisting of 3 bytes. Marine explorations use a ship which trails 240 hydrophones on a 3660 m (12,000 ft) cable. Test shots are fired every 10 seconds which result in the same data rate as above. In 1981, the worldwide seismic work encompassed 312,500 km (500,000 mi) and required 600 crews on land, and 625,000 km (1,000,000 mi) and 40 vessels at sea.

### Seismic Computation

The seismic computation load for 1981 consisted of data derived from 937,500 km (1,500,000 mi) of survey, with 10 million floating point numbers per mile, leading to a computation rate of 1,000 megaflops (millions of floating-point operations per second), or approximately one gigaflop per year. Two-dimensional analyses involve the merging of data from a large number of traces; three-dimensional analyses require a staggering increase in computations.

SEISMIC MIGRATION

(1) 2D Migration

Each result trace partakes of as many as 800 stations

- 1,600 stacked traces
- 96,000 unstacked traces

Computation can be configured to arbitrary I/O-compute ratio

(2) 3D Migration

Each result trace partakes of all stations with radius $\leq$ 400 station intervals

- $(400^2)$ x Pi = 500,000, stacked
- 500,000 x multiplicity, unstacked

Staggering data storage/access problem

## Geophysical Computations

Mr. Savage noted that geophysical computations involve correlations, convolutions, and digital filtering of arrays of data points. Many lengthy sorts are required, involving tape-to-disk-to-tape transfers. Loss of an individual record is not critical.

(1) NMO Correction

- Interpolation
- Searching, testing, branching
- Bookkeeping

(2) Correlation

- 100-600 by ditto
- Combinatorial

Convolution

- 100 - 2400 by 150

(3) 2D KF Filtering

- 2400 by 192

(4) Normalization

(5) Multi-trace Processing

- Weighting

## 1981 World Seismic Work

| | LAND | MARINE | TOTAL |
|---|---|---|---|
| Miles | 500,000 | 1,000,000 | 1,500,000 |
| Cost | $2.7 Billion | $1.2 Billion | $3.9 Billion |
| How Gathered | 600 Crews | 40 Vessels | |

Seismic explorations are performed both by corporations and private entrepreneurs. The latter sell their data to interested parties. New data tapes are received on a weekly basis.

## Discussion and Conclusion

It was noted that the proposed application's recording rate would not pose a technological problem for $OD^3$. The biggest problem is sorting, involving the assembly of 240 records in a batch. It would be desirable to be able to request a batch of 240 records and allow the controller to pull these together in whatever manner it preferred **(see figs. 1 and 2).**

The operating environment on board is that of a typical computer room. The shipping conditions have a worldwide range, and shock conditions encountered on shipboard may require specialized environmental standards for the disk.

Mr. LaBudde noted that the application described by Mr. Savage has a definite need for a data interchange standard.

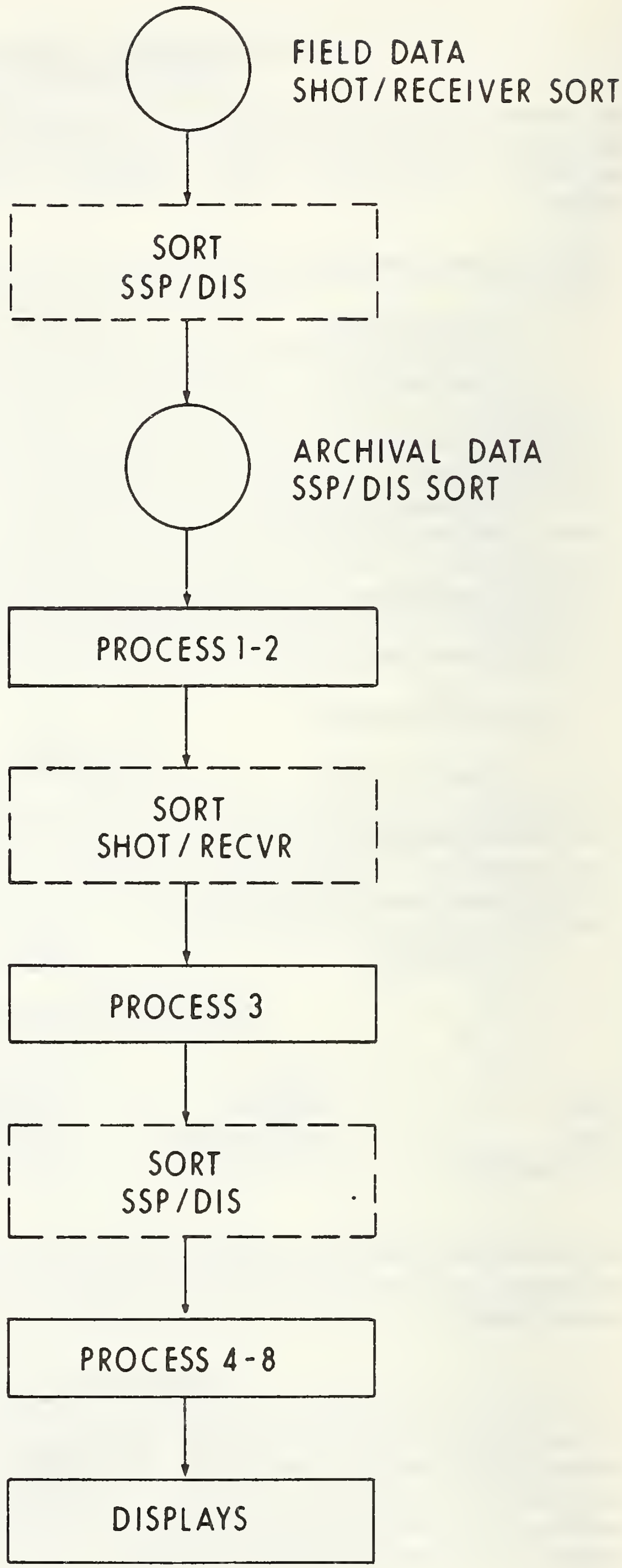



Figure 1.
(Savage - Shell Oil Company)

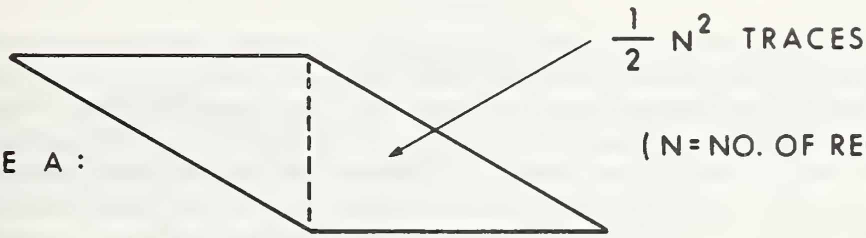
Figure 2.

# CONTINUOUS SORTING - STORAGE REQUIREMENTS

(Savage - Shell Oil Company)

SHOT ORDER ⟷ STATION ORDER

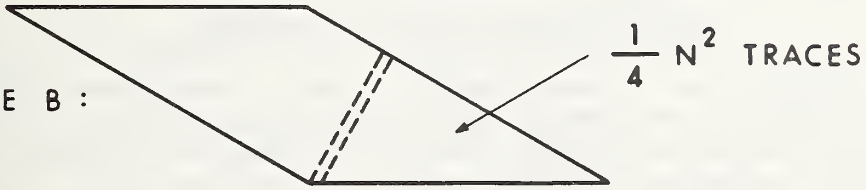
CASE A :




(N = NO. OF RECEIVERS)

SHOT ORDER ⟷ SSP ORDER ⟷ STATION ORDER

CASE B :




| N | CASE A | CASE B |
|---|---|---|
| 120 | 36 M bytes | 72 M bytes |
| 192 | 92 M bytes | 184 M bytes |
| 240 | 144 M bytes | 288 M bytes |
| 384 | 369 M bytes | 737 M bytes |

(10,000 BYTES/TRACE)

## 2.1.4 A CARTOGRAPHIC MAPPING AND DATA BASE MANAGEMENT SYSTEM

**By Ted Albert**
**U.S. Geological Survey (U.S.G.S.)**

Key words: cartographic digital data; data storage capacity; pictorial data; photographic film.

### Introduction

The USGS is building the world's largest collection of earth science and cartographic digital data comprised of data obtained from land, sea, and satellite. The data bases include all earth sciences data of concern to the United States, including data relating to earthquakes, Landsat, coal and other minerals, aeromagnetics, gravity, and volcanos, water supply and stream flows, etc. The archiving of Landsat data alone involves $10^{15}$ bits, over five years. Several network services are used as well as extensive computer facilities. The estimated storage capacity requirement by 1986 will be $10^{16}$ bits.

The primary needs are for reliability, great capacity for modeling, and the ability to merge data from multiple sources. High altitude and satellite photography yields pictorial data comprised of many data points. Therefore, the digitizing of the base map of the U.S., at a scale of 1/24,000, will result in an extremely large digital data base and will take many years to accomplish.

### Storage Requirements and Conclusion

Mapping techniques have conventionally utilized photographic film-oriented methods for production and updating, and for high density storage. Production and updating are generally very lengthy processes requiring many months and often, years. Modern computer technology offers the potential for a transition to improved methods along with greater utilization of the data and information. However, in order to move fully into the digital era, a breakthrough in mass storage technology and spatial data management would be required. For example, one of the basic digital cartographic files will require an estimated $10^{14}$ bits of capacity. The laser optical disk appears to be a candidate for handling the great volumes of mapping data which are required. Further, there is currently no available data base management system that can handle very large spatial data bases. Artificial intelligence techniques are being investigated to provide improved data management methods.

Mr. Albert discussed the relative storage capacities of various media and outlined the advantages of $OD^3$ for this storage application.

## 2.1.5 A MOBILE PLATFORM APPLICATION FOR DISTRIBUTED OPTICAL STORAGE

**By Jack Petruzelli**
**United States Air Force (USAF)**
**Rome Air Development Center (RADC)**

Key words: airborne data collection; durability; interchangeability of $OD^3$ media; optical disk environmental considerations, optical disk requirements; transportability of $OD^3$ media.

### Introduction

Mr. Petruzelli described the need for an airborne data collection device to store data for later ground-based processing. The device would be carried in transport-type aircraft **(see figs. 1 and 2).**

Rome Air Development Center (RADC)
Durable Optical Disk Requirements

| | | |
|---|---|---|
| (1) | Data Rate | 0.5 to 20 x $10^6$ bits per second (bursts to 40 x $10^6$ bits per second) |
| (2) | Storage | 5 x $10^{10}$ bits/disk |
| (3) | Data Access | 500 x $10^{-3}$ seconds |
| (4) | Bit Error Rate (BER) | $10^{-8}$ with Error Detection and Correction (EDAC) |
| (5) | Size | 0.057 $m^3$ (2 $ft^3$) |
| (6) | Weight | 45.4 kg (100 lbs) |
| (7) | Power | 110 vac; 50-60 Hz |

RADC Durable Optical Disk
Environmental Considerations

| | | |
|---|---|---|
| (1) | Temperature | |
| | Non-Operation | -40°C (-40°F) to 65.5°C (+150°F) |
| | Operation | 10°C (+50°F) to 37.8°C (+100°F) |
| (2) | Humidity | |
| | Minimum | 20% from 10°C (+50°F) to 16°C (+61°F) |
| | Maximum | 100% (condensing) from 10°C (+50°F) to 27.2°C (+81°F) |
| (3) | Pressure | 20.58 in Hg or 10,000 ft above sea level |
| | Shock | NTE 1.5 g along any axis (MIL-E-5400-T, para 3.2.24.6) |

(4) Vibration — Sinusoidal dynamic (MIL-E-5400T, Page 31, Figure 2, Curve II-A Jet Aircraft)

<u>Conclusion</u>

This application requires interchangeability of the OD[3] media among machines, transportability of media, device operation in/on various platforms, and the ability to survive air-drop (non-operational). A study contract to characterize the eventual hardware design has been awarded to RCA Corporation, Camden, New Jersey.

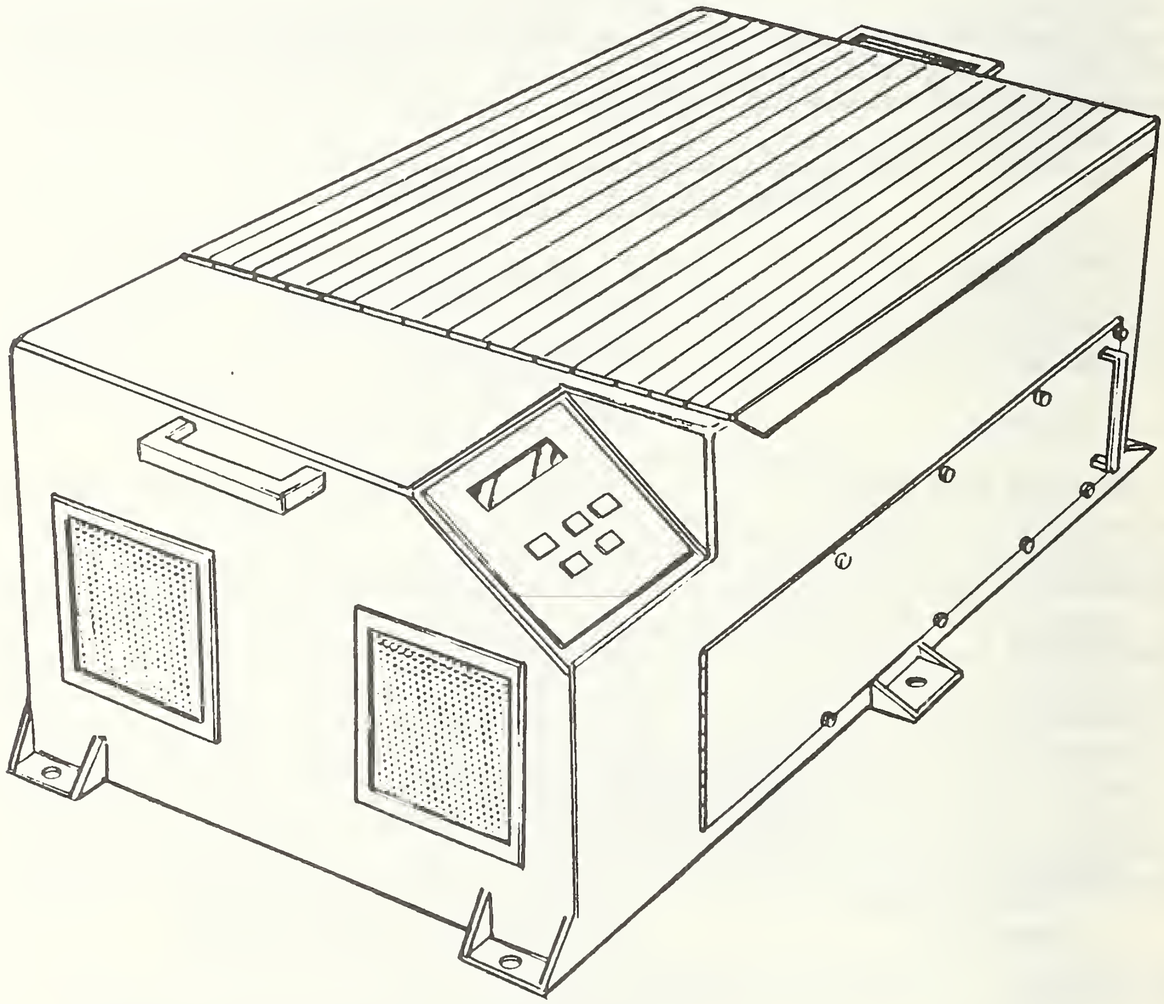


Figure 1. Durable Optical Disc System (Operational View)
(Petruzelli - United States Air Force)
(Rome Air Development Center)

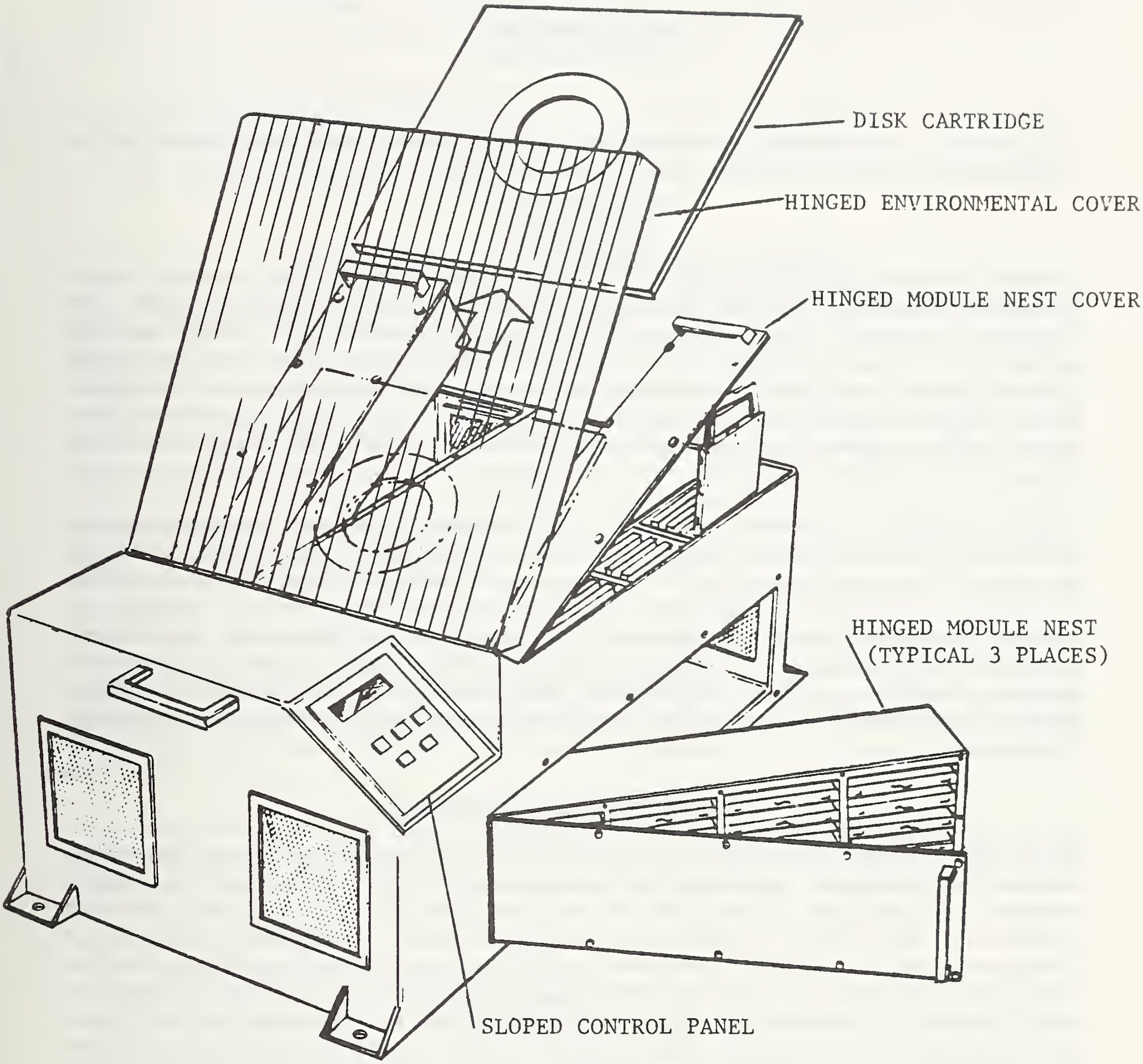



Figure 2. Durable Optical Disc System (Servicing Position)
(Petruzelli - United States Air Force)
(Rome Air Development Center)

## 2.1.6 OPPORTUNITIES FOR DOCUMENT AND CHARACTER STORAGE
### In Commercial Applications

**By Leonard Laub**
**Vision Three, Inc.**

Key words: accessibility; characteristic record length; cost; data distribution technologies; storage capacity; technological demand.

### Introduction

Existing computer and office automation systems use semiconductor random access memories (RAM's), fixed and removable magnetic disks, magnetic tapes, and microform as data storage devices. Whether by tradition or through careful analysis, users and system's architects have determined ways to use these technologies so that short, new and frequently accessed files are stored in random access devices such as magnetic disks—while lengthy, old, and rarely accessed files are stored on magnetic tape and microform, both of which have slow data access but are most capable of compact, low cost storage.

Optical storage equipment need not be configured into a plug-compatible replacement for any one of these technologies; it is easier and more effective to provide an integrated storage system, using several technologies that are controlled by dedicated computing capability, which is assigned to move files among the storage devices based on changing patterns of access and importance. Straightforward guidelines for determining how much of each technology to use in a given application have been developed. This work impacts hardware and media product requirements and should be considered as part of the process of standards development.

### Data Distribution Technologies

The variety of telecommunication services available to users of computer and office automation equipment continues to increase as satellite and optical fiber links become abundant and as wholesalers and retailers of data carrying capacity proliferate. Enthusiastic predictions of widespread remote searching of data bases have been made, but economic and technical issues must be resolved. The growth in computing expected in the next decade cannot be supported primarily by centralized data storage; the capacity available will not suffice, and the cost per unit data transferred will be too high. The alternative, just becoming visible in practical commercial products, is to distribute copies of public and private data bases to users on read-only optical disks. One category of such distribution is also becoming known as "electronic publishing." Formats appropriate for data base distribution include both the 30 cm (12 in) LaserVision$^{tm}$ videodisk (capable, using appropriate channel and error correction coding, of holding up to 3000 MB of well-corrected user data per surface) and the 12 cm (5 in) Compact Disc$^{tm}$ digital audiodisk, as well as any of the locally writeable formats now under consideration. Standardization of read-only formats will have considerable commercial importance.

## $OD^3$ Technological Demand

Mr. Laub's organization, Vision Three, Inc., performs consulting, systems integration, and business development in optical and other data storage. He sees demand for $OD^3$ technology due to the following:

(1) Large volume of documents
(2) Desire for rapid random access
(3) Desire for remote access
(4) Desire for computer-assisted access
(5) Desire to merge image and character files.

## $OD^3$ Storage Capacity, Costs, and Accessibility

The availability of lower cost CRTs, scanners, and printers, improved file-finding processors and magnetic disk, RAM, and the availability of optical disks have enhanced the demand for $OD^3$ technology. Mr. Laub reviewed the relative capacities of various magnetic storage media versus optical disks. A 356 mm (14 in) optical disk has a capacity of about 9,400 x $10^6$ bytes or 260,000 images of A4 document pages. The relative information storage costs for various storage media were compared. The media cost for $OD^3$ was 3 cents per $10^6$ bytes or 95 cents for 1,000 images. This latter figure compares very closely with microfilm at 90 cents per 1,000 images. Relative access times for various media are tens of seconds for magnetic tape, 0.05 to 0.5 seconds for rotating magnetic storage, and 0.1 second for optical disks.

Considering accessibility, Mr. Laub noted the high throughput capacity of drives, with reference to a "characteristic record length." He noted the utility of hierarchical organization of drive types and stressed the importance of memory management outside of the central processing unit (CPU), removing this concern from the user. An additional, important requirement is for multi-dimensional search capabilities.

The characteristic record length, previously mentioned, is defined as that for which the transfer and access times are equal. It is useful for optimization in a hierarchical storage structure. Typical values are as follows:

(1) RAM: 1 byte
(2) Magnetic disk: 15-90 x $10^3$ bytes
(3) Optical disk: 200-1,000 x $10^3$ bytes
(4) Magnetic tape: 2-20 x $10^6$ bytes.

Mr. Laub envisioned the possibility of improving accessibility by anticipating a user's requirements for successive pages of data and files, based on recognized interrelationships among the data and files. He called attention to the fact that, without proper storage management, the high capacity of an optical disk could lead to large user queues.

Mr. Laub contrasted the relative costs of transporting data by various methods, both physical and electronic. Because of the high capacity of an optical disk and the availability of overnight express mail, the mailing of a disk can be a very cost-effective way of transferring data. For example, 12,000 x $10^6$ bytes of data can be sent 3,000 miles in 18 hours at a cost of \$9.35, for a net data rate of 1.5 x $10^6$ byte/second and a cost, including disks, of 0.4¢/$10^6$ byte.

He described the storage capacity and access rate needed for imagery. He structured a hypothetical case of a system involving 3 x $10^6$ images on file, having 100 users, each generating 30 requests per hour. The hardware for meeting this requirement with $OD^3$, consisting of 108 read-write optical disks, 12 disk drives and 1 automatic media handler ("jukebox"), was stated to be available soon for less than \$100,000, exclusive of terminals, communications, and other processing equipment.

## Conclusion

Considering system issues, Mr. Laub discussed hardware and software compatibility, hierarchical memory architecture, the need for removable media, erasability, and media transport versus the telecommunication of digital data.

## 2.1.7 PERSPECTIVES OF AN $OD^3$ INTEGRATOR: OFFICE APPLICATIONS

**By David Fain**
**Integrated Automation Corporation**

Key words: interchangeability; photographic film; pixels per inch; replicability; resolution; United States Library of Congress; vector storage.

### Introduction

Mr. Fain described a large, film-based data system. He stressed the inherent resolution limits of film, which he felt from a practical standpoint to be about 120 pixels/inch. While higher values may be claimed, they tend not to be achieved and sustained in a production environment. The processing of photographic film required to produce a visible image lengthens the production time. This imposes the burden of having to keep input documents accessible until the processing is completed and the film is quality-controlled. With an optical disk system, a resolution of 8 to 16 pixels per mm (200 to 400 pixels per in) is achievable, and in some instances reaches 118 pixels per mm (3000 pixels per in). The cost of optical storage was cited to be lower than for film storage.

Integrated Automation, Inc., has been awarded a contract to provide a system which will use digital optical disks for computerized mass storage, preservation, and retrieval of printed materials, including text and halftone illustrations, to the United States Library of Congress, located in Washington, D.C.

Mr. Fain showed a diagram of the proposed integrated system, illustrating the incorporation of $OD^3$ technology with data processors, communications equipment, display terminals, and printers. Data compression at a ratio of approximately 10:1 is being used. He envisioned systems of this type as being well-suited to transaction processing such as handling remittances. He also envisioned their applications in the widespread printing of documents and books, on demand. For the input of large diagrams, he anticipates the use of vector storage rather than raster storage. **See fig. 1**, which is the system level diagram of the $OD^3$ information system planned for the Library of Congress.

### Conclusion

Mr. Fain stressed the need for archival storage, interchangeability, replicability, and reasonable cost per disk, although the latter factor does not seem to be a major consideration. Regarding $OD^3$ standards, he prefers a maximum of diversity of $OD^3$ products at the present time. He has confidence in the ability to interface diverse products. Within an installation, interchangeability of the media is needed from drive to drive. He would like to see the drives designed to provide good access to the spindle in order to facilitate integration with automated handling equipment ("jukebox" arrangement).

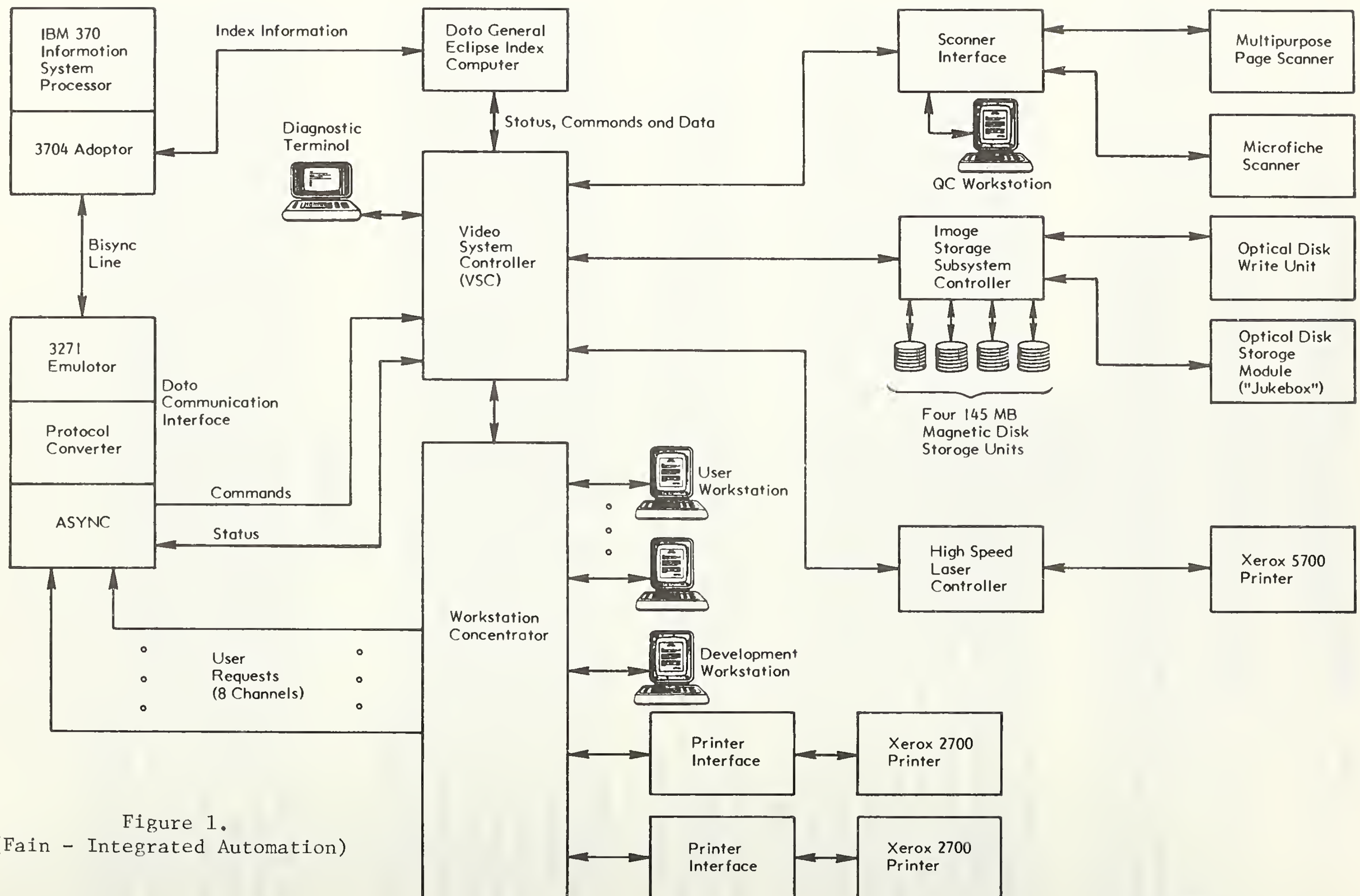



Figure 1.
(Fain - Integrated Automation)

Library of Congress
Preservation and Retrieval System
System Level Diagram

## 2.1.8 TECHNICAL REQUIREMENTS FOR DOCUMENT STORAGE APPLICATIONS

**By Gerry Walter**
**Planning Research Corporation**

Key words: bit per pixel; document storage systems; image quality; resolution; storage requirement.

### Introduction

Mr. Walter observed that there is no "average" user of document storage systems. He distinguished between data and documents. The latter have a post mortem character and can serve in an evidential role; i.e., as evidence. A legal requirement for the retention of the original document exists in many government situations. Microfilm is not considered legal evidence, and it is questionable as to how $OD^3$ will be viewed in this regard.

Mr. Walter characterized four types of images and indicated their digital storage requirements, as follows:

### Types of Images

| Monotone | | Chromatic | |
|---|---|---|---|
| Bi-Tonal (Digital) | Continuous Tone | Partial Spectrum | Full Spectra |
| - Line Drawings<br>- Type, Handwriting<br>- Halftone | - Photos<br>- Art Work<br>- Converted Chromatics | - Line Art<br>- Two Color Conversions | - Orthochromatic Photos<br>- Artistic Pictures |
| One Bit Per Pixel* | 4 to 16 Bits Per Pixel* | 9 to 32 Bits Per Pixel* | 32 to 128 Bits Per Pixel* |

*Pixel = Picture Element

Note: The pixel count remains constant, as determined by resolution. The quantity of bits per pixel, therefore the quantity of bits per page, depends on the type of imagery.

Image quality was related to resolution by Dr. Walter as follows:

Note: lpi = lines per inch

(1) 100 lpi (16 pixels/$mm^2$) - Marginal
(2) 200 lpi (64 pixels/$mm^2$) - Provisionally Acceptable
(3) 300 lpi (144 pixels/$mm^2$) - Good
(4) 400 lpi (256 pixels/$mm^2$) - Excellent

The digital storage requirement for documents scanned at various resolutions was given by Dr. Walter as follows:

| | | 100 lpi | 200 lpi | 300 lpi |
|---|---|---|---|---|
| (1) | Resolution | Marginal | Satisfactory | Good |
| (2) | Bits/Inch$^2$ | $10^4$ | $4 \times 10^4$ | $9 \times 10^4$ |
| (3) | Bits/Document | $9.35 \times 10^5$ | $3.74 \times 10^6$ | $8.415 \times 10^6$ |
| (4) | Compaction | 3 x | 7 x | 15 x |
| (5) | Net Bits/Document | $3.12 \times 10^5$ | $5.34 \times 10^5$ | $5.61 \times 10^5$ |

The storage requirement for 300 lpi (lines per inch) is so close to 200 lpi, that one might as well disregard the 200 lpi case.

## Conclusion

Dr. Walter stated that, in terms of user requirements, the storage and retrieval system should be transparent to the user. The display should retain all of the desirable characteristics that are associated with paper-based storage while replacing the undesirable ones. Also, the technology should be the most cost-effective over its life cycle. As an illustration, using a seven year life cycle, the cost of a paper system works out to 92 cents per page, for microfilm it is $1.05 per page, and for automated, digital data disk storage and remote CRT display, it is $4-5 per page.

The need for duplicate image carriers in a central data bank system was stressed. Dr. Walter advocated 1 to 3 working copies and 1 to 2 security copies. He emphasized the value of having backup copies in the same form as the working copies. In a distributed image data bank system, he observed that there were typically from 6 to 30 working copies, 1 master copy, and 1 to 2 security copies. He felt that these systems outnumber the centralized systems, several hundred times. There is a need for accommodating the great amount of information that is not solely generated inside an organization.

## 2.1.9 OPTICAL STORAGE IN AN OEM ENVIRONMENT

**By Joseph Zajaczkowski**
**Sperry Corporation**

Key words: applications; original equipment manufacturer (OEM); specifications; standards development.

### Introduction

Mr. Zajaczkowski began by stressing the importance of user input at the earliest stages of standards development. The extreme reliability required in $OD^3$ applications was emphasized, and the term YBF (Years Between Failures) was advocated in place of MTBF (Mean Time Between Failures). He noted the broad spectrum of standards, specifications, codes, and design practices that an OEM must deal with, ranging from details of product design to overall system considerations.

Mr. Zajaczkowski referred to standards as both a double-edged sword and a chain that you drag along forever. Standards remove some of the risk, at the cost of reducing some of the choices and impacting innovation. There have been cases of potentially useful products which failed because no one would invest in them, due to a lack of standards.

Problems can occur, even in a well-established field, due to lack of agreement on definitions, interpretation, and understanding. The language affiliated with standardization should be kept simple.

## 2.1.10 REQUIREMENTS FOR EASILY DESTRUCTIBLE OPTICAL MEDIA UNITS

**By Mark Goldberg**
**National Security Agency**

Key words: accessibility; compact; destructible; encryptable.

### Introduction

Optical disks offer advantages in a secure environment—including data storage in digital form, which is computer compatible and encryptable. The compact physical size and rapid accessibility of data stored on disks are other distinct advantages to $OD^3$. These factors also provide an advantage when transporting data from one site to another, or when disposing of the data.

### Conclusion

Dr. Goldberg described a possible installation as having 30,000 documents, which would form a stack more than 6 feet high, comprising 20,000 square feet of paper. On magnetic tape, this would require 30 reels each 730 m (2,400 ft) in length. A single optical disk of one square foot area could contain the same amount of information--and unlike the other media, could be quickly disposed of, in response to a security threat.

### 2.1.11 Panel Discussion: $OD^3$ Applications and Standards Requirements

**Panel Participants:**

Di Chen, Optical Peripherals Laboratory
John Davis, ITTRI
Mark Goldberg, National Security Agency (Moderator)
Michael Hogan, National Bureau of Standards
Edward LaBudde, LaBudde Engineering Corporation
David Morin, Naval Ocean Systems Center
Del Shoemaker, Shoemaker and Associates

(These Comments are not Transcribed Verbatim.)

**E. LaBudde:** There is a desperate need among users to define the media environmental and life expectancy issues, to establish definitions and test methods, and to avoid being locked into a specific implementation of a combined product and design. There is a widespread need for $OD^3$ media removability and reading disks on remote devices to achieve data interchange. The need for interchange affects the file structure and data formats as well as the mechanical and optical characteristics of $OD^3$ systems and media.

**D. Chen:** There is latitude for various manufacturers to conform to a standard at this stage of development.

**M. Goldberg:** A diversity in standards is needed to accommodate the range of disk sizes and requirements needed for various applications. For instance, among the low-end $OD^3$ products, there may be a need for automated disk handling that inherently has different requirements and applications as compared to automated handling within high-end $OD^3$ products.

Dr. Goldberg suggests the term "optical disk library (ODL)" be used in lieu of "jukebox" to denote the modularity of automatic disk handling hardware.

Dr. Goldberg referred to video and digital audio disk technologies to acknowledge that some standardization-related issues between these and optical disk technologies may be similar. However, only those issues directly related to $OD^3$ would be addressed in this workshop.

**Floor:** Should non-spinning media be considered in this standardization workshop? These media were not included in the program as they were not considered to be compatible with $OD^3$ technology.

**D. Morin:** Development of processing systems for use in Department of Defense (DOD) systems requires a very large investment in hardware very early in the development cycle. Significant changes in the functional and/or interface characteristics of <u>any</u> piece of hardware within the system at <u>any</u> point within a 5-year development cycle can significantly increase the development cost and schedule. Standards help to reduce the risk of the use of a new piece of hardware (e.g., optical disk) in a system (1) by guaranteeing that compatible hardware will be available at all phases of the development cycle and (2) by stimulating the development of multiple sources of that piece of hardware by the end of the development cycle so that actual system production requirement can be met. The lack of standards will discourage the use of an optical disk in DOD systems.

**J. Davis:** The publishing industry uses video disks, and thousands of replications of these disks are anticipated. As an industry, they could not see standardizing any aspect of $OD^3$ technology that would not facilitate data interchange.

**D. Shoemaker:** Manufacturers are starting to look increasingly toward standards activities for guidance in product design. Therefore, there is a growing awareness of a particular standard's value. Simultaneously, the standards process is being accelerated and becoming more responsive to the groups that are writing standards.

**Floor:** The integration of $OD^3$ devices and system upgrades relies on compatibility achieved through software and hardware expertise. According to this $OD^3$ systems integrator, environmental standards for this $OD^3$ application are even more valuable to systems integration than hardware and software standards.

The lack of data interchange through media compatibility for office products (word processors) is a situation which occurred due to the lack of data interchange standards.

**D. Shoemaker:** Most of the speakers have emphasized the desire for compatiblity and interchangeability of media.

**E. LaBudde:** Some users want anything they can get now while others would prefer to wait for more product stability.

**M. Hogan:** Examples can be cited of the lack of economies in a particular market, due to a lack of standards. The lack of standards could impact the growth of the $OD^3$ market.

### 2.1.12 $OD^3$ Media Exhibit

Optical digital data disks were brought to the Workshop on Standardization Issues for $OD^3$ Technology, by their developers. This collective effort was requested of the workshop participants by the workshop program committee. The disk collection was set up specifically to illustrate one of the key topics of the workshop--the diversity of current disks, which was obvious in the various dimensions and disk storage capacities.

The disk "display," assembled for technical information only, within the context of the workshop, had disks ranging in size from 120 mm (4.7 in) outside diameter disk with 15 mm (0.6 in) inside diameter to a 356 mm (14 in) outside diameter disk with 168 mm (6.6 in) inside diameter. These same disks, which were the smallest and largest disk, considering physical dimensions, had a storage capacity of $150 \times 10^6$ bytes and $4 \times 10^9$ bytes, respectively.

Following is a description of the optical digital data disk, from the Library of Congress "Demand System," that was exhibited by a representative from the Library of Congress.

362 mm (14.25 in) disk
168 mm (6.6 in) inside diameter
Data Encoding Method is Modified MFM - Single Sided
Raw formatted capacity = 4.866 GBytes
User Data Capacity = 3.8 GBytes
Recording Surface is 300 Angstrom Layer of Tellurium Alloy
Substrate is Optical Glass 1 mm Thick
Hole size = .4 micron, Hole Spacing = .8 micron, Track Spacing = 1.1 micron
Total Tracks = 49,500, Sectors per Trace = 192, 512 bytes/sector

## 2.2 SESSION II PRESENTATIONS AND DISCUSSIONS - LEGAL AND ARCHIVAL REQUIREMENTS OF AN OPTICAL MEDIA UNIT

### 2.2.1 OD$^3$ SYSTEM CONSIDERATIONS OF BUSINESS ARCHIVAL INFORMATION

**By Morris Cohen**
**NCR Corporation**

Key words: audit; business record; time insensitive schema.

#### Introduction

Mr. Cohen emphasized the importance of business record keeping methodologies which support auditors. Business archival documents must be reliable, meaning that they should be protected from alteration. There should be a means for identifying when a record was written and a mark of its authentication identification. There should be protection against automated forgery; e.g., electronically building a falsified image from pieces of valid images. The collusion factor should be minimized. The worst case is where a single individual can perpetrate a crime; i.e., the more people who have to collaborate, the harder it will be to achieve successful collusion. The potential use of OD$^3$ technology for "permanent" data storage of business-related information has many advantages, including eliminating the "check written-in-pencil" syndrome.

#### Record Survivability

Survivability is essential for business records. Ten years is not a magical number; for some records, useful life may be 7 years, for others, 25 or more. The period for which records need to be updatable, need not be as long. Stored information should be insensitive to the following:

(1) Time
(2) Use
(3) Unforeseeable missions
(4) Broken equipment
(5) Abuse
(6) Theft
(7) Breakage of media
(8) Misplacement

#### Information Recovery

Recoverability of business information is important. There should be on-board schema to aid in locating, identifying, and interpreting information, as well as on-board encoding algorithms, in machine-independent form. Consideration must be given to the maintenance of defined terms needed to find and understand the data. A balance must be achieved between long-term understandability and long-term security.

## Conclusion

The necessary requirements for the secure computer storage of business information can all be met if there is a method of achieving multiple certifiably-true, read-only copies, with on-board schema and algorithm information all properly distributed and protected. The existence of multiple copies of the information in different locations provides protection against a perpetrator who may be able to alter a particular copy, but does not have access to all of the copies. A malicious act can be circumvented by comparing the false and true copies.

## 2.2.2 A PARTIAL SOLUTION TO THE DATA INTEGRITY PROBLEM

**By Dennis Branstad**
**National Bureau of Standards (NBS)**

Key words: authentication; cryptography; data integrity; data protection; secrecy; security.

### Introduction

The advent of new technologies in data processing result in new questions being raised, as well as the old. The development of new data storage technologies, such as Optical Digital Data Disk ($OD^3$), have again raised the question, "Will the integrity of the data be assured?"

$OD^3$ can replace many forms of storage media that are used for long-term retention of records. Integrity assurance means that recorded data can be read correctly and that there has been no accidental or unauthorized modification of the data while they were stored. Additional security requirements for vital records often include both the secrecy of the data and the ability to verify the authenticity of the originator of the data. Since many documents can be stored on a single disk, it may be necessary to control access to the data on such a shared storage medium.

### Integrity Problems and Solutions

The $OD^3$ storage media are subject to several potential data integrity problems. Writing errors and reading errors can be detected with conventional "read-after-write" or "read while write" methods. Media degradation and read/write alignment requirements must also be evaluated before $OD^3$ can replace the alternative media for long-term data retention. Backup copies should be made for all vital data and these should be stored separately, however, the backup may or may not be recorded on $OD^3$ media. Potential media degradation under various physical environments must be evaluated before a backup media is chosen.

Intentional, undetected modification of data is the part of the integrity problem discussed in this presentation. A solution to this problem also results in a solution to the problem of detecting accidental modification, but not vice versa. A slight modification of the solution also solves the problems of unauthorized access to data and unauthorized disclosure of data.

### Authenticating Stored Data

Authenticating stored data is a process which verifies that the data has not been modified, either accidentally or intentionally, subsequent to storage. Various error detection codes may be used to detect any accidental modifications but cryptographic-based error detection codes are generally necessary to detect intentional, intelligent modifications of data. The term "generally" is used because other methods can be used for certain media under certain circumstances. For example, modified credentials such as driver's licenses can be detected optically if high quality images are pre-printed on high quality paper, under the age or identifier that was changed.

The Data Encryption Standard (DES) algorithm is a cryptographic algorithm that may be used to protect the integrity, secrecy, or both, of data. The algorithm computes a 64-bit code for a 64-bit data input, using a 64-bit key. The 64-bit data input generally represents 8 characters of data. For secrecy purposes, the 64-bit code is communicated or stored. The receiver or reader can transform the 64-bit code back to the 64-bit original input, only if the original 64-bit key is used.

A cryptographic-based error detection code, now commonly called a Message Authentication Code (MAC), can be easily computed with the DES algorithm on data stored on $OD^3$ media (or any media). The data to be protected are divided into 8-character groups (terminated by zeros if necessary). The first group is encoded with the DES. The result is added (modulo 2) to the second group. This result is then encoded with the DES. The result is added (modulo 2) to the third group. This process continues until a final 64-bit result is obtained. The first 32 bits (alternately, the entire 64-bits) of the result is called the MAC, which is then appended to the data and stored on the media.

When the stored data is read, the same sequence of operations is performed on the read data; i.e., another MAC is computed. The cryptographic key used to compute the first MAC must be used to compute the second MAC. If the MAC computed on the data before it was stored is identical to the MAC computed on the data after it was read, then it is concluded the data has not been modified, with a probability equal to $2^{32}$ (alternately $2^{64}$) MAC length. No one can change the data and change the MAC to correspond with the modified data unless the key is known. A key management system must therefore be used which stores the key until the data is read. The key must be protected from disclosure, destruction, and replacement.

If integrity protection and secrecy protection are desired, a MAC is similarly computed and then the data and MAC are enciphered. NBS has proposed a standard for performing these functions.

A good key management system will also provide access control to data on a shared disk. Each user must supply a personal key which is used to unlock the stored key which protects the data. Such a system thus authenticates the originators and users of the data.

## Conclusions

The $OD^3$ storage technology should make use of available integrity and security technologies as they are developed. This presentation described one method which can be used to provide a high degree of protection for $OD^3$ technology, as well as other data storage technologies.

## 2.2.3 MEDIUM TERM, LONG TERM, AND ARCHIVAL PROPERTIES OF PHOTOGRAPHIC MATERIALS

**By Peter Adelstein**
**Eastman Kodak Company**

Key words: American National Standards Institute (ANSI); archival; archival photographic film; long term photographic film; medium term photographic film; photographic film.

### Introduction

The life expectancy of data recording materials is a property of increasing importance to the consumer. The critical needs for long time keeping have been reflected in an increasing number of publications on the keeping characteristics of various materials, particularly photographic film and magnetic tape. Although standards on the permanence of photographic film have existed for close to 40 years, the last decade has witnessed much greater activity in the specification of storage conditions and of material permanence.

The need for research activity on life expectancy, and the consequent reflection in national standards, is necessary to provide the user with the needed confidence in the permanence of his media materials. This information is particularly important for an emerging technology in which there is not a great deal of practical keeping experience to draw from. The purpose of this paper is to describe the standardization activity, in the photographic industry, on permanence and the resulting definitions that have been agreed upon. It is expected that this background may be of some use to those who must answer similar questions on optical disks.

### American National Standards Institute

The American National Standards Institute (ANSI) is the recognized national standardization body in this country. It publishes the standards and specifications prepared by various national societies (such as the American Society of Testing and Materials (ASTM), Technical Association of the Pulp and Paper Industry (TAPPI), etc.) as ANSI documents. These are then recognized in international organizations as standards from the United States.

Overall coordination of standards activity in image formation is implemented by the Image Technology Standards Management Board (ITSMB). Their scope includes not only conventional photography, but the audio visual field, graphic arts, and areas of electronic imaging. The ITSMB has set up seven photographic (PH) committees **(see fig. 1)**, each responsible for a different area of interest. These committtees are sponsored by trade organizations or technical societies who provide the administrative and secretarial functions. Storage and permanence is handled by Committee PH1 which is divided into various subcommittees and task groups to work on specific assignments. The National Association of Photographic Manufacturers is the sponsoring society.

## Definitions

Before specifications can be written on photographic materials having various levels of life expectancy, terms must be agreed to--which define these different levels. This has proven to be one of the more difficult tasks in these standardizing efforts. Fortunately, this assignment is now completed with three different levels of permanence being defined.

(1) medium-term film is a photographic film which has a useful life in excess of 10 years,
(2) long-term film is a photographic film which has a useful life in excess of 100 years, and
(3) archival film is a photographic film which is suitable for the preservation of records having permanent value.

All three definitions recognize the concept that these films must be stored under appropriate storage conditions to achieve the indicated life expectancy.

The most controversial of these definitions is the word "archival." This term has been used and misused over the years, describing life expectancies varying from 10 to 500 years. Such practices have led to considerable confusion and misunderstanding. Unfortunately the term "archival" has sometimes been employed to promote a particular product rather than to impart information about its life expectancy.

The word archival was first used in image technology standards to define the preservation conditions for silver microfilm intended for "the maximum period obtainable." Since silver images had over a century of excellent stability, this term was subsequently incorporated by Committee PH1 into the film specification for black-and-white silver images(1). The committee recognized that maximum storage life should not imply absolute permanence. Consequently, they define archival film as suitable for "records having permanent value." A specific time period was not established.

This very demanding definition of archival materials was most recently reexamined during deliberations on film specifications for medium and long-term film. A definitive statement was requested by and received from the Archivist of the United States(2). He stated that the term "archival" is synonymous with "permanent." While being permanent cannot be guaranteed, it is important that any new archival record film be equal to or better than current archival film as defined by ANSI(1). This viewpoint, representing the current thinking of U.S. Government agencies and of ANSI, must be considered in the preparation of permanence standards in image technology.

There is another aspect of photographic film standards which should be mentioned. All film specifications on permanence apply only to copies which are storage copies and are not work copies. The committee felt that work copies may become dirty, scratched, or contaminated so that they may not exhibit the behavior expected from the inherent properties of the film itself. This is a question which will have to be addressed by the optical disk community. The answer may depend on the possible disk damage that could occur during use.

Reference

(1) American National Standards specifications for photographic film for archival records, silver-gelatin type, on cellulose ester base, PH1.28.

(2) J. B. Rhoads, letter to P. Z. Adelstein, Journal of Applied Photographic Engineering, vol 2, 2, p. 64A, spring 1976.

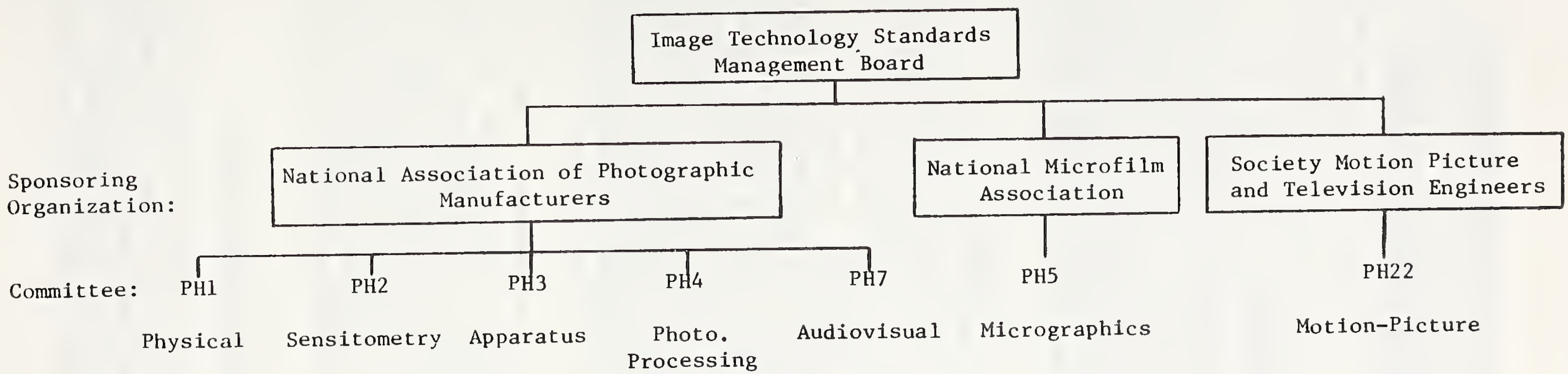



Figure 1. Organization of Photographic Standards Activities in the United States (Adelstein - Eastman Kodak Company)

## 2.2.4 THE MEANING AND USE OF "ARCHIVAL"

**By Thomas Brown**
**National Archives and Records Service (NARS)**

Key words: archival; archival life.

### Introduction

Two definitions or usages of the word "archival" are seemingly common. First, the ADP community uses the term for "long-term" tertiary storage and in the process has created a verb "to archive." But in most ADP environments, this "long-term" is really a very limited time. Indeed, some vendors promote products as "archival" if it has a storage life of as little as five years. The professional archivist has a different concept. As an example, the professional archivist glossary does not include a verb "to archive."

### Definition: Archival

"Archival" in the professional sense of the word is derived from ancient Greece and stresses the concept of records created by an organization rather than individual. Such organizational records are "archival" if they have permanent value, continuing value, enduring or unending value. Simply put, "archival" means permanent or forever. Given this difference in definitions, the professional archivist might argue that his or her definition is the correct one because of its usage in Western Civilization for two and half millenia (2500 years). A stronger position, however, is Federal law (44 U.S.C. 2103) which adopts the professional definition when it defines archival records from Federal agencies as those which "have sufficient historical or other value to warrant their continued preservation by the United States Government." Lest someone argue that this refers to only paper documents, 44 U.S.C. 3301 specifically includes machine-readable materials in the definitions of records. This would mean optical digital data disks as well as magnetic media.

Obviously, not every record an organization creates has permanent or enduring value. Indeed, only a small minority of the records would fall into this special category. Who makes this determination? It is the archivist. Once the archivist makes that decision, the determination does not make the media of the record of archival quality. Rather for the media to have archival quality it must have the same permanency as the information. If archival information is on a less than permanent media, then the information must be transferred to another media of archival quality or to another media of transitory quality until an archival quality media is developed.

### Attributes of Archival Quality Media

For a media to be certified as "archival," it must meet three tests. The first of these tests is the media life. When the Archivist of the United States declared that "archival" is synonymous with "permanent" and "forever," he admitted that it was a "rather positive statement and which none of us can guarantee." As a practical matter in certifying materials for permanent records use, they must have a media life equal to or greater than the media with the longest, long-term keeping ability. When film was certified as archival, it was determined through accelerated aging tests that it was equal to or greater than high-quality rag paper, that experience had shown to have a media life of at least 500-1000 years. Based on this precedent, newer materials can be approved as archival if they are equal to or greater than the present materials that have been certified for permanent record use. In making this determination, the media should be evaluated in conditions resembling an archival environment. Since the need to access materials declines over time, media will hold information that is used infrequently. As a corollary to such infrequent use, speed of access to records in archival custody is not significant. Also, an archives will store the records in an environment to optimize the media life.

The second attribute of archival quality media is that the image should be preferably unalterable. If it is alterable, it should have a built in audit trail. This is necessary to make an archival record a legal record. The last attribute is interchangeability, accessibility, or transportability. This is necessary because the information must be able to be sent for deposit to an archives. And the archivist must be able to allow researchers access to the information. Thus the media must be independent of any software or hardware. This interchangeability is complicated by the fact that future equipment must be able to access the media. Hence the media must be transportable across time to future equipment, yet to be designed.

## Conclusion

These attributes of archival quality are admittedly stringent, but necessary to the true definition of the word. My impression of the present $OD^3$ technology is that no product presently meets these criteria. For these reasons, $OD^3$ archival standards should not be developed at the present time. Any standards in the future must not associate "archival" with any time scale as this will only serve to muddle the definition. Hopefully, technology will advance and develop a storage technique which will meet the professional and strict definition of archival.

## 2.2.5 WHAT CONSTITUTES A LEGAL DOCUMENT?

By Thomas Bagg
National Bureau of Standards (NBS)

Key words: copies; evidence; legal documents; legality; microforms; optical media.

### Introduction

The legality of optical media, or any other record media, is based on the acceptance of the information on the media as admissible evidence in a court of law.

For a record to be accepted, it must be admitted to the court's proceedings. This requires the permission of the judge and it is helpful if both sides agree; if not, the judge decides.

In general, records can be considered under the "best evidence rule" or the "hearsay rule." Different jurisdictions treat each rule and their exceptions in various ways, be they originals or copies. There are a number of precedents for accepting various types of records but none cover more than one type. The verification of authenticity is essential to any record being admitted as evidence.

### Human Readable Legal Documents

Several commissions have been formed to draft procedures that would establish conditions under which microfilmed records could, in general, be accepted as legal evidence. One commission proposed the "Uniform Photographic Copies of Business and Public Records as Evidence Act." Another developed the "Federal Rules of Evidence" for Federal Courts. These two sets of rules differ slightly and most states have adopted them in whole, or in part and consider the record as evidence without distinguishing whether it be original, facsimile, or a reduction copy. (The details of the form and media are subject to definition by the various jurisdictions and type of proceedings.)

Microfilming "in the normal course of business" is an important criterion which is supported strongly if records management procedures for microfilming are documented, including quality control and inspection procedures, and are rigorously followed. When microfilming, it is helpful to have a certificate giving the date filmed, the authorizing person, and the name of the camera operator recorded on the same roll of film.

### Conclusion

To improve the chances for a human-readable record to be accepted as legal evidence, it must be made according to the following minimum requirements:

(1) The original record must have been made in the ordinary course of business. If a facsimile, the copy must be made in the ordinary course of business - particularly when the records retention schedule permits that the original record may be destroyed or distributed such as checks, sales

slips, etc. (Computer generated microforms have been considered as an original and sometimes as a copy.)

(2) If copies are made, the process used must accurately reproduce the original on a durable media. For this purpose, a durable media appears to have several connotations. One, it must have a life expectancy of at least as long as the evidence (information) could be legally required; i.e., as long as the statute of limitations. Another, it must be possible to detect if the record has been altered. This is a means to reduce or detect fraud.

(3) The record must be identified and authenticated to be a true copy of the original.

References


(1) G. Walters, "The Optical Data Disk and the Office Information System," Association for Information and Image Management, Silver Spring, Maryland, publication no. D008.

(2) J. R. White, "Practical Preservation of Information," Association for Information and Image Management, Silver Spring, Maryland, publication no. D009.

(3) R. E. Williams, "Legality of Microfilm," Cohasset Associates, Inc., North Lake Shore Drive, Chicago, Illinois, 1980.


### 2.2.6 Panel Discussion: "What is the distinction between legal and archival requirements for any document; how could OD$^3$ be used in an application that requires both a legal and archival storage medium; how could archivability be viewed with respect to a new technology?"

**L. Fujitani, of Optimem** summarized the discussion following presentations of legal and archival requirements of an optical media unit, with the observation that microfilm can be read visually, whereas OD$^3$ requires a system to be read. The typical manufacturing lifetime of data processing products is 5 years; this means a useful life of 15 to 20 years, after which the product obsolesces. Therefore, when defining and specifying the life expectancy of OD$^3$ media, it is important to keep in perspective, its hardware requirements and their built-in life expectancy. Both aspects must be reasonably quantified, in relation to each other. There appears to be a major discrepancy between archivists and the OD$^3$ technologists regarding archival life.

## 2.3 SESSION III PRESENTATIONS AND DISCUSSIONS - TEST METHODS FOR DETERMINING RELATIVE MEDIA & DATA LIFE

### 2.3.1 UNRECORDED MEDIA - SHELF LIFE

**By Martin Levene**
**RCA**

Key words: accelerated aging test; activation energy; Arrhenius equation; relative humidity; shelf life; temperature; unrecorded media.

#### Introduction

Mr. Levene explained that "unrecorded" in the context of this presentation referred to media having no user-recorded data. He stated that the typical shelf life requirement for unrecorded media was 4 years, while the post recording requirement (expectation) was 10 years.

#### Accelerated Aging Tests

There is presently little supporting material available for projecting media shelf life. Accelerated aging test procedures are needed. The Arrhenius relation is one that has been used, since it gives some insight into the effect of prolonged elevated temperature on aging. (Reference: "Accelerated Versus Real Time Aging Tests," E. W. Kimball, 1980 Proceedings Annual Reliability and Maintainability Symposium.) The Arrhenius equation, based on time and temperature, is expressed as follows:

$$D = \frac{L}{e^{\frac{E}{R}\left(\frac{1}{T_N} - \frac{1}{T_A}\right)}}$$

where D is the test duration in days,
L is the life equivalent in days,
E is the activation energy (ev),
R is Boltzmann's constant $8.63 \times 10^{-5}$, ev/deg.,
$T_N$ is the normal temperature ($298^{\circ}K$),
$T_A$ is the accelerated aging temperature in degrees K.

Note: In $OD^3$ accelerated aging tests, high temperature is the principal environment factor while high humidity is a second factor.

The activation energy is the energy required to move an element out of a metastable state and into a stable state. The use of the Arrhenius relation assumes that there are no discontinuities in the behavior of the test specimen over the range of interest.

**Fig. 1** presents a plot, based upon the above Arrhenius equation, which can be used to predict the test duration needed to simulate a 10-year life for several test temperatures. The dashed line example in **fig. 1** shows that for activation energy (E) of 0.36 ev and accelerated test temperature ($T_A$) of 100°C, the test duration should be 220 days in order to project a 10-year lifetime. This approach can be of value to a vendor's quality assurance operation, once the appropriate values of E and $T_A$ are known.

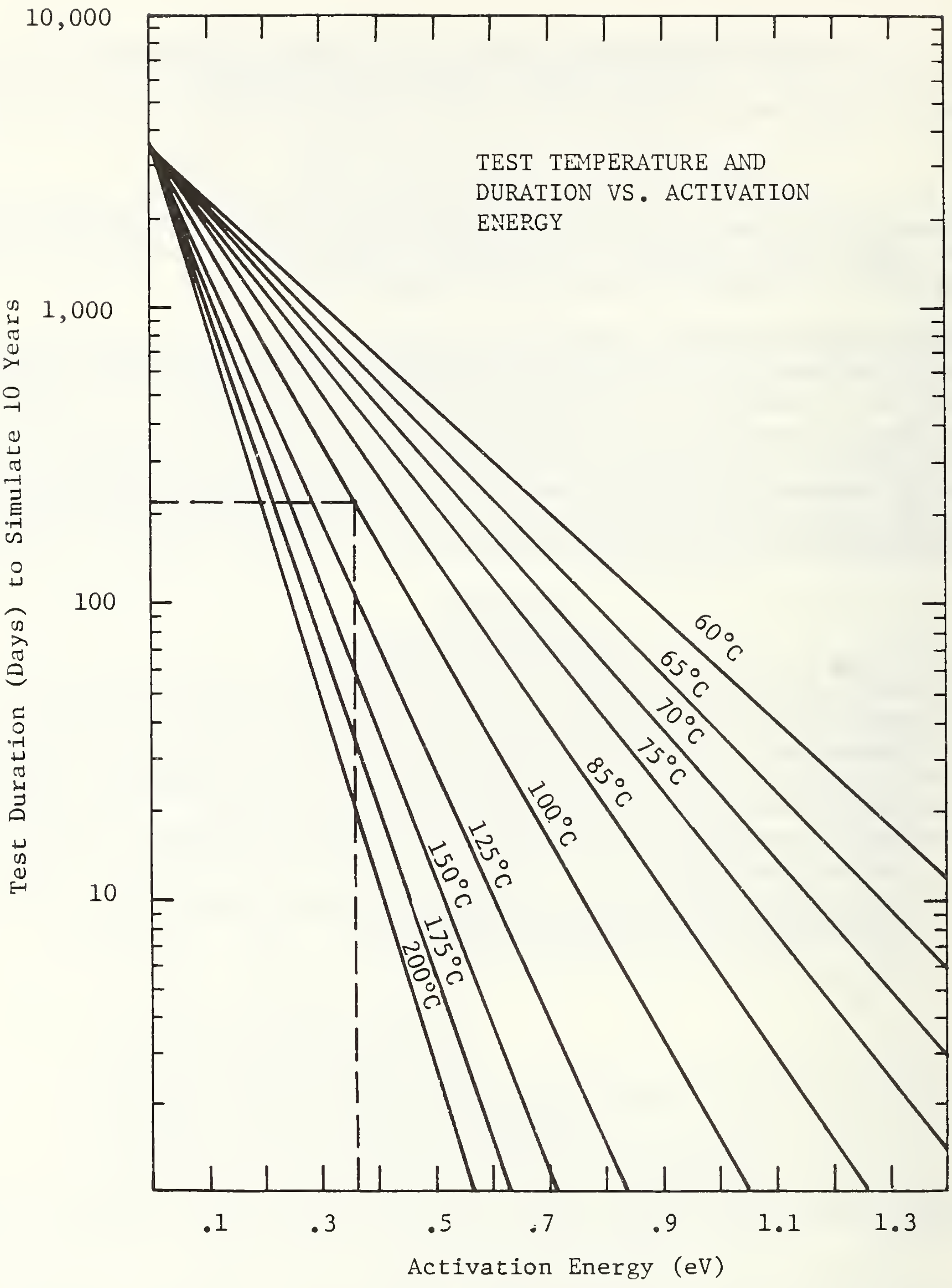
**Fig. 2** shows a replotting of the same Arrhenius equation, but this time graphed for a specific activation energy (again E = 0.36 ev as the example). With this plot, some further insight may be gleaned if the disk fails before 220 days. A failure after 100 days at 100°C, for example, would predict a 4-year life.

Humidity is another important factor in the aging process. If, however, the aging process can be shown to be relatively unaffected by variations in humidity, then the humidity level selected for accelerated testing can be chosen on the basis of convenience. Otherwise, it becomes necessary to determine the effects of humidity and then choose a test level in relation to the anticipated storage conditions. **Fig. 3** shows the expected Life vs. Temperature and Life vs. Relative Humidity (RH) curves for the situation wherein temperature is dominant and the variation of relative humidity is of relatively low significance.

## Conclusion

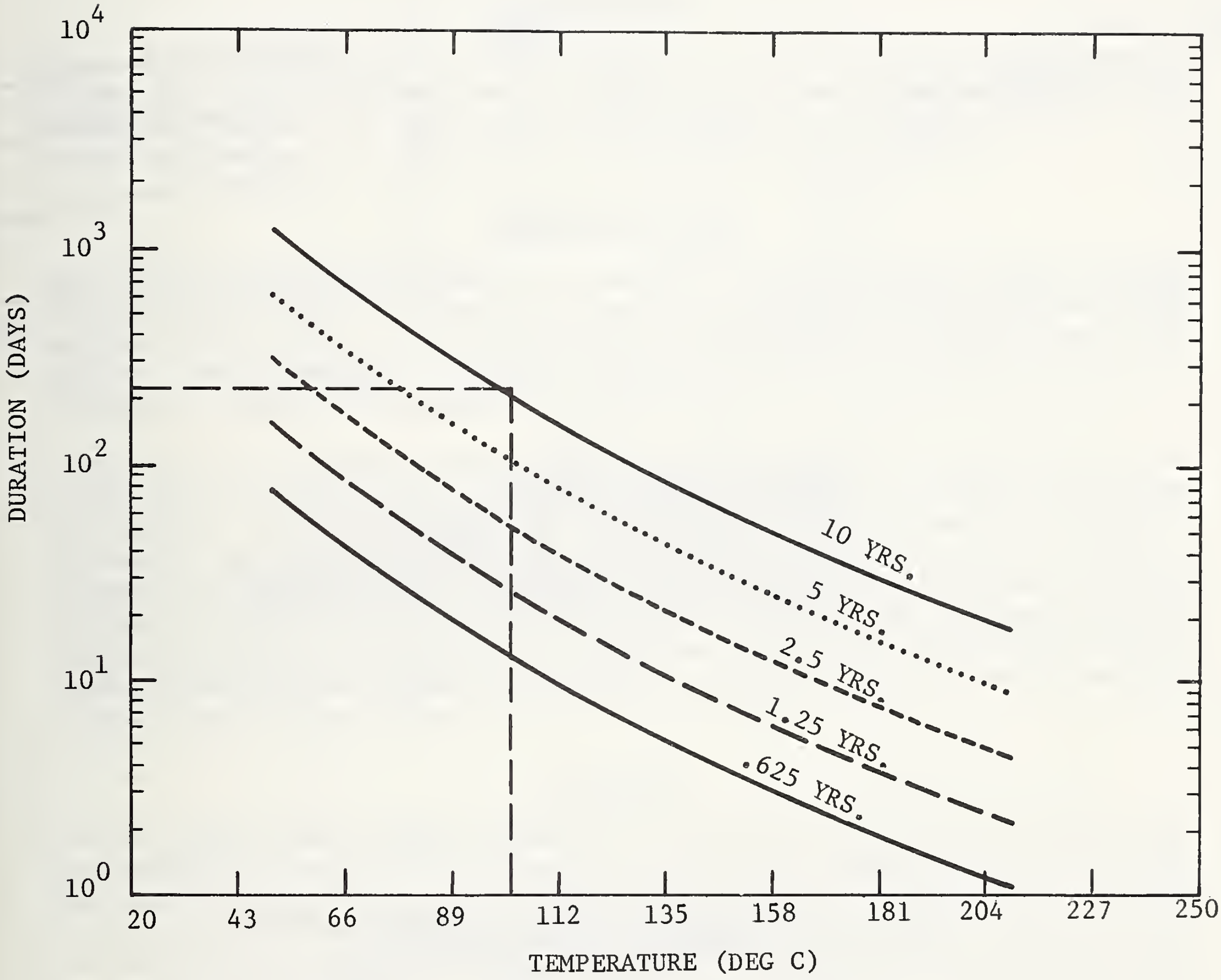
Important questions to be resolved relative to aging tests include the following:

(1) What are the appropriate activiation energy values for the candidate materials?
(2) Is oxidation or corrosion or another process (u-v exposure?) the important one?
(3) If both temperature and humidity variation is significant, how do we evaluate the data?
(4) Can a good correlation be established between accelerated aging test results and normal environment experience?




. Given activation energy and test temperature line
. Find duration of test before failure to predict ten year life

Figure 1. Optical Disk Testing Test Temperature and Duration vs. Activation Energy (Levene - RCA)



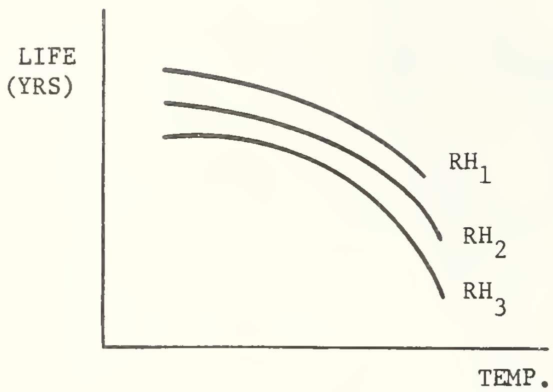

- GIVEN TEMPERATURE OF TEST AND DURATION OF TEST TO FAILURE
- FIND LIFE PREDICTION

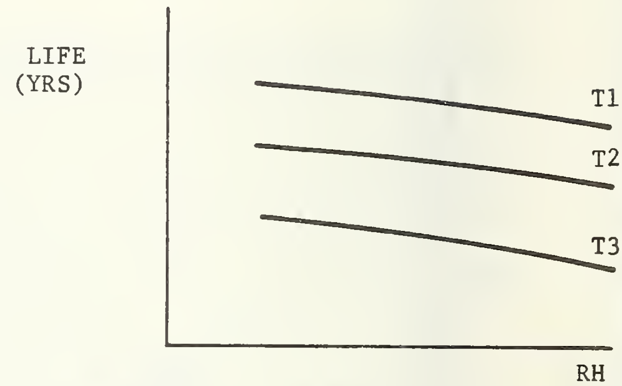
E = .36
AGING

Figure 2. Optical Disk Testing - Life Prediction
(Levene - RCA)

PROCEDURE FOR ONE POSSIBLE CONDITION, WHEREIN:

- TEMPERATURE IS DOMINANT INFLUENCE
- RH VARIATION IS OF LOW SIGNIFICANCE




THEN, FOR A GIVEN MATERIAL:

- SELECT FAILURE CRITERION
- SELECT CONVENIENT RELATIVE HUMIDITY (RH)
- PLOT PREDICTED LIFE VS. TEMPERATURE
- COMPARE NORMAL DETERIORATION RATE (LONG TERM TESTING) WITH ACCELERATED AGING TEST RESULTS

Figure 3. Optical Disk Testing - Humidity Included but Temperature Effect Dominant (Levene - RCA)

## 2.3.2 RECORDED MEDIA - DATA LIFE

**By Louis Spruijt**
**Optical Media Laboratories (OML)**

Key words: accelerated life test; corrosion of tellurium alloy; data life/error growth; degradation mechanisms; disk construction life; disk-drive interface (degradation of functional parameters); temperature/humidity test.

### Introduction

Louis Spruijt emphasized the importance of understanding the degradation mechanism of $OD^3$ recorded media. Degradation is not limited to only the $OD^3$ media construction. It can occur at other points in the system, such as the disk/drive interface or at data level of the disk/drive/system.

### Degradation Testing

Mr. Spruijt described advantages of using glass for protecting the $OD^3$ media's sensitive layer. Glass is known to be very stable, impervious to contaminants, and quite scratch resistant. It can be processed to achieve a ten-fold improvement in its ability to resist breakage. The glass substrate used in the OML disk is treated to increase its resistance to breakage.

A standard I.E.C. temperature/humidity test for degradation of media life involves daily cycle for a prolonged period. In this testing the effect of water and oxygen on the tellurium alloy is the increase of the transmittance, thereby lowering the reflectivity and reducing the signal. The choice of composition for the alloy is important for stability against corrosion. Also, the accelerated test shows changes on tracking and synchronization drive/disk system margins. On data level, an error analysis is helpful to determine the degradation mechanisms of the data integrity. A comparison between original data and life tested data errors on media identified by their exact location is used.

### Conclusion

Disk life can be tested using an accelerated life test. Life of the data written or the usability of empty tracks depends on different mechanisms; e.g., life of the hermeticity of the disk, life of the reflectivity within the system margin or growth in number and/or size of defects. Special testing conditions are necessary for open and closed disks. Acceleration factors for the different degradation mechanisms for the test can be estimated. For OML disks, the corrosion of the tellurium layer and the growth of the number of micro-sized errors showed to be (relatively) the important factors for degradation, occurring only after the moment the hermeticity of the disk is broken introducing condensation of water onto the disk recording surface during test conditions. **(See figs. 1-12, table 1, and figs. 13-14.)**

## AGING OF OPTICAL MEDIA

- DEGRADATION MECHANISM OF MEDIA
- ACCELERATED AGING TESTS

Figure 1. Factors to Determine for Estimating the Expected Life of Media (Spruijt - Optical Media Laboratories)

## DEGRADATION CAN OCCUR ON DIFFERENT LEVELS

- DISK CONSTRUCTION
  - . MECHANICAL
  - . OPTICAL
  - . HERMETICITY
- DISK - DRIVE INTERFACE
  - . FOCUSSING
  - . TRACKING
  - . SYNCHRONIZATION
- DATA
  - . READ RELIABILITY
  - . WRITE RELIABILITY

Figure 2. Degradation Levels (Spruijt - Optical Media Laboratories)

## DISK CONSTRUCTION

MECHANICAL

- VIBRATION TESTS
- SHOCK MECHANICAL
- IMPACT TEST
- DROP TEST

OPTICAL

- SCRATCH TEST
- DUST TEST

HERMETICITY

- SHEER TEST
- THERMAL SHOCK TEST
- PRESSURE TEST
- HUMIDITY/TEMPERATURE TEST

Figure 3. Degradation Mechanisms and Tests
(Spruijt - Optical Media Laboratories)

## DISK - DRIVE INTERFACE

FOCUSSING - HUMIDITY/TEMPERATURE TEST

- BLISTERING OF SENSITIVE LAYER
- WARPING OF SANDWICH
- CORROSION OF SENSITIVE LAYER

TRACKING/SYNCHRONIZATION

- CORROSION OF SENSITIVE LAYER
- SWELLING OF SUBBING LAYER

Figure 4. Degradation Mechanisms and Tests
(Spruijt - Optical Media Laboratories)

## DATA

READING:

- GROWTH OF DEFECTS
- GROWTH OF NOISE LEVEL
- REDUCTION OF SIGNAL TO NOISE RATIO

WRITING:

- CHANGE OF HOLE OPENING PROCESS
- CHANGE OF THE FOCUS QUALITY DUE TO DISK DEGRADATION

Figure 5. Degradation Mechanisms and Tests
(Spruijt - Optical Media Laboratories)

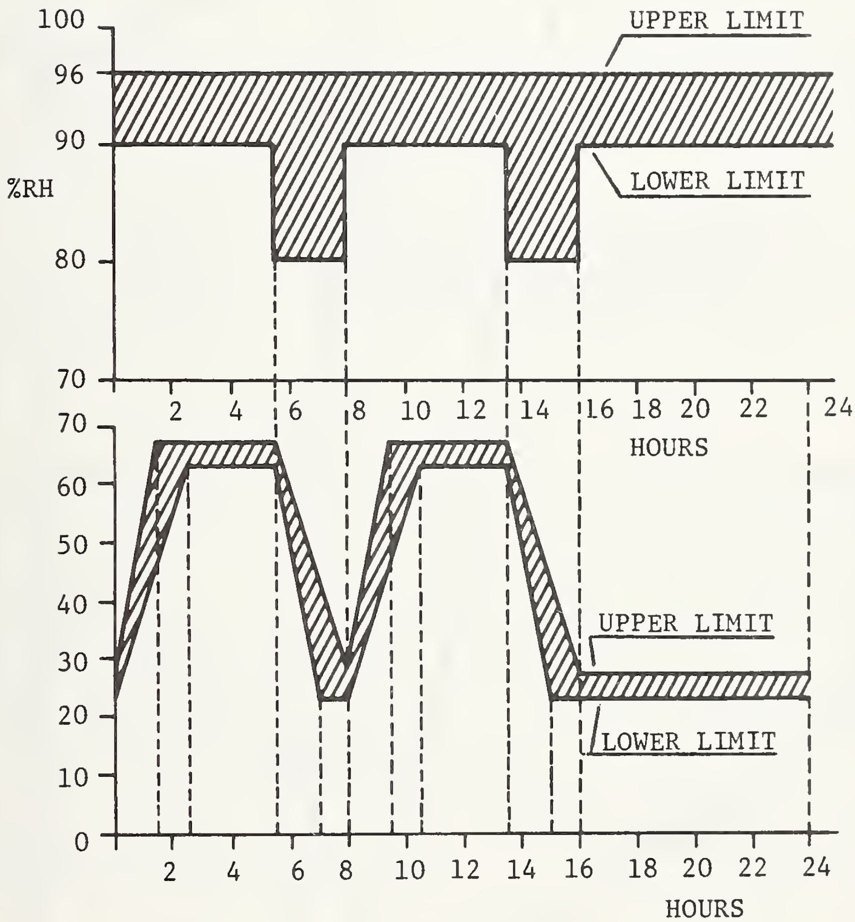



Figure 6. Z/AD Temperature and Humidity
I.E.C. Test (Z/AD) Daily Cycle
(Spruijt - Optical Media Laboratories)

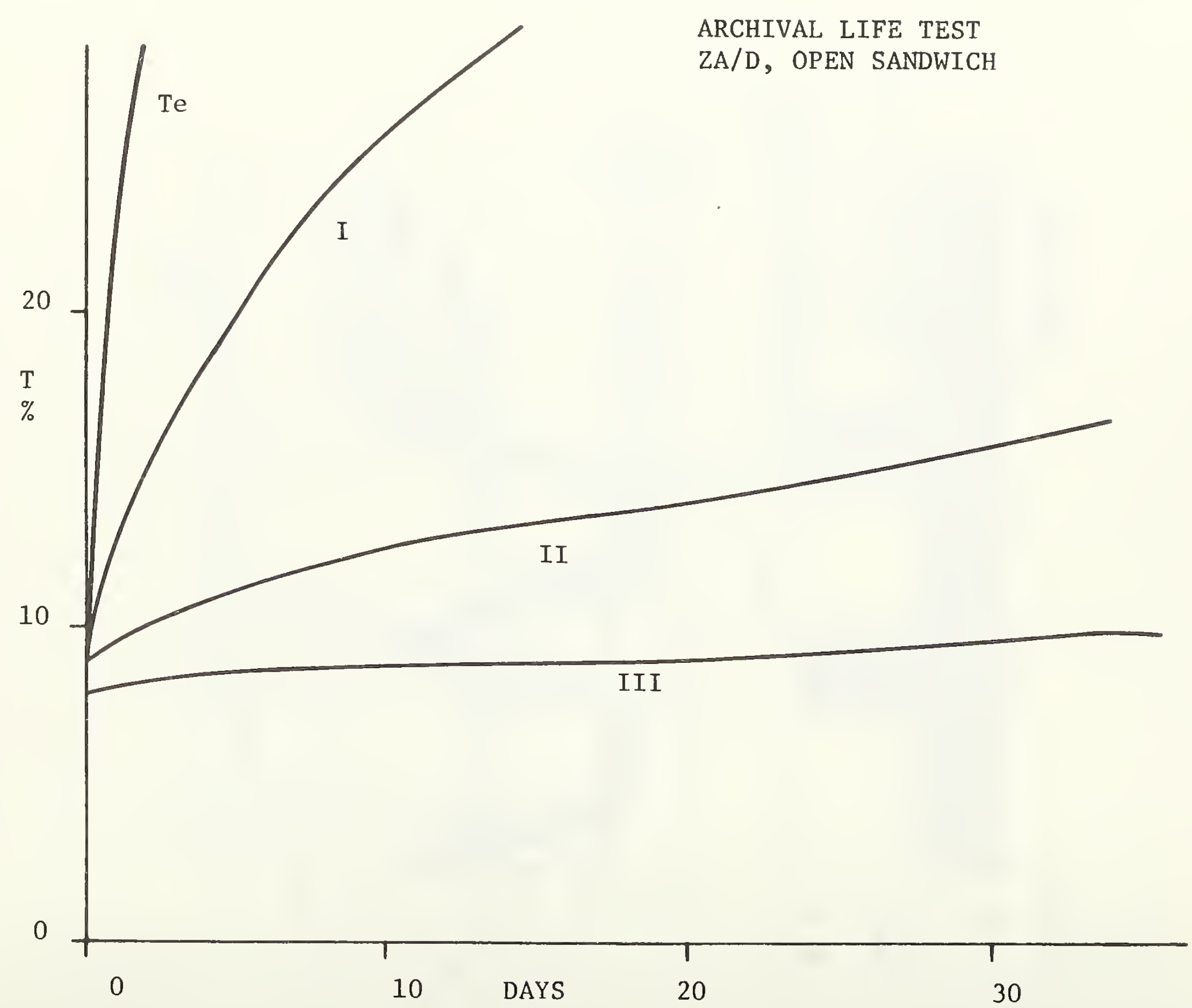



Figure 7. Corrosion of Te and Te Alloys, Impact on Transmission or Reflection (Spruijt - Optical Media Laboratories)

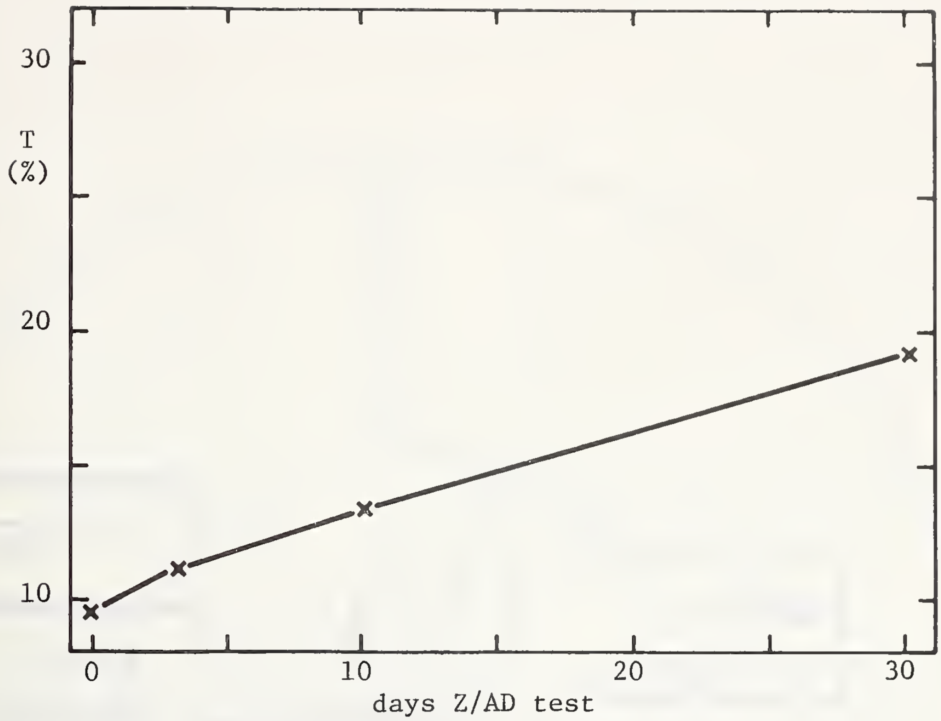
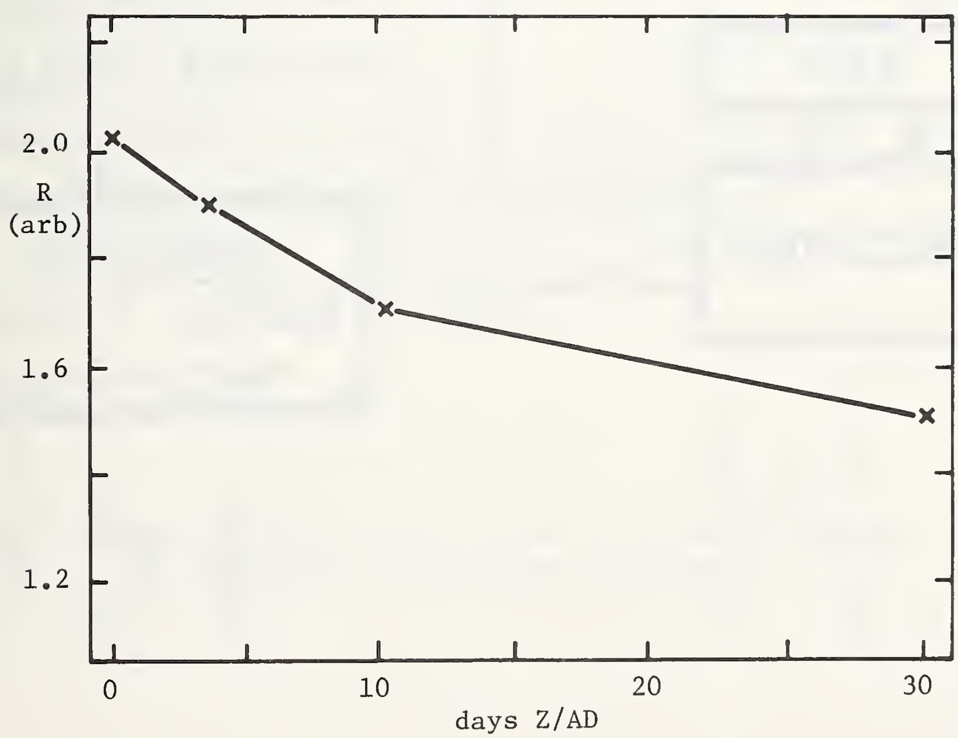



Figure 8. Corrosion of Te and Te Alloys,
Impact on Transmission and Reflection
(Spruijt - Optical Media Laboratories)



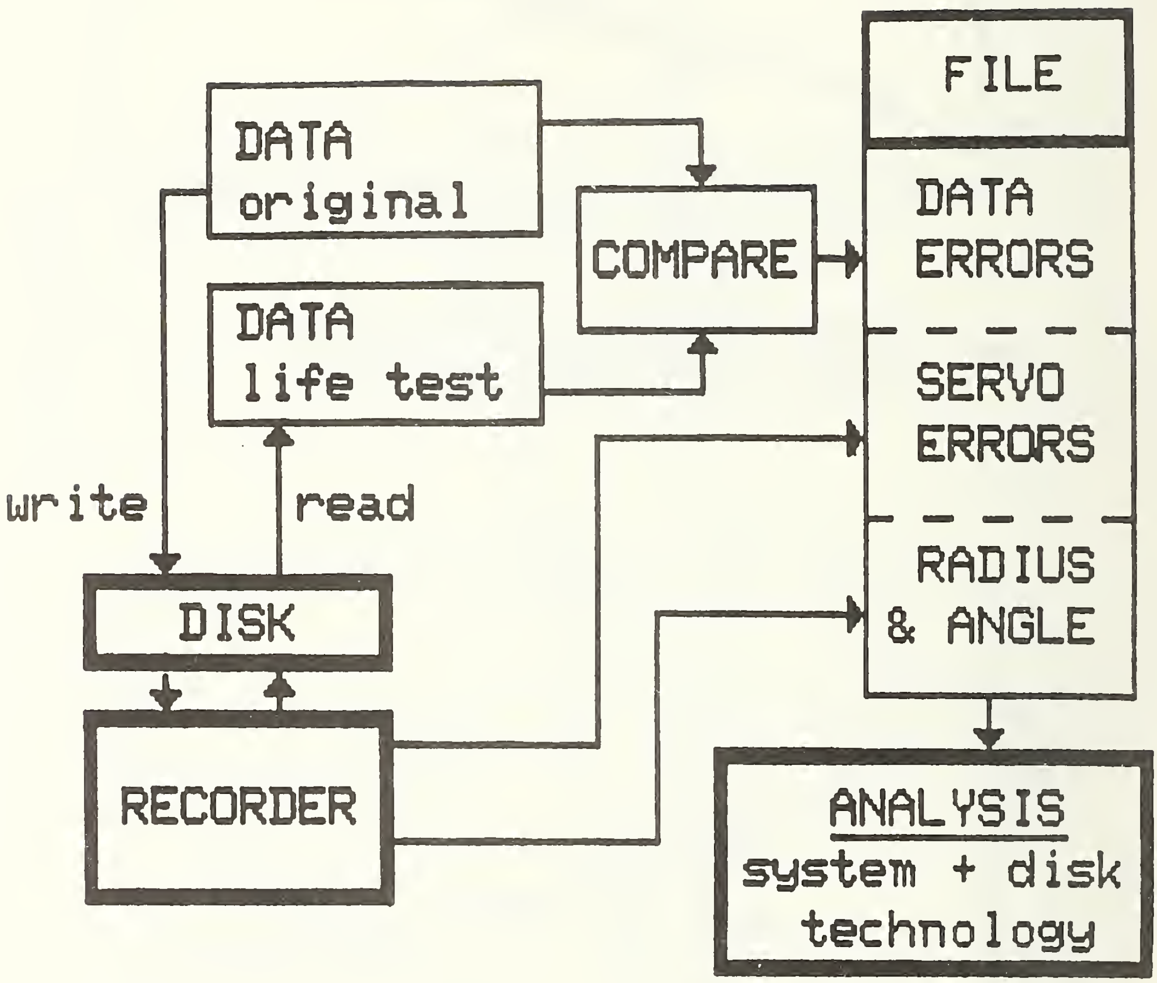



Figure 9. Analysis Setup of Error Growth in Number or Size
(Spruijt - Optical Media Laboratories)

FILE CODE:

20588/01200

FIRST TRACK:

20000

LAST TRACK:

21498

BIT ERROR RATE:

3.28E-06

SECTOR ERROR(S):

0

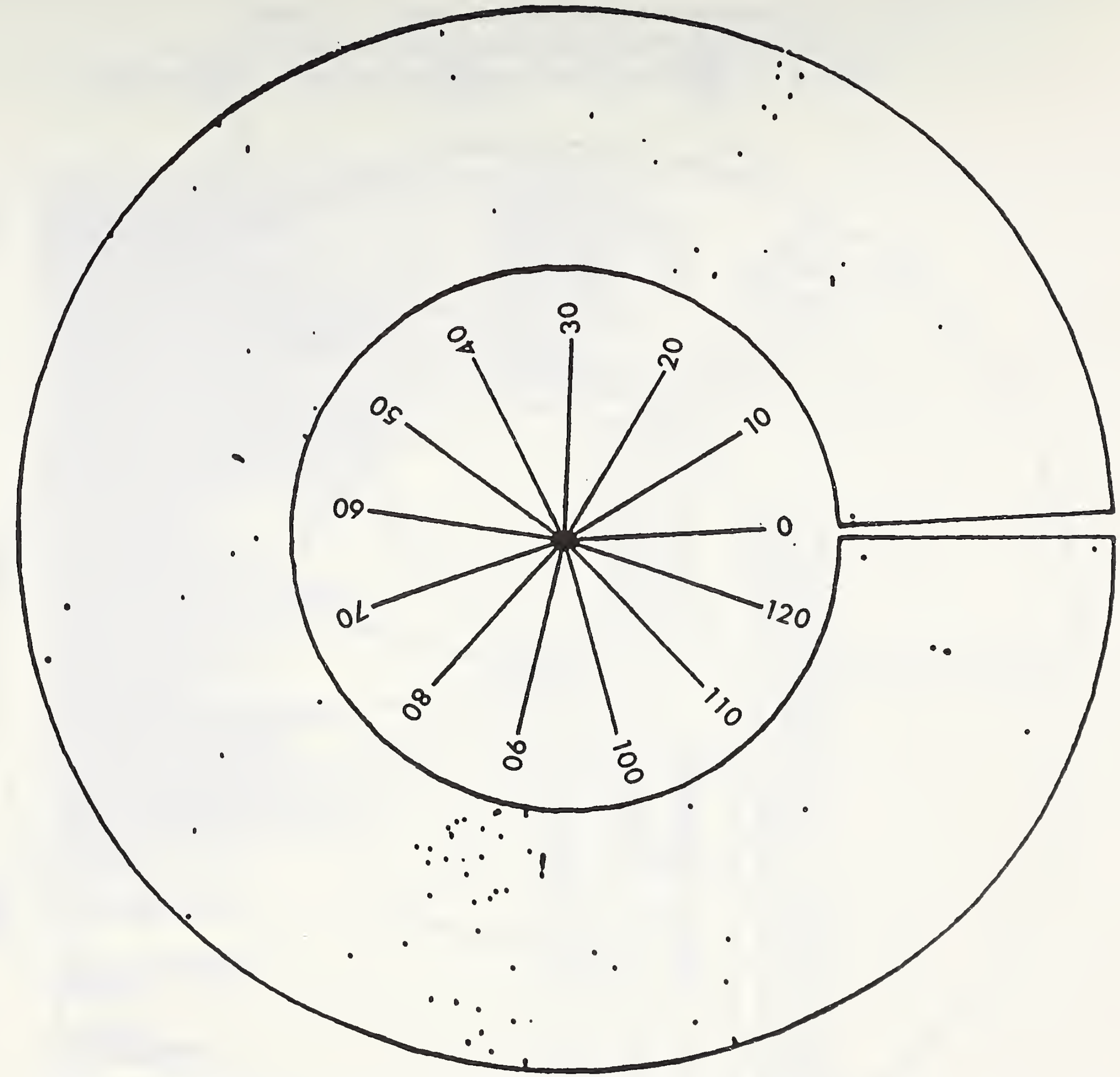



Figure 10. Typical Bit Error Rate Increase of a Z/AD Life Tested Non-Hermetic Disk, Ten Days (Spruijt - Optical Media Laboratories)

FILE CODE:
20588/01200

FIRST TRACK:
20000

LAST TRACK:
21498

BIT ERROR RATE:
6.34E-05

SECTOR ERROR(S):
0

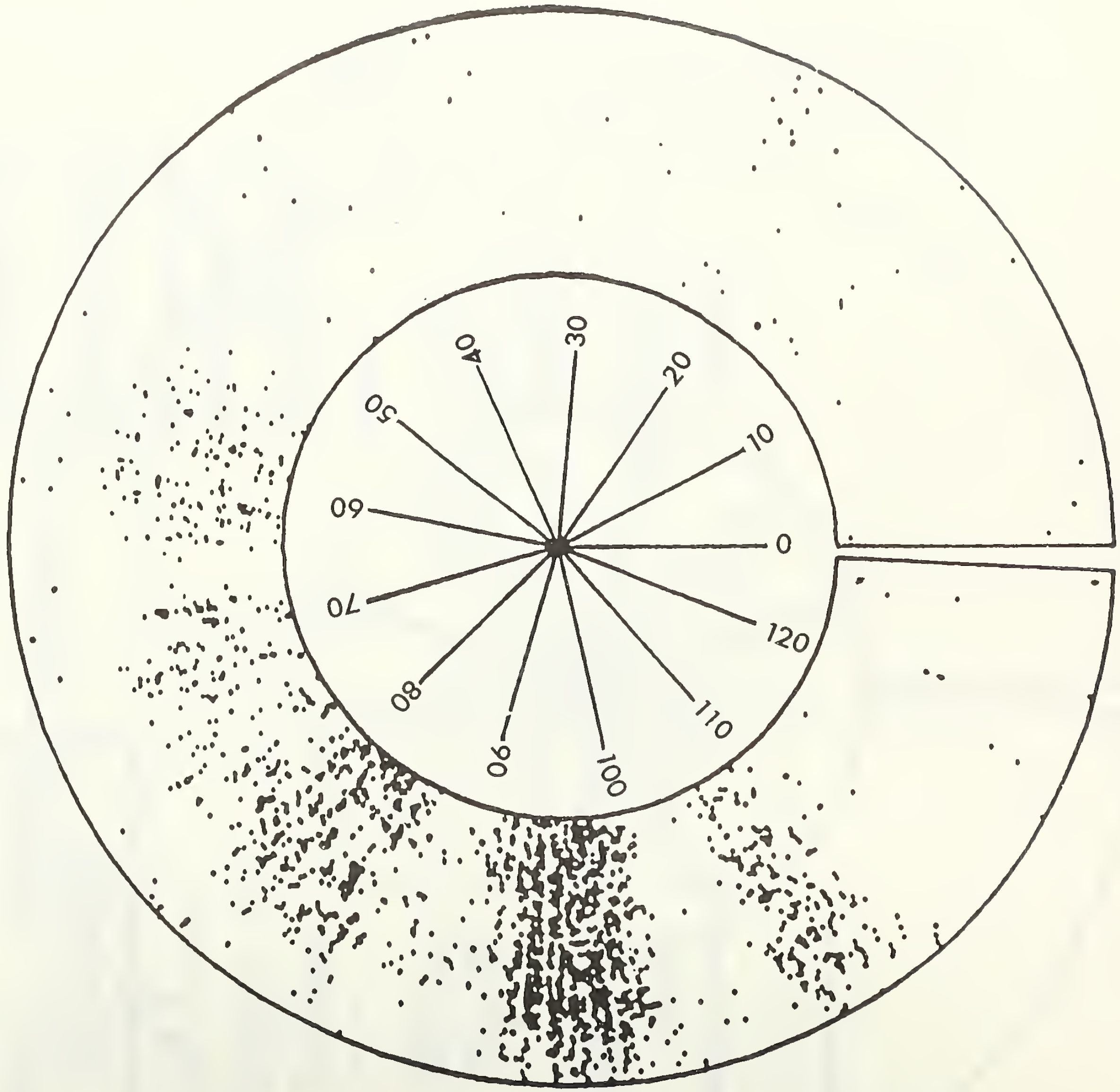



Figure 11. Typical Bit Error Rate Inrease of a Z/AD Life Tested Non-Hermetic Disk, Thirty Days (Spruijt - Optical Media Laboratories)

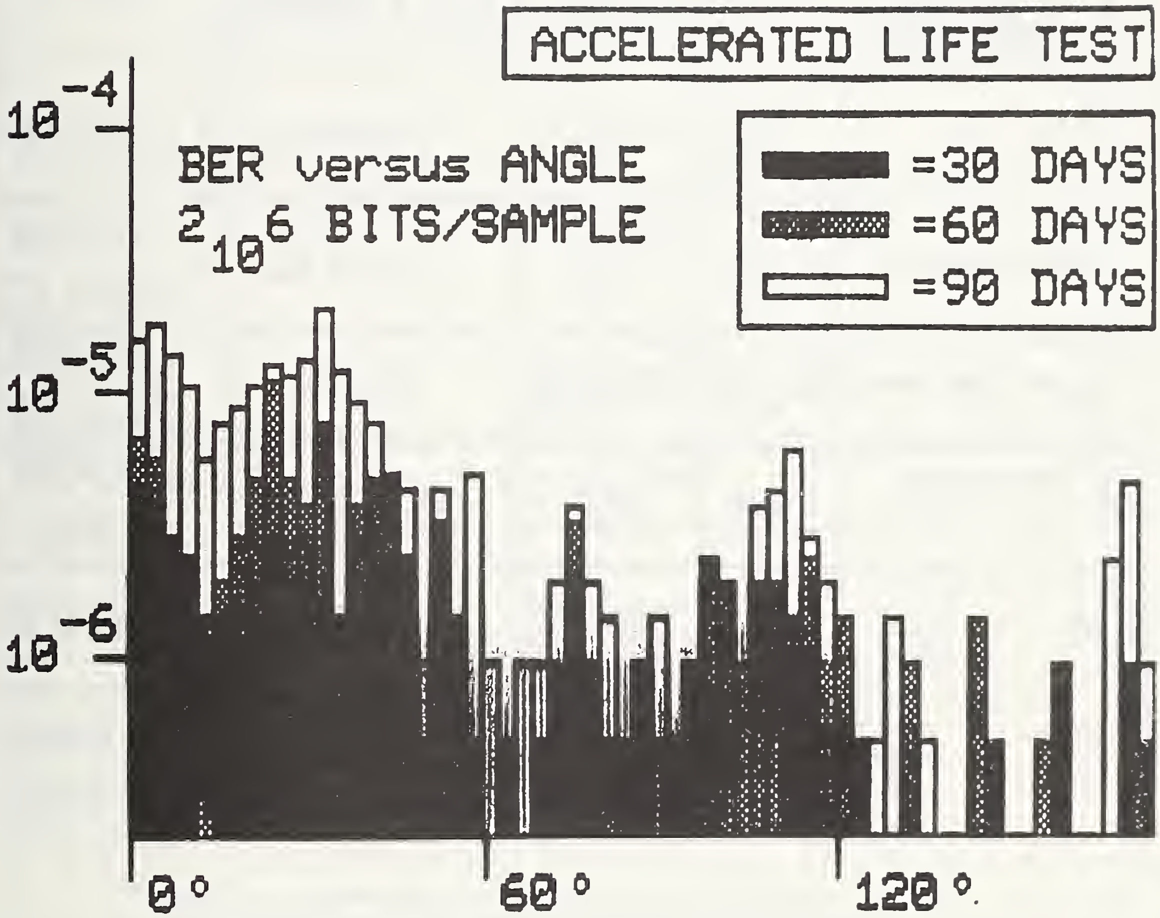



Figure 12. Typical Bit Error Rate Increase of a Z/AD Life Tested, Non-Hermetic Disk (Spruijt - Optical Media Laboratories)

| TIME | IN HOURS | 1 | 700 |
|---|---|---|---|
| BER X $10^{-6}$ | | 5.0 | 35.0 |
| TRANSMISSION | % | 13.2 | 15.2 |
| PNR | IN dB | 47 | 42 |
| SNR (WRITTEN HOUR 1) | IN dB | 56 | 53 |
| SNR (WRITTEN HOUR 700) | IN dB | | |
| SENSITIVITY | IN nj | 0.40 | 0.45 |

Table 1. Typical Degradation of Functional Parameters of Non-Hermetic Disks in Accelerated Test After 700 h. Test (Spruijt - Optical Media Laboratories)

| DISK | STORAGE CONDITION | T (°C) | RH % | ACC. FACTOR |
|---|---|---|---|---|
| SINGLE | OFFICE | 25 | 50 | 5 |
| SANDW. CLOSED | OFFICE | 25 | 50 | <<1 (?) |
| SANDW. CLOSED | ZA/D | 25-65 | 93±3 | 1 (?) |
| SANDW. OPEN | OFFICE | 25 | 50 | 4 - 10 |
| SINGLE | ZA/D | 25-65 | 93±3 | 50 - 100 |
| SANDW. OPEN | ZA/D | 25-65 | 93±3 | 200 - 1000 |

Figure 13. Acceleration Factors for Different Disk Constructions Compared with Office Condition (Spruijt - Optical Media Laboratories)

## 2.3.3 TEST METHODS FOR MEASURING LIFE EXPECTANCY OF PHOTOGRAPHIC MATERIALS

**By Peter Adelstein**
**Eastman Kodak Company**

Key words: American National Standards Institute (ANSI); Arrhenius relationhip; permanence, predicting useful life; optical density; photographic materials.

### Introduction

Defining the useful life of a material is only the first step in the preparation of a specification. Much more difficult is establishing the useful life and in standardizing test conditions which can predict it. The past decade has witnessed a considerable number of studies on photographic materials with these objectives. Most of these followed a very similar approach. A study of diazo film can illustrate the method that was used[1].

### Arrhenius Approach Applicable

A number of diazo films were stored in the dark for periods up to three years at a series of elevated temperatures and at a constant moisture level. Photographic density was determined as a function of keeping time. **See fig. 1**, which illustrates the typical density increase of a low density area at a series of temperatures. Similar curves were obtained for other films, as well as for other measurements of image change (such as density decrease of a high density area).

In addition to determining the temperature dependence of the images, it was necessary to specify the maximum density change which could be tolerated without affecting the usefulness of the film. The concept of usability is difficult to quantify, but definitive density changes must be agreed to before a specification can be written. This was done for the diazo films by examining different diazo images which were specially prepared with a wide range of density values. Two criteria of density change were agreed to, one specifying the maximum tolerable density in the Dmin (minimum density) areas, and the second specifying the minimum difference between the low and high density areas. These density criteria were then used to analyze the density-time plots such as shown in **fig. 1.**

At each temperature, the time was determined at which the useful life was exceeded. In other words, the high temperature incubation studies were able to yield useful lifetimes at a series of elevated temperatures. The next step was to extrapolate the useful lifetime to room temperatures. This was accomplished using the classical chemical kinetics approach of Arrhenius[2]. He had determined that there is a linear relationship between the log of the rate of a chemical reaction and the reciprocal of the absolute temperature. In the diazo study, a linear relationship was obtained when the log of the useful lifetime (which is inversely proportional to rate) was used. Typical graphs are shown in **fig. 2** from which the useful life at 21°C was determined by extrapolation.

It is recognized that the Arrhenius plot is intended to apply to simple chemical reactions. However, it is being used for rather complex behavior featuring both the reactions of various diazonium compounds and their light absorbing properties. For this reason, it can be considered as an empirical treatment of the data. However, this does not detract from the usefulness of this approach. As will be shown later, it is extremely difficult to prepare a meaningful permanence specification when the Arrhenius approach breaks down.

The Arrhenius plots in **fig. 2** for the three films are almost parallel. This indicates that the temperature dependence of density change are fortunately very similar for these films. This allows the construction of an Arrhenius graph which can establish appropriate incubation conditions for a dizao stability test. **Fig. 3** shows Arrhenius plots, drawn with the same slope as found in **fig. 2**, through points for long-term and medium-term keeping behavior at 21°C. Incubation test conditions at 70°C and 80°C were established and incorporated into the ANSI specification.

The Arrhenius treatment of high temperature incubation results has proven to be very useful for other products besides diazo films. **Fig. 4** shows a similar graph for the cyan dye fading of color motion-picture film(3). More extensive dye fading data has been recently published(4), as illustrated in **fig. 5**, which gives the Arrhenius relationship found for a color professional film at various density changes. This data treatment has also been successfully applied to the density increase of a silver image x-ray film **(fig. 6)** which was washed to different levels of retained thiosulfate(5).

Besides its application for changes in the photographic image, Arrhenius plots have been used to follow physical changes of photographic products. **Fig. 7** shows the rate in surface brightness decrease of photographic paper plotted against the reciprocal of absolute temperature(6). The rate of fold decrease of photographic paper(7) is given in **fig. 8** and the tensile strength loss of photographic film(8) in **fig. 9**. These physical changes are equally as important as the image changes in determining the useful life of a material.

<u>Arrhenius Approach not Applicable</u>

It has been demonstrated that when the rate of image or physical change follows the Arrhenius relationship, high temperature results can be used to predict room temperature behavior. While this involves a great deal of laboratory work and is a very extended and extensive study, the approach is quite straightforward. However, when the Arrhenius relationship does not apply, prediction of room temperature behavior becomes an extremely difficult technical problem.

A good example of this type of behavior was experienced by a PH1 task group who were preparing an ANSI specification on the permanence of vesicular film. Vesicular film is a light-sensitive photographic material in which the developed image consists of many small bubbles, or vesicules, or nitrogen gas which are embedded in a polymer matrix. The vesicles scatter the incident light and create an opaque image when viewed by reflection. The stability of the image depends on the preservation of the very small vesicles in the polymer matrix.

Unlike the image changes observed with diazo and color films at elevated temperatures which are the result of chemical reactions, image changes with vesicular film are due to a physical change. At high temperatures, the polymer matrix softens, the vesicles collapse and the image disappears. The fallacy in applying the Arrhenius treatment to predict long-term room temperature behavior is that the polymer softening which occurs at high temperatures is not a good reflection of room temperature behavior[9,10]. This is illustrated by the Arrhenius plots[9] in **fig. 10**. The solid lines represent the time for a 10% loss in the high optical density area and there is a discontinuity at a temperature of 63°C. This temperature represents the softening temperature or glass transition temperature of the polymer binder. Extrapolation of the high temperature data would predict a useful life which is considerably less than extrapolation of the low temperature data. However, the latter extrapolation is not practical to use to evaluate films because of the long incubation times required.

The discontinuity in polymer behavior with temperature is shown by the dashed lines in **fig. 10**. These plots were obtained by measuring the penetration of a weighted probe into the thickness of the image layer. The change in slope of the Arrhenius relationship also occurred at the glass transition temperature of the polymer binder. This was additional evidence that flow properties of the binder at high temperature cannot be used to predict those at more moderate conditions.

The problem in predicting the useful life of vesicular film can be simply stated. High temperature data cannot be interpreted and moderate temperature data show image changes which are much too small to use for extrapolation. The latter behavior may give strong support (depending on the glass transition temperature) to the viewpoint that image stability should not be a significant problem if the film is stored below the glass transition temperature. However, it does not give comfort to the user who would like an accelerated test with which to evaluate the product.

The ANSI task group worked on this problem for a number of years and finally resolved it by taking a very empirical approach. They agreed to standardize a test procedure which involved a relatively long time at an incubation temperature slightly below the glass transition temperature. The criteria for passing was an optical density change just above the noise level of the densitometer. This rather severe test, coupled with 20 years of practical keeping experience, should give the user confidence that such films will have a useful life of at least 100 years. However, the physical behavior of vesicular films as a function of temperature precludes the use of a scientific method of useful life extrapolation.

## Conclusion

Standardizing the permanence of materials in the image technology field has been an ongoing activity for over four decades. This has resulted in the publication and dissemination of information which has increased manufacturers' awareness of product requirements and consumers' awareness of product performance. In addition, a technical approach has been established which can determine the useful life of materials which show a continuous property change with temperature. It is expected that this experience can be of benefit to those in the optical disk field who are concerned with establishing the permanence of these media.

Figure 1. Density Change of Diazo Film after Incubation (Adelstein - Eastman Kodak Company)

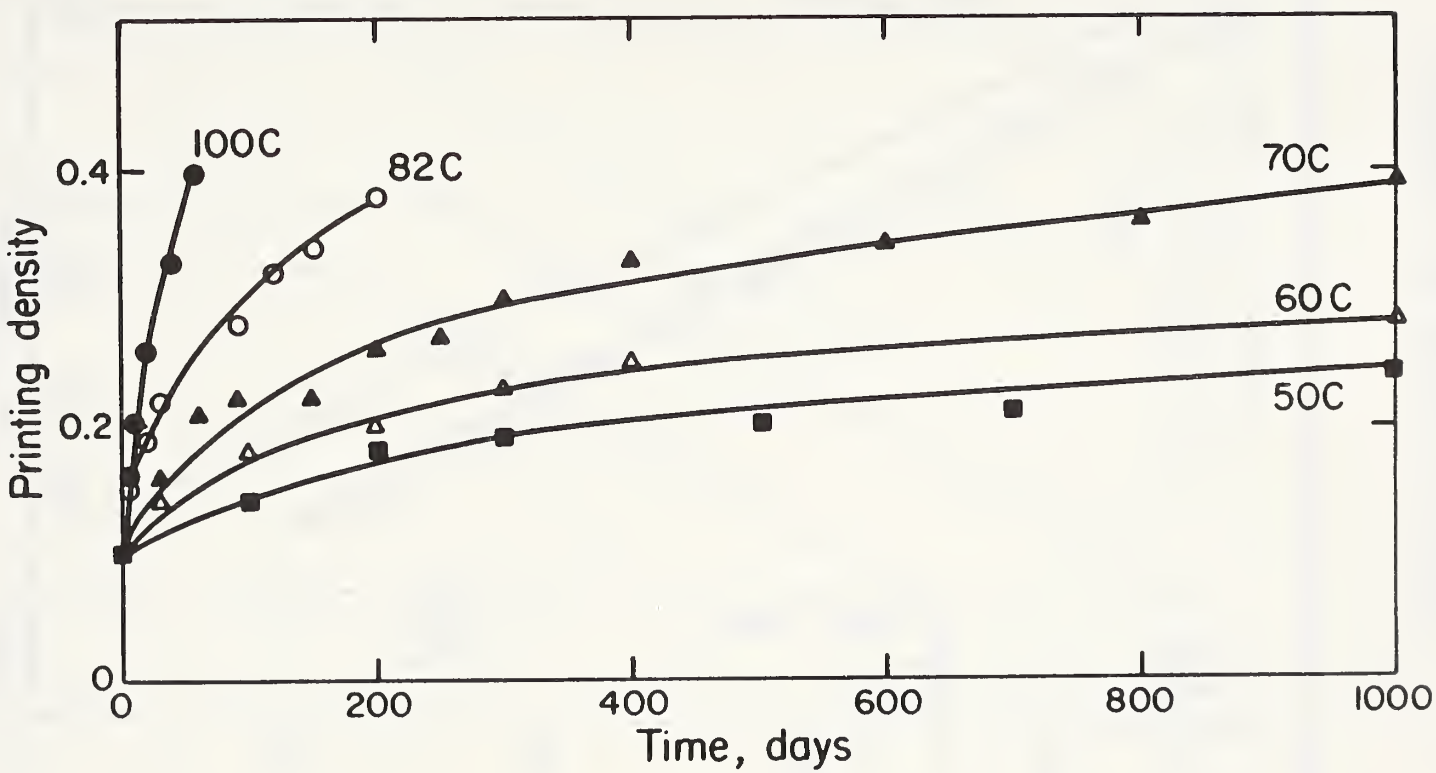


Figure 2. Arrhenius Plots for Printing Density Change of Diazo Film
(Adelstein - Eastman Kodak Company)

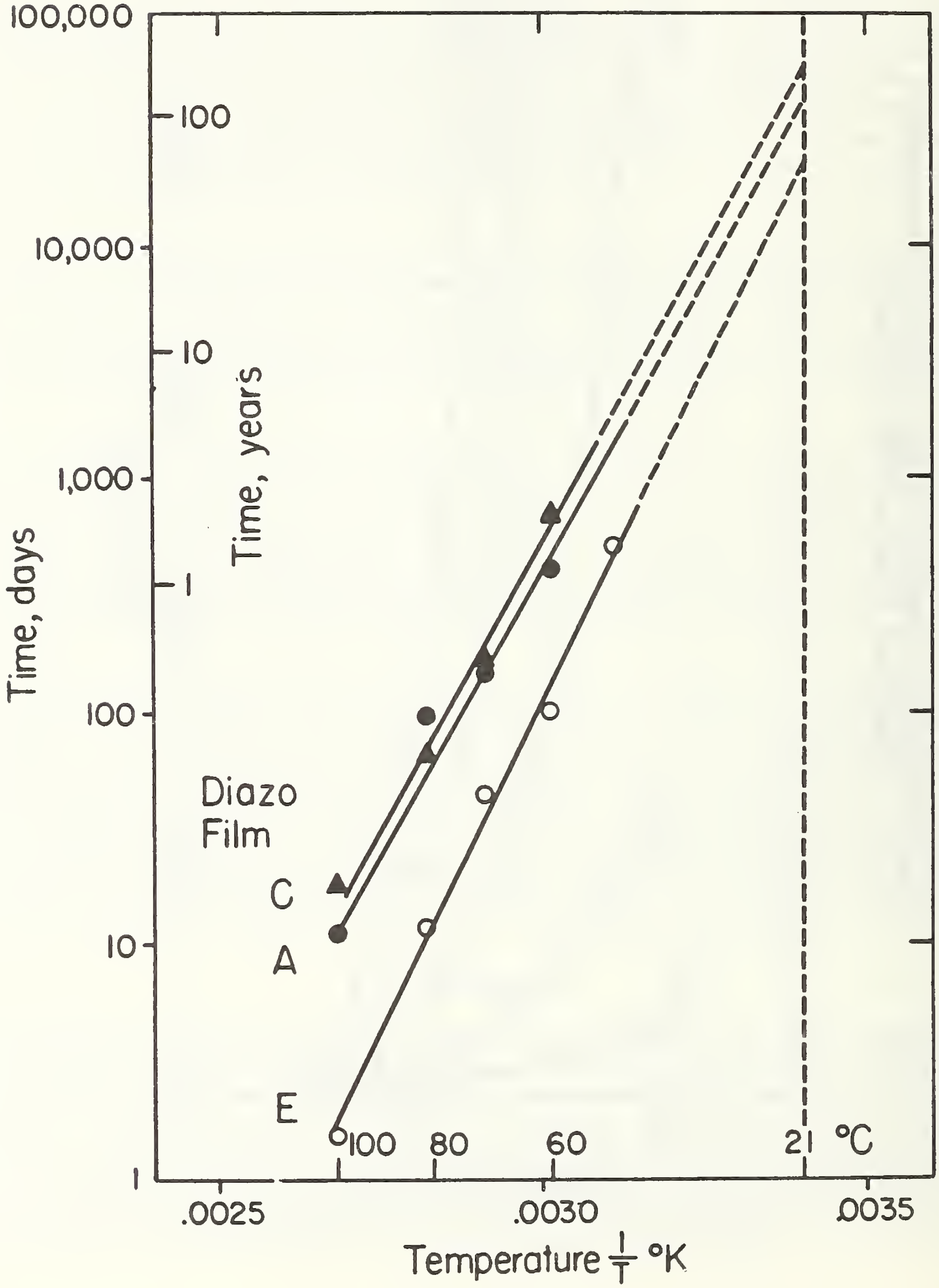


Figure 3. Arrhenius Plots to Establish Incubation Conditions for Image Stability Test of Diazo Films (Adelstein - Eastman Kodak Company)

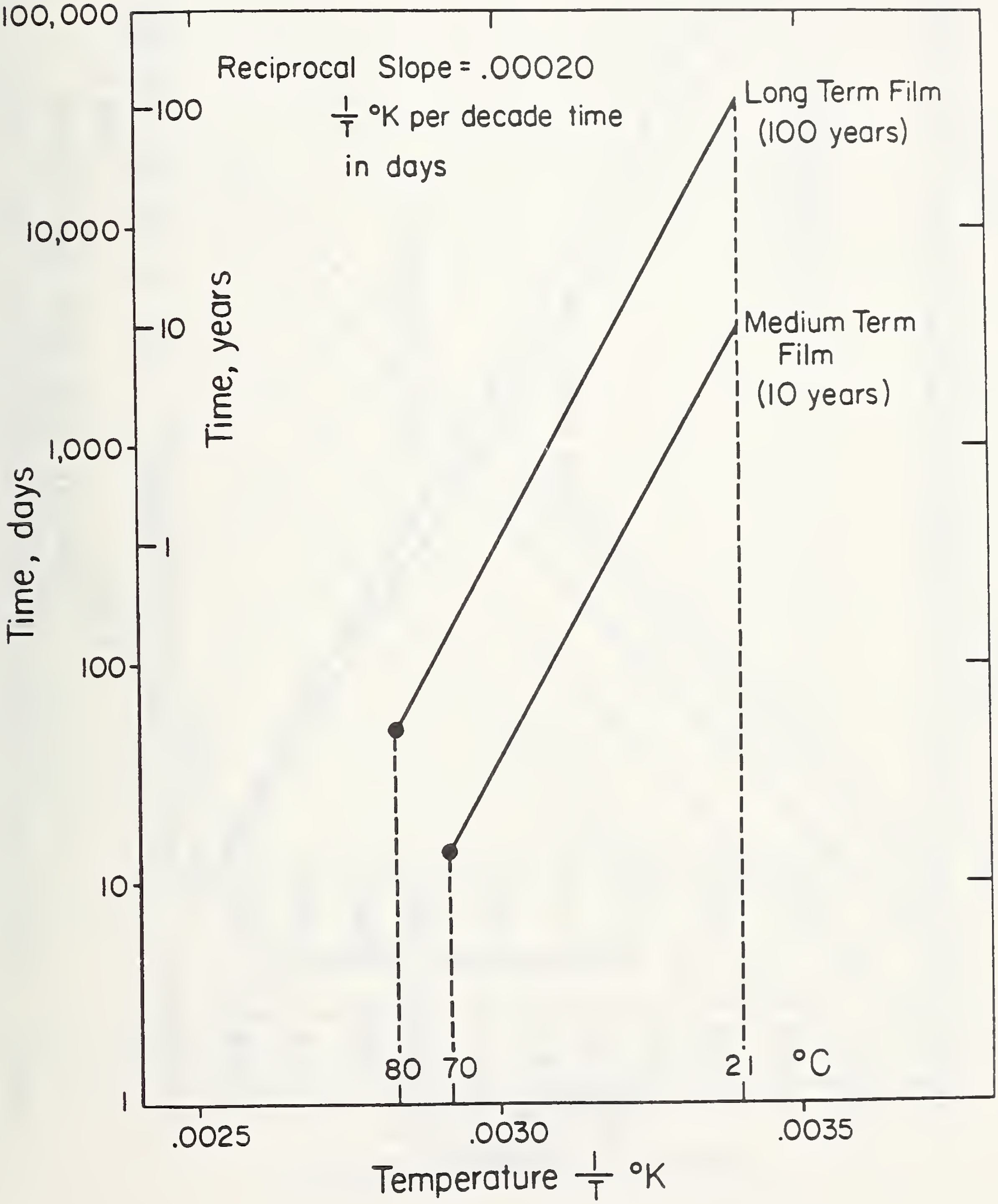


Figure 4. Arrhenius Plots for Cyan Dye Density Decrease of Motion-Picture Film
(Adelstein - Eastman Kodak Company)

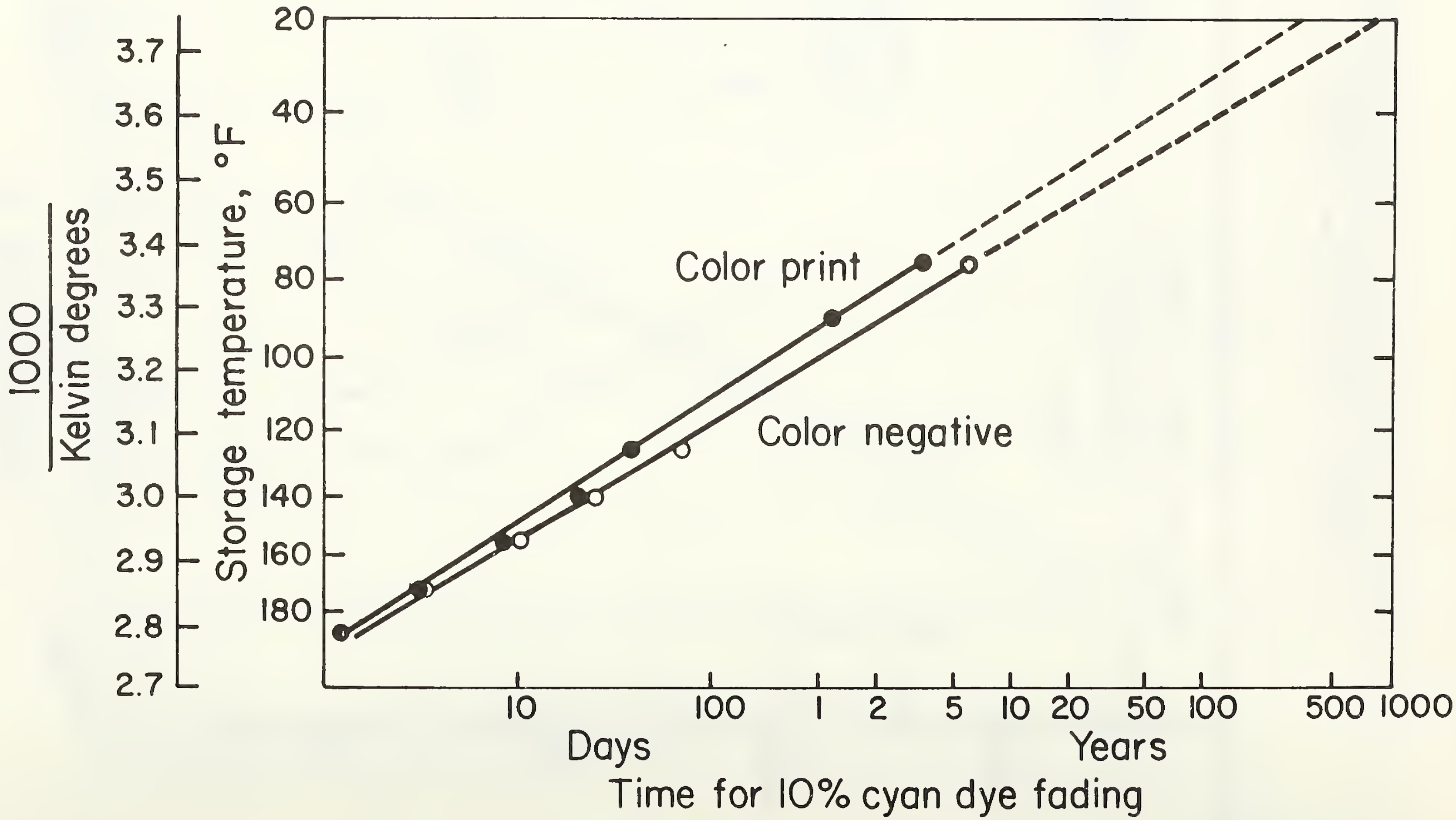


Figure 5. Arrhenius plots for cyan dye density decrease of color film. Original density = 1.0
(Adelstein - Eastman Kodak Company)

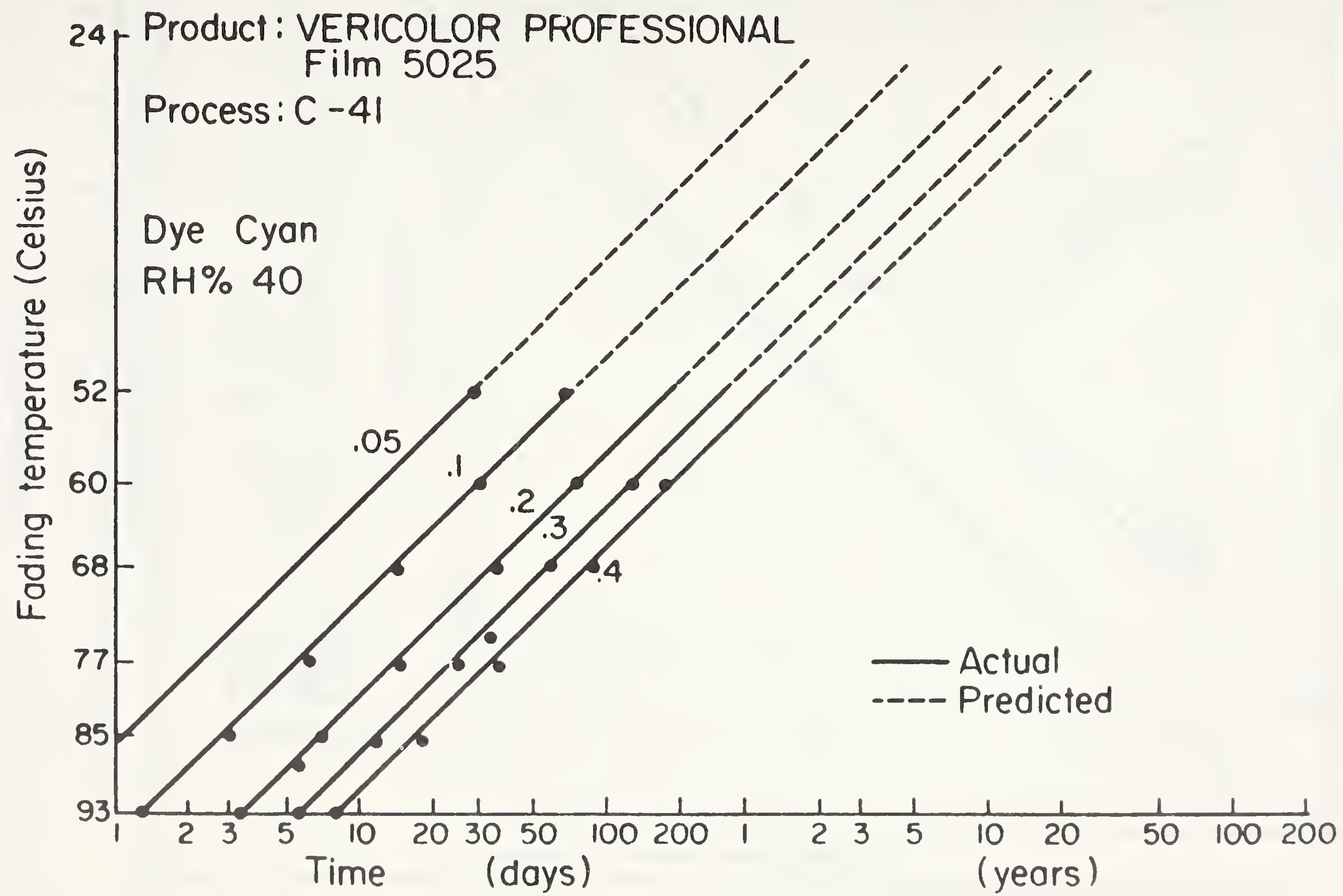
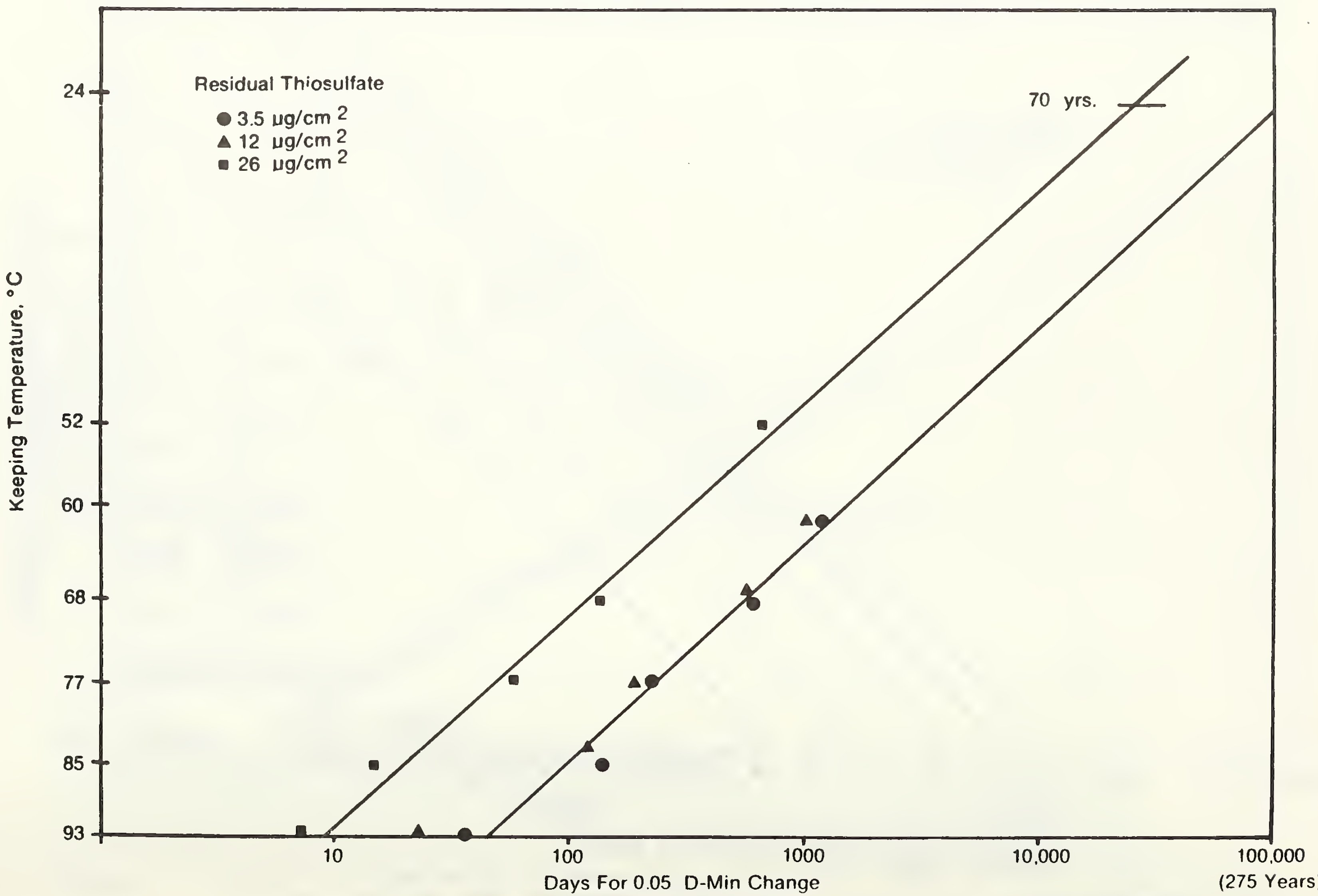


Figure 6. Arrhenius Plots for Density Increase of X-Ray Film with Different Residual Thiosulfate Levels
(Adelstein - Eastman Kodak Company)



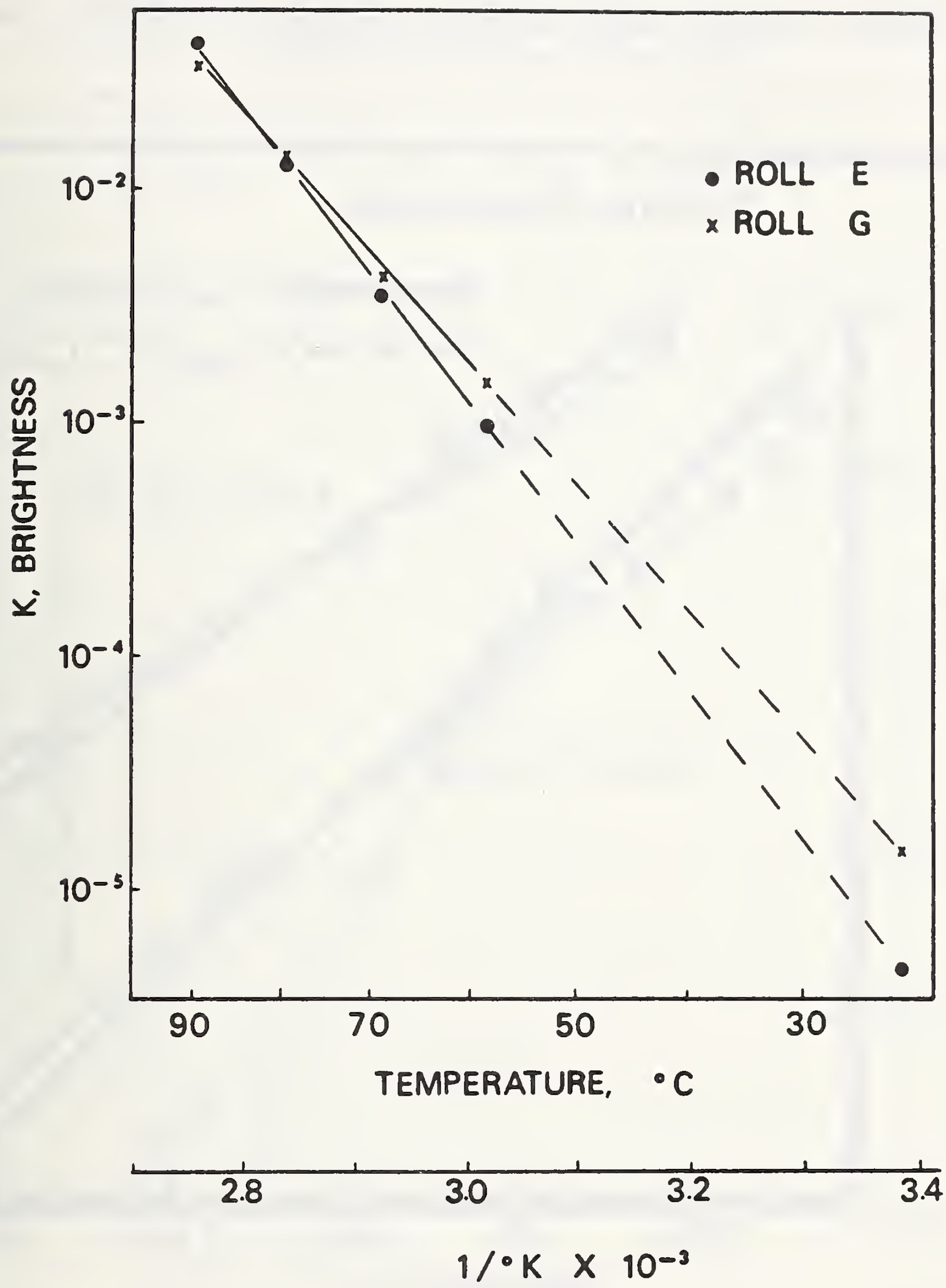



Figure 7. Arrhenius Plots for Surface Brightness Decrease of Photographic Paper (Adelstein - Eastman Kodak Company)

Figure 8. Arrhenius Plot for Folding Endurance Decrease of Photographic Paper (Adelstein - Eastman Kodak Company)

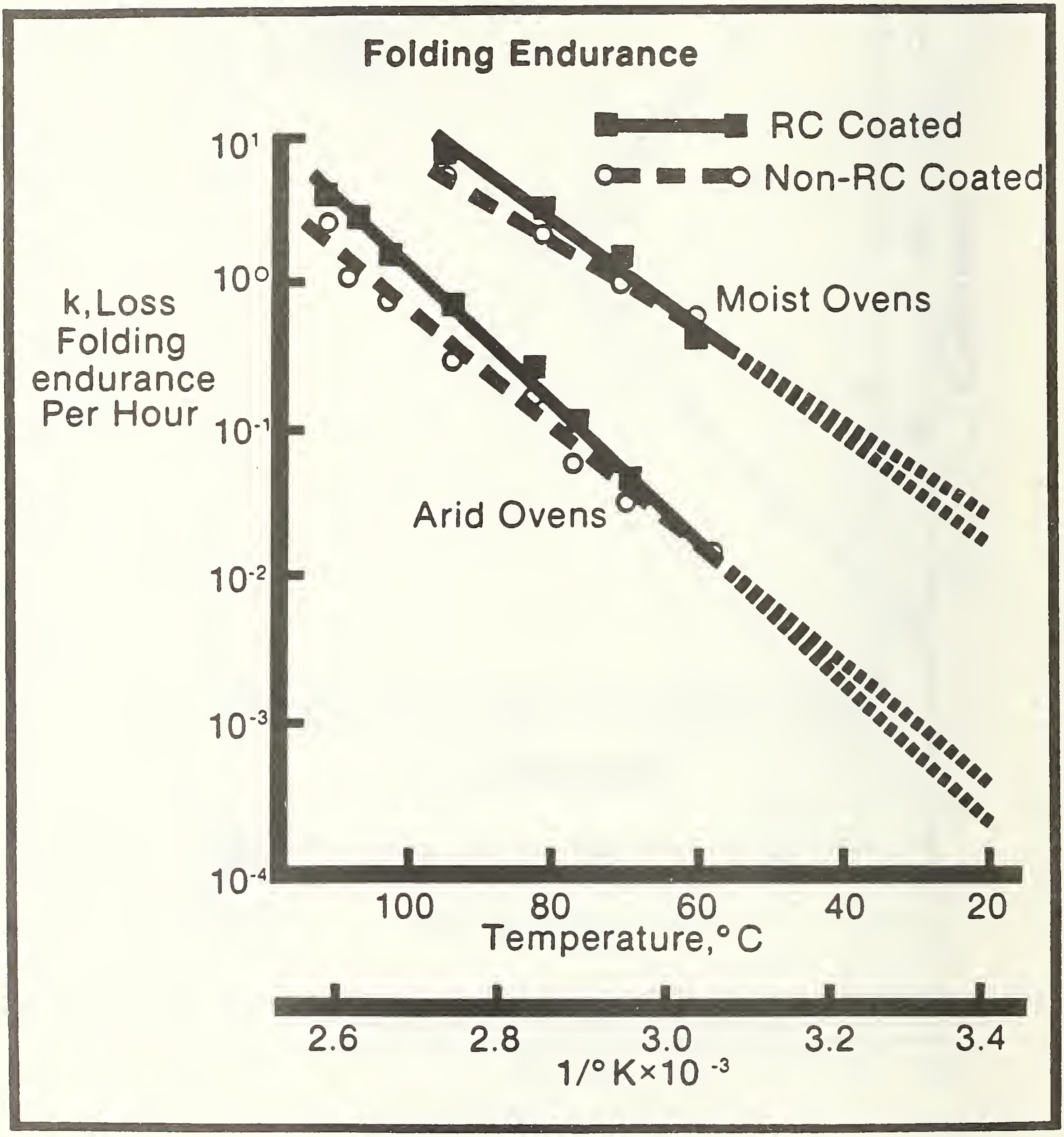


Figure 9. Arrhenius Plots for Tensile Strength Decrease of Photographic Film (Adelstein - Eastman Kodak Company)

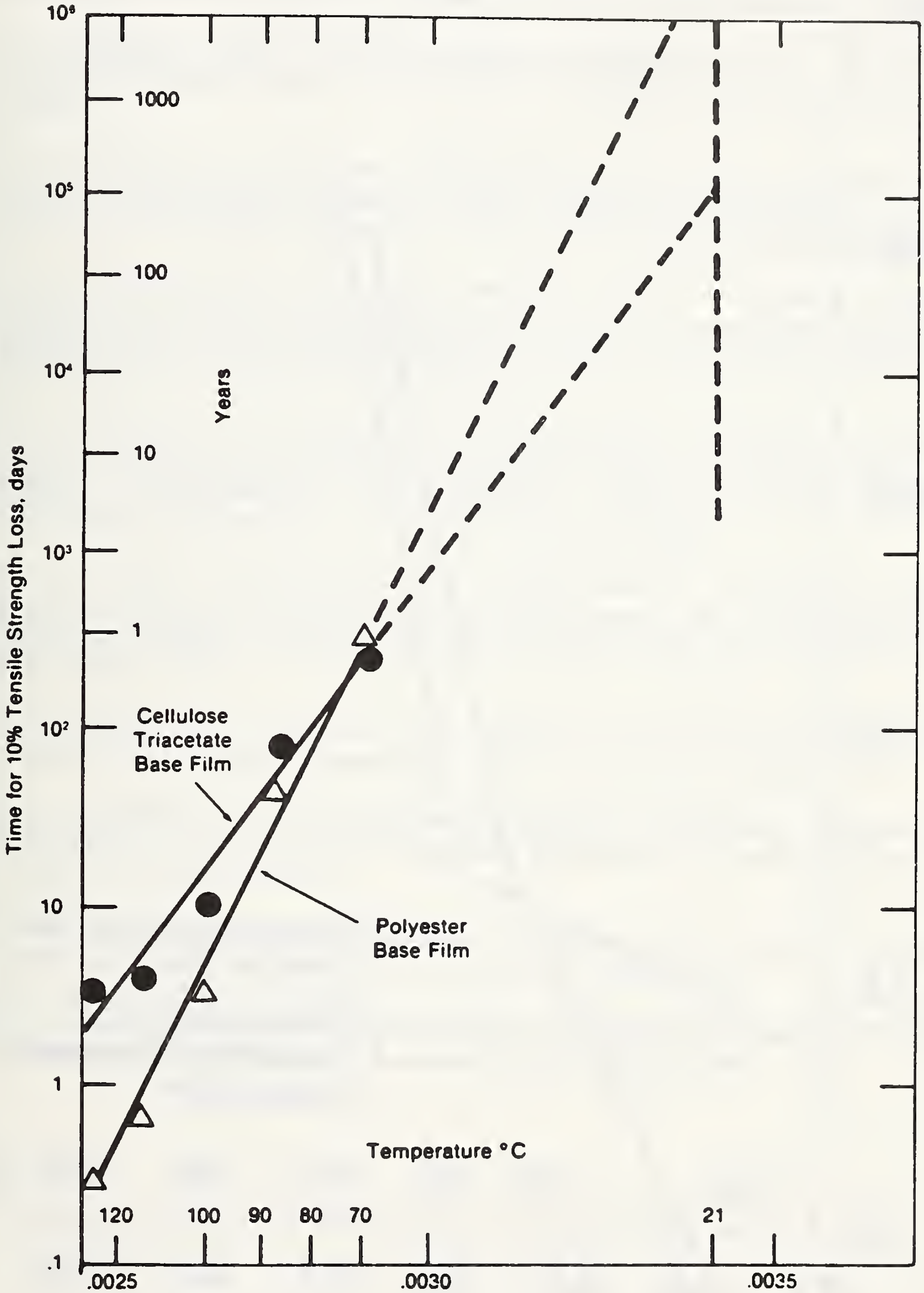
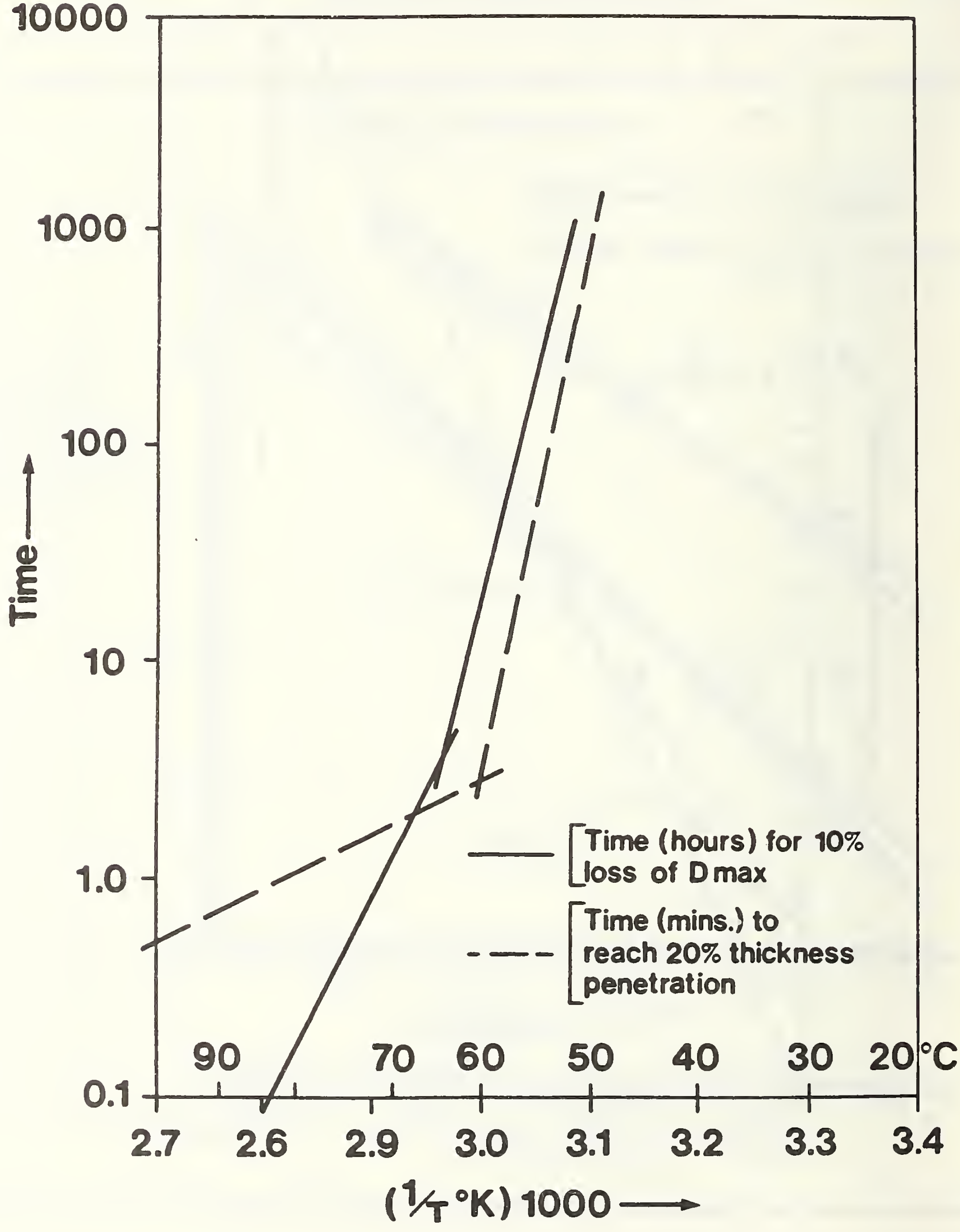


Figure 10. Arrhenius Plots for Density Change and Thickness Penetration of Vesicular Films

(Adelstein - Eastman Kodak Company)



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## 2.3.4 MEASUREMENT TECHNIQUES AND STANDARDS: THIN FILM TECHNOLOGY

By Jane Clover
Optical Coating Laboratory, Inc. (OCLI)

Key words: characterization; coatings; durability; environmental; testing.

### Introduction

There are measurement techniques and standards currently being used in thin film technology that can be adapted to optical data disk technology. These include the following:

(1) Environmental durability tests are well documented and may be used to predict archival life if proper acceleration factors can be established.
(2) Spectral properties of disks can be measured using standard techniques on commercially available equipment.
(3) Calibration standards for reflection can be established.

Mrs. Clover described the tests for coated optics as inclusive of physical factors such as dimension and cosmetic, spectral factors such as reflectance, transmittance and absorption, and environmental factors.

Standard environmental tests for coated optics were also described by Mrs. Clover as inclusive of humidity, abrasion, adhesion, salt spray, solubility, solvent immersion, and cleanability, and exposure to dust and fungus. These tests are summarized as follows.

### Standard Environmental Tests Used to Characterize Performance of Coated Optics

(1) Humidity

Steady State: 24 hours at 49° C, 95% relative humidity (RH)

Cycling: ten 24 hour cycles of from 30°C, 85% RH to 65°C, 95% RH within 2 hours, hold for 6 hours and cycle back to 30° C, 85% RH within 16 hours.

(2) Abrasion

Severe: 40 strokes with eraser at 2-2 1/2 pounds force in special apparatus

Moderate: 50 strokes with cheesecloth pad at 1+ pound force in special apparatus

(3) Adhesion

Slow or fast removal of tape from surface coating.

(4) Salt Spray

24 or 48 hour exposure to 6% salt solution fog at 33°C

(5) Solubility

| | |
|---|---|
| Salt: | 24 hour immersion in 4.4% salt solution |
| Water: | 24 hour immersion in distilled water |

(6) Solvent Immersion and Cleanability

(7) Special Qualification Tests (per Mil-Std-810C)

| | |
|---|---|
| Dust: | 24 hour exposure varying wind velocity, dust (fine sand) concentration, and temperature |
| Fungus: | 28 day exposure to various fungus spores |

## 2.3.5 ACCELERATED LIFE TESTING - OPTICAL MEDIA

**By Philip Scheinert**
**Burroughs Corporation**

Key words: accelerated life testing; environmental specifications; media performance characteristics.

Phil Scheinert of Burroughs spoke on accelerated life testing of optical media. He also discussed environmental specifications which include: dry and wet bulb temperatures, relative humidity, thermal shock, altitude, mechanical shock, vibration, exposure to various gases ($H_2S$, $NH_3$, $NO_X$, $O_3$, $SO_2$), and salt spray.

These specifications are typically cited for four conditions: shipping, operating, conventional storage, and archival storage. (The optical media unit must retain all performance specifications during the specified lifetime of the unit.) There are three basic lifetime models: Arrhenius, power model, and Eyring model (from quantum theory). **Refer to fig. 1.** Mr. Scheinert described the experimental setup for testing performance under stress conditions and showed waveforms used in measuring test patterns **(see fig. 2)**. Test results based on several hundred hours of testing were briefly summarized **(see fig. 3)**.

Figure 1. Media Accelerated Life Testing and Data Analysis (Scheinert - Burroughs)

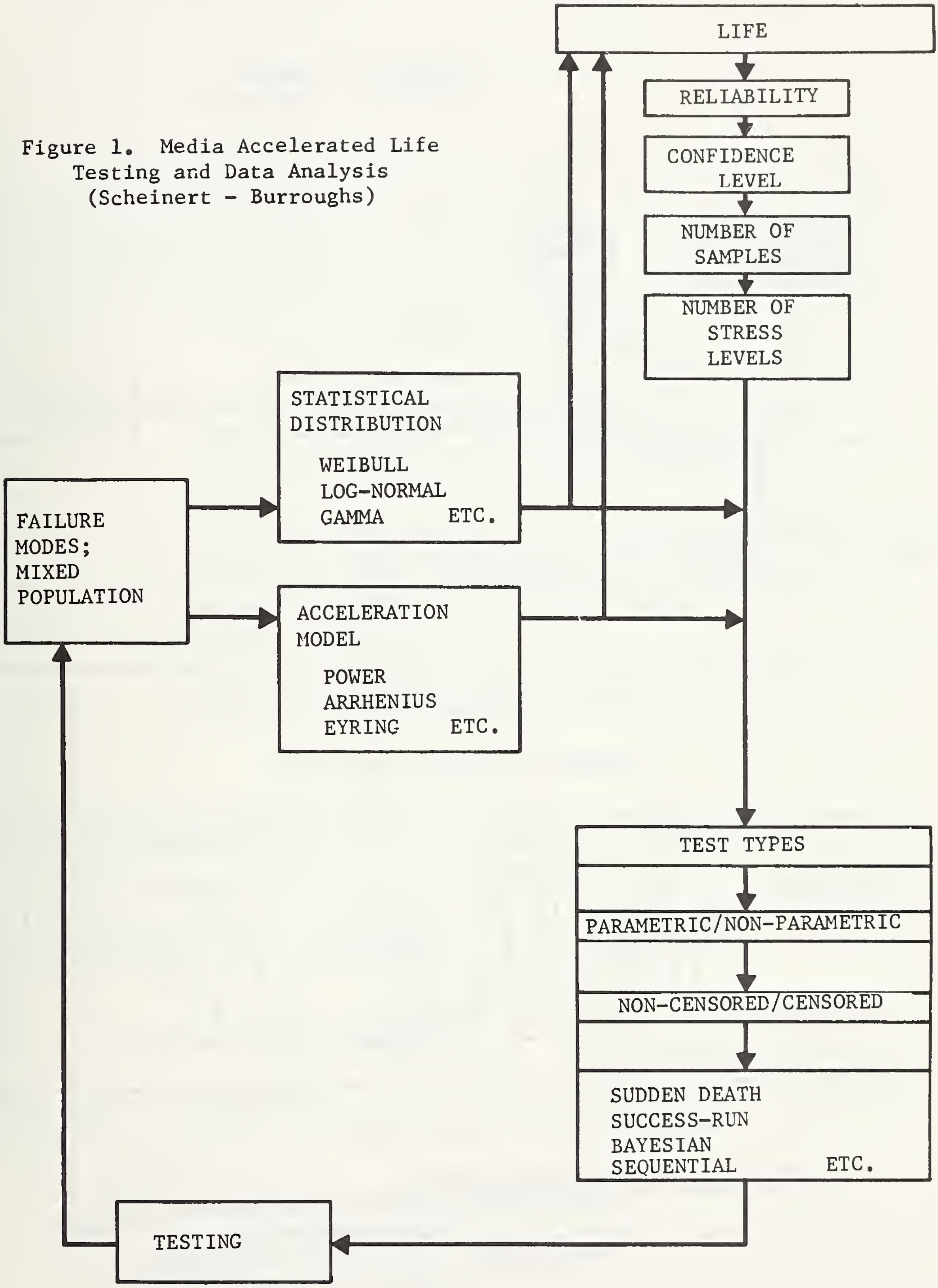
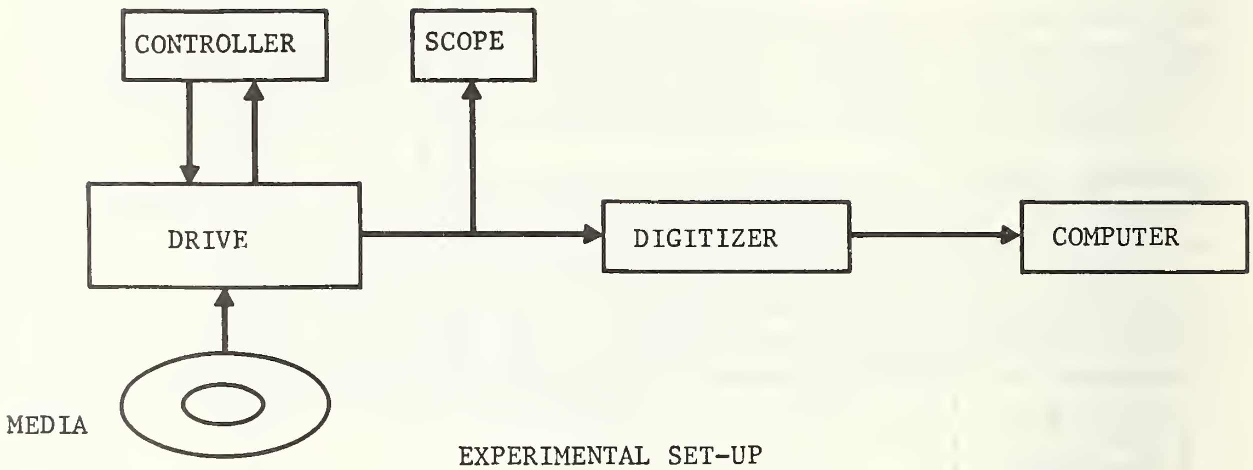
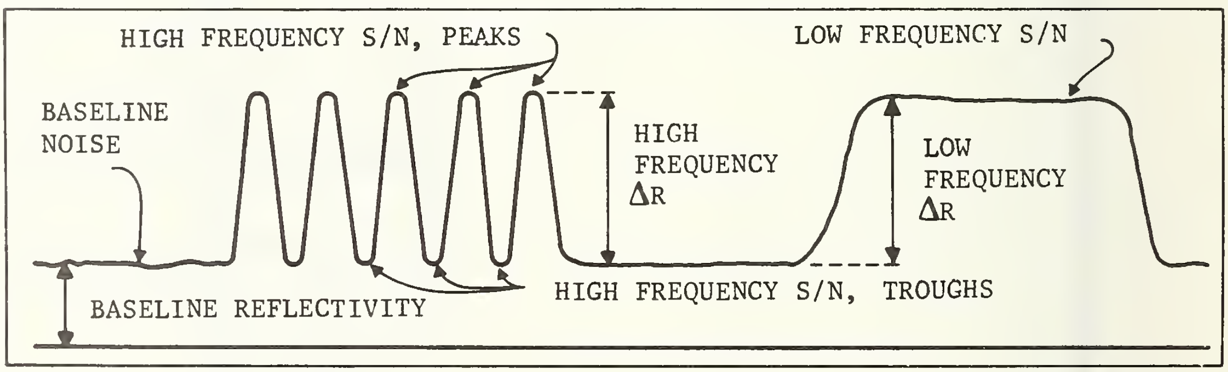


Figure 2. Testing
(Scheinert - Burroughs)




EXPERIMENTAL SET-UP

PARAMETERS CURRENTLY MEASURED:




ANALOG WAVEFORM OF TEST PATTERN

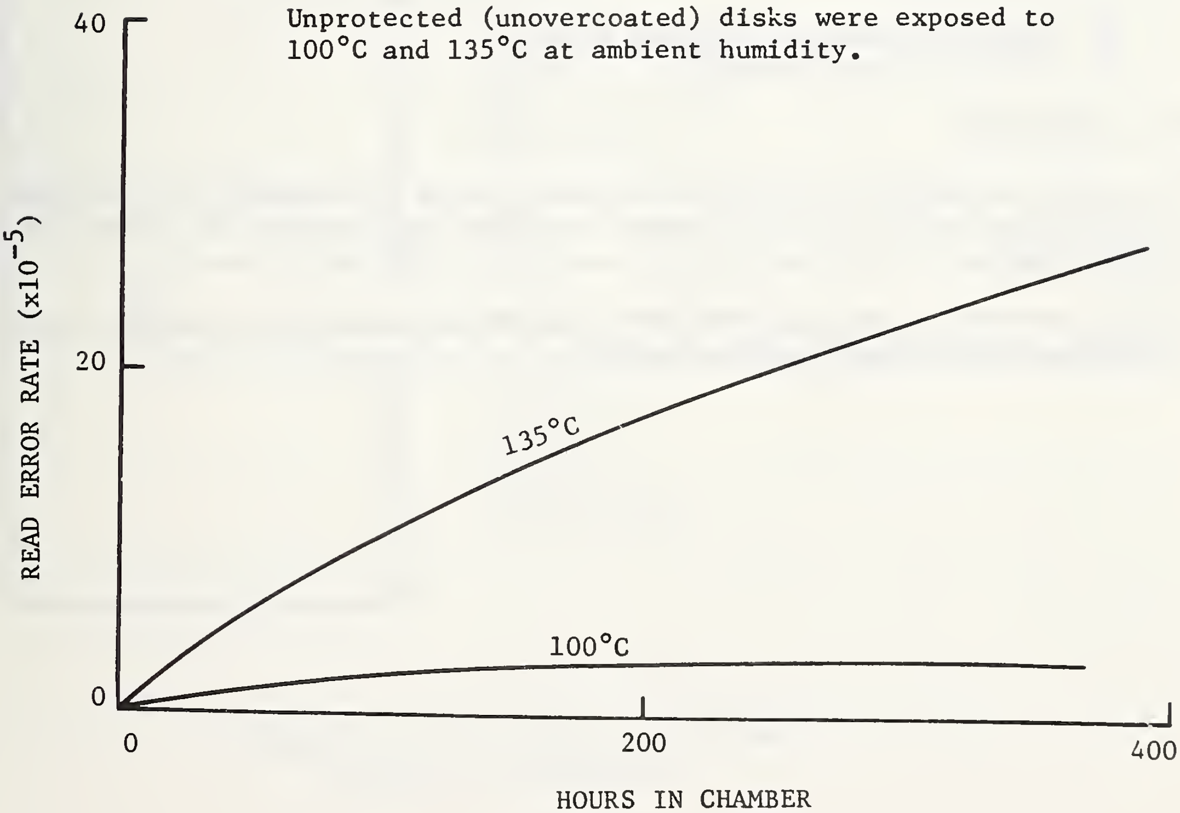
AND ADDITIONALLY: UNWRITTEN DEFECTS
WRITE DEFECTS (DATA WRITTEN INCORRECTLY: CAUSES RELOCATES)
READ DEFECTS (NOT DETECTED AT TIME OF WRITING, BUT APPEAR LATER)

Figure 3. Results
(Scheinert - Burroughs)

Tests at 45°C, 75% relative humidity show little change in performance characteristics and no increase in errors for 900 hours.

To quickly characterize media aging characteristics, initial testing involved severe temperature overstress. This also aids in the calibration of proper observation intervals for "normal" accelerated tests.

Unprotected (unovercoated) disks were exposed to 100°C and 135°C at ambient humidity.



### 2.3.6 SUMMARY OF MEDIA LIFE

By Tomio Yoshida
Matsushita

The media life of a write once optical digital data disk depends on the life of the recording media itself and also has a close and strong relationship with the disk substrate material and construction. From a user's point of view, the total stability and reliability of the media including both the recording media and the disk construction are important. The following fundamental characteristics of the recording media are to be constant under a specified operating environment after long term usage.

(1) Write Sensitivity

- (a) The recording power to obtain minimum C/N ratio
- (b) Threshold recording power
- (c) Gamma characteristics

(2) C/N Ratio

- (a) C/N ratio vs. recording power
- (b) Maximum C/N ratio

(3) Second Harmonics

- (a) Second harmonics vs. recording power
- (b) Minimum second harmonics

(4) Reflectivity

The write sensitivity, C/N ratio, and reflectivity items are important for the design of the optical drive, while the second harmonics are important to obtain high packing density.

In this presentation, the properties which must be satisfied by the recording media, test items, and test routine will be reported.

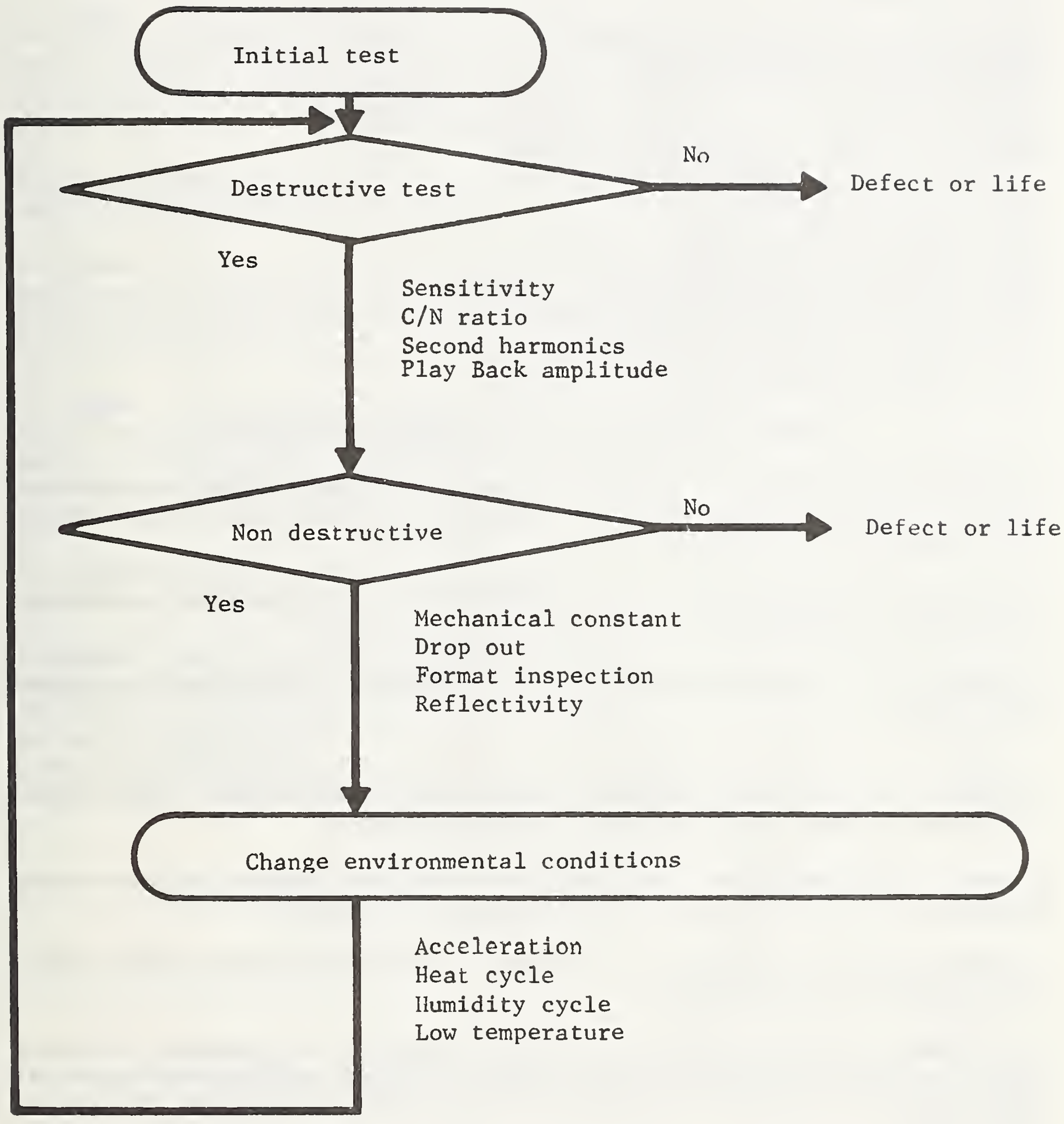



Figure 1. Test Routine of the Media
(Yoshida - Matsushita)

### 2.3.7 Panel Discussion: "What test methods could be used for the measurement of media life? Is there a possibility of a standard test and if so, what should it be?"

**Panel Participants:**

Peter Adelstein, Eastman Kodak Company
Ted Albert, U.S. Geological Survey
John Bray, NCR
Miguel Capote, Optical Coating Laboratory, Inc. (Moderator)
Mike Deese, Storage Technology Corporation
Charles Dollar, U.S. National Archives
John Dove, U.S. Air Force
Mark Goldberg, National Security Agency
Kent Hughes, U.S. Patent Office
Edward LaBudde, LaBudde Engineering Corporation
Pat Savage, Shell Development Company
Peter Sparks, U.S. Library of Congress
Gerry Walter, Planning Research Corporation

(These Comments are not Transcribed Verbatim.)

**M. Goldberg:** It is possible to conceive any number of difficult tests. The important thing is to establish tests which are meaningful and practical in terms of the conditions to be encountered.

**M. Capote:** The tests described by Jane Clover of OCLI are standard tests that are used in thin film industries.

**T. Albert:** Test demonstrations should be performed in one's own (the user's) environment.

**C. Dollar:** The National Archives and Records Service would prefer to see a tabulation of $OD^3$ data degradation rates and accompanying environmental conditions, in order to establish archival storage conditions.

**J. Bray:** Media-independent test procedures to serve as a basis for performance specifiations for the evaluation of archival media are preferred.

**J. Dove:** There are specialists in the physics of failure who might be able to offer useful insights into media testing.

**M. Goldberg:** The best we might hope for is an impartial test procedure that puts a relative rating on any media that is put forth. (A further comment was made that there should be "classes" of tests for media that is designed for various applications.)

**M. Deese:** There is a need for tests that would be representative of improper media handling ("ape and banana" tests).

**P. Adelstein:** Such tests should be kept distinct from aging characteristics.

**G. Walter:** There should be a distinction between the requirement for the life of a material, versus the means of testing against this requirement. If magnetic tape is to be replaced, the media should have a life at least equal to that of magnetic tape.

**T. Albert:** We have experienced some loss of data on magnetic tape. $OD^3$ media tends not to deteriorate with use, which distinguishes it from other media-which may be subject to wear, fading, and other changes due to handling and environment. The United States Geological Survey's storage requirements are for a minimum of 10 years.

**Floor:** A storage requirement of 5 to 7 years for medical images was noted as desirable although NIH has a requirement to keep its images "forever."

**P. Sparks:** The U.S. Library of Congress has documents and records that need to be kept forever. Therefore, they attempt to use the most reliable media for secondary format presentation. What they need to know is the reliability of the disk and when it is advisable to transfer data from one disk to another.

**K. Hughes:** The United States Patent Office is not presently planning on the use of $OD^3$ as a permanent storage method. They rely on microfilm as an archival backup medium. They are interested in $OD^3$ from the standpoint of its effectiveness as a long-term storage medium, and for potential use in an active image retrieval system.

**E. LaBudde:** There is a need to distinguish among qualification tests for acceptance, stress tests, and aging tests of optical media.

**P. Savage:** Seismic data is considered permanent. Currently, Shell Oil samples the data tested for degradation and these are recopied as needed. It is not likely that $OD^3$ could be backed up with any other technology. Shell will assess $OD^3$ first with non-critical applications.

## 2.4 WHAT IS A DATA INTERCHANGE STANDARD?
## A Magnetic Media Example

**By Michael Hogan**
**National Bureau of Standards (NBS)**

Key words: compatibility; formatted; interchangeability; label and file structure; magnetic media; recorded; user.

Mr. Hogan discussed two types of magnetic media: computer tapes and flexible disk cartridges (FDC). He presented figures on the number of drives and the amount of media being shipped annually.

(1) 1983: 1/2 inch computer magnetic tape

35,867,000 reels
$538M value

(2) 1985: 1/2 inch computer tape drives

136,000 drives
$1,414M value

(3) 1983: flexible disk cartridges

$400M value

(4) 1985: flexible disk cartridges

$1,080M value

(5) 1985: flexible disk cartridge drives

12,020,900 drives
$5,231.9M value

For each of these two types of magnetic media, a family of three standards is used to facilitate data interchange, representing three levels of compatibility.

1. Unrecorded or unformatted. This specifies the physical and magnetic properties of the unrecorded media and assures the interchangeability of media derived from various sources.

2. Recorded or formatted. This is for recorded media. It includes the code (e.g., American Standard Code for Information Interchange (ASCII)), data and track format, and modulation method to assure compatibility and interchangeability among information processing systems.

3. Label and file structure. Label and file structure deals with the recorded labels and file structure to facilitate the exchange of information on the recorded medium among different users and information processing systems.

Each level of compatibility may or may not have an impact on the various design areas of an information processing system. **See table 1.** These media standards are not intended as procurement specifications but can be incorporated in such specifications. For instance, error definitions are stated in the standards, but requirements on error rates must be specified by the user in the procurement specification. The standards are considered to be the minimum requirements necessary to achieve data interchangeability.

These magnetic media standards have been prepared under the auspices of the American National Standards Institute (ANSI), the International Organization for Standardization (ISO), and the European Computer Manufacturers Association (ECMA). **See tables 2 and 3.** Various time scales are involved in the preparation of standards, typically in the range of 3 to 7 years. These standards are dynamic and therefore can be revised as conditions dictate, as technological changes influence the need for update.

Mr. Hogan alluded to the current status of microfloppy magnetic disks. There are currently four diameters which are devoid of commonality. This type of situation is bewildering to potential users, many of whom may choose to avoid the technology altogether until they see which of the various sizes is most likely to dominate. Mr. Hogan suggested that one solution to the problem of data interchange among these disk technologies might be to write standards on formats, labels, and file structures. These type of standards could be developed even though the media are being marketed in various physically-incompatible sizes. These standards would then be in place, at such time as the market coalesces around a particular disk size.

Mr. Hogan voiced an urgency for the development of $OD^3$ standards on a worldwide basis. He advised those involved in establishing the standards to remain active beyond the formulation of draft standards, which will be written for the U.S. sector of the $OD^3$ industry, and to coordinate among the different standards bodies in order to achieve multinational commonality.

| LEVEL OF DATA INTERCHANGE STANDARD | LEVEL OF IMPACT ON INFORMATION PROCESSING SYSTEM DESIGN | | | |
|---|---|---|---|---|
| | MEDIA | DRIVE | CONTROLLER | OPERATING SYSTEM |
| MEDIA: | | | | |
| optical properties | x | x | ? | — |
| magnetic properties | x | x | x | — |
| mechanical properties | x | x | x | — |
| dimensional properties | x | x | ? | — |
| PHYSICAL FORMAT ON MEDIA: | | | | |
| track locations | x | x | x | ? |
| modulation schemes | x | x | x | ? |
| data correction techniques | x | x | ? | ? |
| data compression techniques | — | ? | ? | x |
| data code (ASCII) | — | ? | ? | x |
| LOGICAL FORMAT FOR MEDIA: | | | | |
| logical volume labels | — | — | ? | x |
| logical file structures | — | — | ? | x |

Key: x = definite impact
? = possible impact
— = no impact

Table 1. Level of Data Interchange Standard
(Hogan - National Bureau of Standards)

Table 2. Computer Tape Standards
(Hogan - National Bureau of Standards)

Unrecorded and Recorded Standards

| TYPE OF MEDIA | ANSI (X3B1) | ISO (TC97/SC11) | ECMA (TC17) |
|---|---|---|---|
| Unrecorded Tape, 12.7 mm (1/2 in) Wide | X3.40-1976 | ISO 1864-1975 | 62-1980 |
| 7-Track, 8 cpmm (200 cpi), NRZ1 | —— | ISO 1861-1975 | —— |
| 9-Track, 8 cpmm (200 cpi), NRZ1 | X3.14-1973 | ISO 1862-1975 | —— |
| 9-Track, 32 cpmm (800 cpi), NRZ1 | X3.22-1973 | ISO 1863-1976 | 62-1980 |
| 9-Track, 63 cpmm (1600 cpi), PE | X3.39-1973 | ISO 3788-1976 | 62-1980 |
| 9-Track, 246 cpmm (6250 cpi), GCR | X3.54-1976 | ISO 5652-1983 | 62-1980 |
| Self-Loading Cartridges for 12.7 mm (1/2 in) Wide Magnetic Tapes | X3.85-1981 | ISO 6098-1982 | 56-1978 |

Labelling and File Structure Standards

| | (X3L5) | (TC97/SC15) | (TC15) |
|---|---|---|---|
| 12.7 mm (1/2 in) Wide Magnetic Computer Tapes | X3.27-1978 | ISO 1001-1979 | 13-1978 |

Table 3. Flexible Disk Cartridge (FDC) Standards
(Hogan - National Bureau of Standards)

Unformatted and Formatted Standards*

| TYPE OF MEDIA | ANSI (X3B8) | ISO (TC97/SC11) | ECMA (TC19) |
|---|---|---|---|
| 200 mm (8 in) FDC | | | |
| One side, 6,631 bprad, 1.9 tpmm (48 tpi) | X3.73-1980 | ISO 5654/1-1982<br>ISO 5654/2-1982 | 54-1978 |
| Two side, 6,631 bprad, 1.9 tpmm (48 tpi) | X3B8/78-140 (3rd draft) | —— | 59-1979 |
| One side, 13,262 bprad, 1.9 tpmm (48 tpi) | X3B8/78-139 (3rd draft) | —— | —— |
| Two side, 13,262 bprad, 1.9 tpmm (48 tpi) | X3B8/82-73 (9th draft) | ISO 7065/1-1982<br>DIS 7065/2 | 69-1981 |
| 130 mm (5 1/4 in) FDC | | | |
| One side, 3,979 bprad, 1.9 tpmm (48 tpi) | X3.82-1980 | ISO 6596/1-1982<br>DIS 6596/2 | 66-1980 |
| Two side, 7,958 bprad, 1.9 tpmm (48 tpi) | X3B8/82-79 (6th draft) | DIS 7487/1<br>DIS 7487/2 | 70-1981 |
| Two side, 7,958 bprad, 3.8 tpmm (96 tpi) | X3B8/82-78 (4th draft) | New Work Item Approved | 78-1982 |

Labelling and File Structure Standards

| | (X3L5) | (TC97/SC15) | (TC15) |
|---|---|---|---|
| 200 mm (8 in) FDC | | | |
| One side | monitor ISO | DIS 6863 | —— |
| Two side | monitor ISO | DIS 7665 | 58-1981 |
| 130 mm (5 1/4 in) FDC | | | |
| Two side | monitor ISO | DIS 7665 | 67-1981 |

*Note: To date, the ISO and ECMA standards include track format requirements while the ANSI standards do not.

## 3. DAY 3: Friday, June 3, 1983 - THE PURSUIT OF OD$^3$ DATA INTERCHANGE STANDARDS

### 3.1 SESSION I - PANEL DISCUSSION: WHAT OD$^3$ DATA INTERCHANGE STANDARDS ARE POSSIBLE FOR THE UNRECORDED OD$^3$ MEDIA UNIT?

### CAN A STANDARD TEST PROCEDURE FOR UNRECORDED MEDIA CHARACTERISTICS BE APPLIED ACROSS A RANGE OF MEDIA?

**Panel Participants:**

Peter Adelstein, Eastman Kodak Company
Miguel Capote, Optical Coating Laboratory, Inc.
Mike Deese, Storage Technology Corporation
John Dove, U.S. Air Force
Larry Fujitani, Optimem (Moderator)
Mark Goldberg, National Security Agency
Edward LaBudde, LaBudde Engineering
Roland Malissin, Thomson CSF
Boris Muchnik, Storage Technology Corporation
Noel Proudfoot, Eastman Kodak Company
Delbert Shoemaker, Shoemaker Associates

(The Following Comments are not Verbatim:)

**L. Fujitani:** I have been asked by the Chair to define OD$^3$ unrecorded media, which is OD$^3$ media on which the user has not yet entered data. **Now, let us discuss the possibilities and priorities for data interchange standards for the unrecorded OD$^3$ media unit.**

**R. Malissin:** Standardization priorities should be given to mechanical, optical, and read/write factors. A guideline and definitions are necessary starting points. Moreover several standards are to be defined from low-end products to high-end products. For instance, a 305 mm (12 in) disk containing $10^9$ bytes of data is a medium-end product which could be a standard. A high-end product could be derived from this first one by increasing either the bit density or the number of levels per bit and could give rise to another standard.

**P. Scheinert:** There are many differences in the design of OD$^3$ media and systems. Among these are the different disk diameters, optical path thicknesses, and recording surface configurations. Diameters may be changed in order to promote data interchange, and it is conceivable that the same recording surface chemistry can be applied to disk areas with different dimensions. However, the optical path thickness of the disk is unique to a particular media/system technology. This aspect of the surfaces and their responses may be a starting point for standardization, since it is a key factor to OD$^3$ data interchange.

**L. Fujitani: Can a standard test procedure for unrecorded media characteristics be applied across a range of media?**

**M. Capote:** The same specific tests should not be used for media which are intended for different applications. Factors such as recording wavelengths, lasers employed, data rates, and storage capacities must be considered.

**P. Scheinert:** A series of standardized test methods may be a good approach.

**J. Verhoeven:** These test methods must be, together with definitions, included in the setup of the standards. It should follow already settled definitions and approaches (guidelines) as much as possible. This facilitates the application of standard test procedures across a range of media.

**N. Proudfoot:** There are doubts that a single standard test method could be universally applied.

**M. Capote:** Currently, there are very few products in existence. Therefore, media manufacturers should establish their own internal standards for various critical factors. There are no great problems foreseen in bringing existing products into conformity.

**Floor:** Magnetic tape specification testing in the 1950's was an underdeveloped process. It was customary to evaluate tapes on the basis of their operational performance rather than on specific physical/magnetic qualities. It isn't necessary to solve every problem in order to achieve an initial standard. To develop usable standards, $OD^3$ unrecorded standardization should start with a standard at the level where most products will perform. Test methods for media performance are part of the standard's appendix, rather than the standard itself.

**N. Proudfoot:** I would like to propose the following list of potential parameters for $OD^3$ unrecorded media standardization. (These parameters should be discussed relative to the reference plane.)

(1) Sizes of disk (begin with one or more sizes)
(2) Location of recording layer
(3) Thickness (perhaps)
(4) Mechanical interface
(5) Recording zone
(6) Imbalance (perhaps)
(7) Clamping area

**B. Muchnik:** Ninety percent of the factors for 305 mm (12 in) and 356 mm (14 in) disks would overlap (although some values would be different).

**The following list of $OD^3$ unrecorded media parameters was formulated by panel members:**

(1) Geometric

(a) Inside diameter (ID)
(b) Outside diameter (OD)
(c) Reference plane
(d) Location of recording layer
(e) Recording zone
(f) Thickness
(g) Clamping zone
(h) Handling zone

(2) Mechanical

(a) Radial runout
(b) Radial acceleration
(c) Axial runout
(d) Axial acceleration
(e) Unbalance
(f) Concentricity
(g) Mass
(h) Warp angle
(i) Tilt angle
(j) Revolutions per minute (RPM)

(3) Optical

(a) Optical path length
(b) Birefringence
(c) Wavelength
(d) Reflectivity

(4) Environmental factors

(5) Pregroove information

(6) Signal considerations

(a) Sensitivity
. Write
. Read
(b) Signal-to-noise ratio

**L. Fujitani: Please comment on the $OD^3$ parameters, as they have been listed.**

**M. Goldberg:** It would be useful to note what disk parameters would be easy to change and those that would be difficult.

**L. Spruijt:** An $OD^3$ drive may be able to compensate for some differences among media characteristics, using initialization procedures.

**Floor:** A lower-order consideration might be to include a human-readable region which would contain disk identification, serialization, and other information to ensure that the media will be used correctly in a remote location.

**J. Dove:** The term "mark type" might be useful when specifying recorded data, rather than referring to specific methods of writing such as holes or pits.

**M. Deese:** Relevant to the discussion of what standards are possible, consider a "concrete walkway to the door" syndrome, in which people pour a walkway to where they think the door is going to be. This can be a useful starting point, but this walkway must be flexible so as to accommodate later changes.

**L. Fujitani:** There should be some common definitions written, before separate groups develop standards for different products, which then couldn't be cross-compared.

**P. Adelstein:** The standardization effort should concentrate on what is possible, rather than struggling with questions on which there is no present consensus.

**D. Shoemaker:** It might be useful to formulate lists of those things that are easy to agree on, those that are difficult, and those that are impossible.

**M. Goldberg:** Within families of standards, a prioritization should be made based on the difficulties of achieving the standards.

**M. Capote:** Among the four manufacturers presently making 356 mm (14 in) disks, probably 50 percent of the items listed by the panel could be agreed upon.

**B. Muchnik:** There could be differences in viewpoint among those who make media, those who make drives, and those who make both.

**M. Goldberg:** Changing even the simplest parameter may cause a ripple effect in the overall system, and this should be avoided.

**E. LaBudde:** The basis for standardization has been identified, and there will be families of standards for different manufacturers. Workshop participants are invited to submit working papers, in order to establish their parochial interests.

## 3.2 SESSION II - PANEL DISCUSSION: WHAT STANDARDS ARE POSSIBLE FOR THE OD$^3$ CARTRIDGE?

**Panel Participants:**

John Bray, NCR
Mike Deese, Storage Technology Corporation
Larry Fujitani, Optimem
Martin Levene, RCA (Moderator)
Pat Savage, Shell Development Company
Louis Spruijt, Optical Media Laboratories

**The following list of OD$^3$ cartridge parameters was formulated by the panel members:**

(1) Geometry (dimensional limits)
(2) Mounting reference - surface or points
(3) Optical path
(4) Environment
(5) Keying for positioning and engagement in drive
(6) Label for ID (identification)
(7) Write inhibit
(8) Avoidance of separation of disk from cartridge

**Two disk categories were recognized by the panel:**

(1) Disks remain in cartridge during operation
(2) Disks slide out of cartridge during operation

**M. Deese** envisioned an "envelope" specification rather than tight dimensional specifications. He offered the following list of candidate parameters for OD$^3$ cartridge standardization:

(1) Physical size and weight
(2) Keying for machine insertion into drive
(3) Restraint of cartridge in drive
(4) Machine and/or human-readable ID
(5) Disk support
(6) Disk removal for operation in drive
(7) Tamper proof and encroachment witness indicators
(8) Over-limit temperature/humidity indicators
(9) Machine handling features to facilitate loading
(10) File protect or write inhibit
(11) Cartridge present, mounted, and ready sense feature

(The Following Comments are not Verbatim:)

**M. Levene: Please comment on the standardization of the cartridge parameters that have been listed.**

**L. Spruijt:** A reference plane should be used for the disk, but not for the cartridge; the spindle would be the reference for the system. However, a window cartridge imposes additional standards requirements.

**M. Levene:** There is an interface between the cartridge and the drive. In a multiple-disk access system, there is also an interface between one cartridge and another. Cartridge bowing could be significant in the latter interface.

**P. Savage:** There is a risk of a disk separating from its correct cartridge--for example, during a maintenance operation. Hence, labeling on the cartridge only would not guarantee that a disk and its "mate" cartridge would be together. Therefore, both the disk and its cartridge should be labelled. The practice with magnetic tape is to label the reel rather than the container.

**Floor:** There should be both machine-readable and human-readable ID's on the disk itself.

**J. Bray:** There are other specifications to be considered such as flammability. (It was explained that this and similar points belong in the procurement specifications, rather than in the standards.)

**M. Deese:** There is a need for the same size cartridge for both 305 mm (12 in) and 356 mm (14 in) disks, and possibly for smaller disk sizes as well, in order to facilitate interchangeability in automated disk handling devices.

**P. Savage:** A distinction should be made between outside dimensions of the cartridges, which will be standard sizes, and their inside dimensions, which will vary to accommodate different disk sizes.

**M. Deese:** Considering $OD^3$ cartridge standardization, start with the interface between the cartridges and the drive, and approach the interface with the media later.

## 3.3 SESSION III - PANEL DISCUSSION: WHAT STANDARDS ARE POSSIBLE FOR THE RECORDED OD$^3$ MEDIA UNIT - DATA FORMAT, LABELLING, AND FILE STRUCTURE?

## DISCUSS INTERFACE STANDARDS THAT ARE POTENTIALLY APPLICABLE TO OD$^3$

**Panel Participants:**

Peter Adelstein, Eastman Kodak Company
William Burr, National Bureau of Standards
Larry Fujitani, Optimem
Mark Goldberg, National Security Agency
Edward LaBudde, LaBudde Engineering (Moderator)
John Riganati, National Bureau of Standards
Philip Scheinert, Burroughs Corporation
Jan Verhoeven, Optical Media Laboratories

(The Following Comments are not Verbatim:)

**E. LaBudde: The prospect of standards for the following parameters of OD$^3$ recorded media will be discussed in this session:**

**(1) Physical/optical format**
**(2) Data record format**
**(3) Logical format**
**(4) File format**

**E. LaBudde:** The standardization factors for OD$^3$ unrecorded media which were discussed in Session I could be verified rather easily with basic measurement equipment, whereas the factors related to recorded media (to be discussed in this session) are substantially more involved. Some of these include pregrooved or prerecorded material, modulation codes, sync patterns, and data protection features.

**L. Fujitani:** It is important to differentiate between factors that are drive dependent and those factors that are system considerations. The physical/optical, data record, and logical formats are known to affect the drive/controller.

**P. Scheinert:** Everyone is coming up with different formats; this makes interchange difficult. However, a novel approach, if possible, would be to use a plug-in card to adapt from one format to another.

**L. Fujitani:** The applications would drive the file formats, and they might be significantly different from previous ones.

**P. Adelstein:** A standard can't be formulated around a single vendor; there must be at least two.

**Floor:** The sector size probably can't be standardized. But an identification flag could be put at the beginning of each sector, tying it to the identification of the disk.

**J. Verhoeven:** There should be both track and sector identifiers.

**The following list of candidate items was formulated by the panelists to describe the recorded media parameters that could be considered for potential standardization:**

(1) Physical/optical format

- (a) Tracks
- (b) Tracking
- (c) Addressing

(2) Data recording format

- (a) Modulation
- (b) Timing
- (c) ECC

(3) Logical format

- (a) Labelling
- (b) Sectors/blocks

(4) File format

- (a) Structure
- (b) Directory
- (c) Update

**W. Burr:** The most common block size is 256/512; what block size is current $OD^3$ hardware and software set up to accommodate?

**E. LaBudde:** The factor of block size would be relatively easy to handle in the controller.

**Floor:** There was a discussion regarding the handling of patents in the standardization process.

**J. Riganati:** If a patent holder is a party to the formulation of a standard and agrees to it, that patent holder is expected to grant a license at reasonable cost on an equal basis to the users of the standard. If a patent holder is not a party, then the users must beware. Standards carry disclaimers warning of this situation. It is the function of the standards processing organizations to assure that there will be equal access to known patents before a standard is promulgated.

**L. Fujitani:** People are interested in acquiring $OD^3$ devices and gaining experience with them. This will begin to occur before the standards are formulated and will probably result in useful feedback and refinements in design.

**M. Goldberg:** If only one manufacturer is involved, standards aren't actually needed; standards are needed only when interchangeability between suppliers is required.

## 3.4 SESSION IV - PANEL DISCUSSION: WHAT STANDARDS ARE POSSIBLE FOR $OD^3$ CHANNEL I/O AND STORAGE SUBSYSTEM INTERFACES?

**M. Deese:** SESSION IV, "What Standards are Possible for Data Transfer and Command Interfaces?" will not take place, since standardization for data transfer could be handled by an ANSI interface committee.

**D. Shoemaker:** I suggest that the SPARC (Optical Disk) Study Group establish their requirements for the $OD^3$ interface and advise the X3T9 committee of these requirements so that work on the interface can be done in-line with the other development.

## 3.5 SESSION V - THE PURSUIT OF OPTICAL DIGITAL DATA INTERCHANGE STANDARDS

### 3.5.1 The Pursuit of OD$^3$ Data Interchange Standards

**By Michael Deese**
**Storage Technology Corporation**

Key words: European Computer Manufacturers Association (ECMA); optical disk; project proposal; Standards Planning and Review Committee (SPARC); standards development.

Mr. Deese presented an overview of standards activities relating to OD$^3$. He explained that the initial step involves a project proposal, which can be written by anyone and is submitted to the Standards Planning and Review Committee (SPARC). In the case of OD$^3$, SPARC called for the formation of a Study Group. The first standard, probably on unrecorded media, is expected about the third quarter of 1985. One project proposal on OD$^3$ has already been prepared, and two others are underway. A glossary subgroup is at work. In Europe, there is a study group operating under European Computer Manufacturers Association (ECMA), chaired by Dr. Jan Verhoeven of Optical Media Laboratory (OML). A matrix of possible standards is under consideration, which could identify 15 to 20 standards, probably groupable by families. Mr. Deese foresees 12 to 24 standards for OD$^3$, which is comparable to the magnetic tape family of standards.

Mr. Deese enumerated the advantages of participating in standards development. It presents an opportunity for the exchange of ideas, which in itself is valuable, even if the completion of a standard is a long way off. The standards process allows manufacturers to bring products to the marketplace in an orderly and responsible manner, rather than overwhelming the users with a diverse array of products that differ in relatively trivial ways and suffer from incompatibility.

## 3.5.2 A COST-BENEFIT IMPACT ASSESSMENT OF OD$^3$ STANDARDIZATION

**By Marco Fiorello**
**Titan Systems**

**ABSTRACT**

This report presents a preliminary cost-benefit impact assessment of promulgating information processing standards for the commercially emerging Optical Digital Data Disk (OD$^3$) Technology. The Federal Government perspective is emphasized. The analysis includes: estimates of the market penetration of the OD$^3$ technology; basic models of how standards can affect technology innovation and diffusion; and, a preliminary assessment of the cost-benefit to the Federal Government.

**Key words:** information processing standards; market penetration; mass storage and retrieval; OD$^3$ market projections; OD$^3$ technology; technology forecasting.

### Executive Summary

The objective of this study is to determine the costs and benefits to the U.S. Government for the establishment of standards for the optical digital data disk (OD$^3$) technology as it emerges into commercial acceptance, or to wait until it has matured into commercially proven products.

OD$^3$ technology, as used here, refers to the capability of producing high density, digitally encoded optical storage devices which are suitable for use as computer system peripherals device and media. To date, a number of pre-production prototype OD$^3$ systems have been developed, demonstrated, and evaluated. Currently, commercially available products from different manufacturers, using various recording media and designs, appear imminent and initial commercial sales are forecasted for the 1984-1986 time frame.

Due to time and resource limitations allocated in this study, we focused on the potential OD$^3$ Mass Data Storage and Retrieval (MDSR) market dealing with applications that currently utilize some form of magnetic storage technology, to record machine readable information.

It is recognized that this scope does not include potential OD$^3$ "document scanning" applications for rastor scanned information. Assessing the market for those applications requires considerably more data collection and analysis than was possible in this study. However, we feel that those OD$^3$ technology applications will follow and, to some degree, be affected by the diffusion and success of the OD$^3$ technology in the market niche which is focused on in this analysis. In this study, we have assumed that the most likely initial applications of OD$^3$ technology will be in those areas in which some form of computer storage media is currently employed, and where that technology can be improved upon by the OD$^3$ technology.

The magnitude of the magnetic MDSR market is significant - a recent survey of 70 Federal and commercial organizations with large data processing facilities indicates that by 1987, such facilities anticipate requirements, on average, of over two trillion characters of on-line (includes automatic access) storage and over three trillion characters of off-line storage per installation.* The total population of such installations is expected to be in the many hundreds.

Based on the anticipated cost/capacity comparative advantages of $OD^3$ technology relative to the existing magnetic storage technology, the $OD^3$ technology is projected to penetrate the magnetic storage market significantly. In fact, some forecasts estimate penetration to be as high as 60 percent by 1992. However, there are factors such as standardization effects, $OD^3$ technology risks, and improvements in competing technologies which can cause significantly higher or lower $OD^3$ technology penetration rates.

In normal market settings, there are many forces that can foster or retard the acceptance and diffusion of a new technology. From an economic perspective, a reduction in technical and market risks, for both making and using a product which is in demand, can benefit both producers and consumers. If $OD^3$ technology has a comparative advantage over current magnetic storage technology, for certain established market applications, then it will be used to displace or augment the current products which are used in these applications. To the degree that this advantage holds, then accelerating the diffusion of the new technology can yield additional benefits to both users and producers in a normal market.

One scenario that can be used to assess the economic impacts from technological diffusion is to infer that as a result of reduced risks, attributable in part to standards, the $OD^3$ technology diffusion curve would be accelerated, therefore more $OD^3$ products would be utilized sooner than in the non-standards case. Further, with more users creating a substantial demand, more suppliers would enter the marketplace to produce and sell $OD^3$ products. With an increase in competition (for normal commodity markets), the supply curve typically shifts such that the product price is reduced, relative to the products' price and quantity in the non-standard setting.

The preceding scenario is plausible if the standards' functions are introduced in a timely manner and are compatible with the $OD^3$ technology product and process life cycle development. In past cases (e.g., disk storage devices), where the technology was more mature relative to the precent status of $OD^3$ technology, significant savings of up to 40 percent have been realized or projected based on the logic of that scenario.

For $OD^3$ technology, the following sequence of standards could be most effective in helping to remove the principal technical and market barriers, and being compatible with the current development state of $OD^3$ technology:

* [KERR-82] Kerr, A., User Requirements: Results of a Mass Storage Survey, Digest of Papers: Hardware and Software Issues for Non-Storage Systems, Fifth IEEE Symposium on Mass Storage Systems, October 26-28, 1982, Boulder, Colorado, IEEE Computer Society Press, N.Y. 1982.

(1) Information Standards - for terminology consistency, measurement, and test specifications;

(2) Quality Standards - to define the performance of the technology, including media reliability and durability;

(3) Compatibility Standards - for the I/O channel and $OD^3$ system, initially and eventually full media compatibility.

(4) Variety Reduction Standards - for various disk sizes, after the initial media technology has produced commercial products.

These standard functions should focus on media type, data format, disk configuration, media stability, and level and type of interchangeability.

For the data used in this analysis to define the base case or "no standards" case, the estimated mean cost advantage of $OD^3$ over magnetic media per billion ($10^9$) characters stored on-line is $76,000 one time costs; plus $1,200 per year in recurring costs, in 1983 constant dollars. Thus if an organization requires 100 billion characters of on-line storage, the potential savings from utilizing $OD^3$ technology versus a 50:50 combination of magnetic tape and magnetic disk technology storage is approximately $7.6 million in non-recurring costs and $120,000 per year in recurring costs. Analogously, a one trillion character requirement would yield about $76 million in non-recurring cost savings plus $1,200,000 per year in recurring cost savings.

All of the above estimates and projections are subject to uncertainty about the parameter values, impact factors, and underlying assumptions. The parameter values used throughout are based on most likely values from the literature or best estimates from experts. Changing the device and media costs substantially would affect both the base case and the standardization impacts. Given the linear model forms, a change in the difference in device and media costs for the competing technologies would result in proportional increases or decreases, depending upon the direction of the change. These results are most sensitive to device hardware costs, to media costs, and finally to database handling costs.

The most critical assumption is the expectation that the emerging $OD^3$ technology will demonstrate a comparative advantage (in price and storage performance) over the competing magnetic media technology. If the comparative advantages hold, the actual savings estimates for $OD^3$ technology and its related standardization impacts will probably be much higher than those estimated in this study. On the other hand, the magnetic storage technology is still being improved (historically it has improved its cost per storage capacity ratio by 20 percent compounded annually for the last five years), and significant advances are in their experimental stages. Vertical recording is an example of a potentially important new magnetic recording technology.

The estimated standardization impact value of 10 percent on the $OD^3$ technology is a conservative number. In fact, where standardization has been instrumental in reducing risks and increasing competition, price reductions of over 40 percent has been realized in Federal Government purchases.

A timely and effective set of standards as outlined in the above categories can enhance the diffusion of $OD^3$ technology, and certainly reduce consumer and producer risks. However, enhancements and benefits from standardization that can accrue to producers and consumers can only occur if the basic $OD^3$ technology has an actual economic advantage relative to competing technologies.

For the above computations and underlying assumptions, a case can be made for the strong diffusion of $OD^3$ technology and that additional marginal benefits can accrue from standardization. At a conservative standardization impact of 10 percent on the device and media prices, the estimated $600,000 for standards development costs can be recaptured during procurement in the Federal sector when as few as 80 billion characters are stored using standardized $OD^3$ technology. If the mean value estimates for 1987 noted above are taken as representative for single, large data processing installation storage requirements, then the 2.2 trillion characters for on-line storage alone would yield a return 25 times the standard's development costs. Where multiple installations are considered, as well as the forecasted off-line requirements, the non-recurring standardization savings can be substantially over $100 million, in 1983 dollars. Though substantial, that impact by comparison is less than one-tenth of the value of the 1980 Federal investment in magnetic storage devices and media, and approximately one-third of the Federal Government expenditures projected for 1983-1988 for MDSR requirements.

## 3.5.3 TIMING THE PURSUIT OF OPTICAL STANDARDS - WHEN IS IT RIGHT?

**By Joseph Zajaczkowski**
**Sperry Corporation**

Key words: consensus; de facto; edict, standards process; timing of standards.

Mr. Zajaczkowski pointed out that there are three methods of arriving at standards: de facto, edict, and consensus. In Europe, standards are more often mandated by edict; in the U.S., there is heavy reliance on the voluntary standards process (consensus). The correctness of the timing of a standard is always determined by hindsight.

The objective of standardization is to provide an agreed to arbitrary solution to a recurring problem along with industry accepted measurement methods. Several factors are important in the timing of standards: the technology must be understood, it must be cost-effective, and the standards should satisfy a need. The difficulties associated with even modest changes should not be underestimated.

Mr. Zajaczkowski observed that committees tend to have only a few people actually doing a significant amount of work, and hence proceed more slowly than might be expected. A document does not have to reach completion to begin serving a useful purpose. Standards participants should establish the areas of agreement and build on these. He stressed the importance of being involved in the standards process.

## 3.6 THE ROLE OF THE NATIONAL BUREAU OF STANDARDS (NBS) In the Future Development of $OD^3$ Standards

**By Michael Hogan**
**National Bureau of Standards (NBS)**

Key words: calibration; Federal Information Processing Standards (FIPS); measurement standards; NBS Standard Reference Material (SRM) Program.

Mr. Hogan reviewed the evolution of NBS and its legislative authority. NBS is a Bureau of the U.S. Department of Commerce. It was established by Congress in 1901 to help ensure the compatibility of measurement standards needed by industry, consumers, the scientific community, and other government organizations. The Bureau has limited resources with which to carry out a very broad mandate.

The NBS role in ADP (automatic data processing) was specifically defined by the Brooks Act in 1965, which establishes central management in the Federal Government for procuring and utilizing computers and their associated products. Specific roles were assigned to NBS, the General Services Administration (GSA), and to the Office of Management and Budget (OMB).

Mr. Hogan described the NBS Standard Reference Material (SRM) program which to date has produced over 1,000 types of SRM's. These are calibrated substances and materials which are used in areas where the complete measurement methods cannot be fully described on paper, but instead must be carried out with reference to calibrated samples. Included among the SRM's are reference magnetic tapes and disks for use in the manufacture and testing of magnetic media and associated devices, and in the calibration of operational tape and disk drives. NBS also produces standard resolution test targets for photographic imaging technologies.

NBS has a key role in the development and promulgation of Federal Information Processing Standards (FIPS). Development of these standards is accomplished to the maximum extent possible through voluntary standards organizations, such as American National Standards Institute (ANSI), National Micrographics Association (NMA), and International Organization for Standardization (ISO). NBS staff members participate actively in these organizations. For the most part, the FIPS adopt the relevant voluntary standards and cite them for application within the Federal Government.

The National Bureau of Standards/Institute for Computer Sciences and Technology (NBS/ICST) is also deeply involved in the preparation of FIPS Guidelines and Special Publications which provide guidance, explanatory material, and operating procedures for Federal ADP managers and their staffs. For example, an NBS Special Publication entitled <u>Care and Handling of Computer Magnetic Storage Media</u> (SP500-101), authored by Sidney B. Geller was published in June 1983. This NBS Special Publication deals with the physical/chemical preservation of computer magnetic storage media—principally computer magnetic tapes--and their stored data, through the application of proper care and handling methods, under various conditions. It emphasizes the media handling methods and environmental conditions which should be instituted during the course of controllable day-to-day and long-term archival storage activities. It also considers measures which can be initiated during media transit and in the aftermath of catastrophic or uncontrollable events.

Another ICST product is a bibliography entitled A Bibliography of the Literature on Optical Storage Technology which will be published in the near future. This bibliography will contain citations on video disk recording, holographic storage, and many papers of a background nature in addition to the $OD^3$ technology papers. Several citations relating to $OD^3$ storage media have been annotated. Over 100 patents related to optical data storage will also be cited in this bibliography. For further information, contact J. R. Park, National Bureau of Standards, Institute for Computer Sciences and Technology, Room A216, Building 225, Washington, D.C. 20234 (telephone: 301/921-3723).

NBS can be expected to be active in the development of FIPS for $OD^3$ as the development of standards in this area proceeds within the national and international standards arena.

## 4. Appendix A. List of Symbols, Abbreviations, and Acronyms Used in These Proceedings

| | |
|---|---|
| A | amperes |
| A4 | Basic Size of Paper 210 x 297 mm (8.3 x 11.7 in) |
| ADP | automatic data processing |
| A-K | "a through k," engineering drawing dimensions, 8.5 x 11" (A) through drawings 34" wide by lengths up to 150 ft (roll length) |
| ALT | Administrative Lead Time |
| ANSI | American National Standards Institute |
| ARRADCOM | Armament Research and Development Command |
| ARRCOM | Armament Materiel Command |
| ASCII | American Standard Code for Information Interchange |
| ASTM | American Society of Testing and Materials |
| | |
| BER | bit error rate |
| bit | binary digit |
| bpi | bit per inch |
| b/pixel | bit per pixel |
| | |
| C | celsius |
| CAD/CAM | computer aided design/computer aided manufacturing |
| CAV | constant angular velocity |
| CECOM | Communication and Electronic Command |
| CFB | cipher feedback mode |
| CLV | constant linear velocity |
| cm | centimeter (=$10^{-2}$ meter) |
| CNR | carrier-to-noise ratio |
| COM | computer output microfilm |
| CPU | central processing unit |
| CRC/ECC | cyclic redundancy check character/error correction code |
| CRT | cathode ray tube |
| | |
| DARCOM | Materiel Development and Readiness Command (U.S. Army) |
| DARPA | Defense Advanced Research Projects Agency |
| dB | decibels |
| $\Delta$ | delta, "change in" |
| DES | Data Encryption Standard |
| DMA | direct memory access |
| DMSP | data management support package |
| DOD | Department of Defense |
| DRAW | direct read after write |
| DSREDS | Digital Storage Retrieval Engineering Data System |
| | |
| E Size | 34 x 44" (engineering drawing dimensions) |
| ECC | error correction code |
| EDAC | error detection and correction |
| ECMA | European Computer Manufacturers Association |
| EIA | Electronic Industries Association |
| ERADCOM | Electronic and Research and Development Command |

| | |
|---|---|
| fig. | figure |
| FIPS | Federal Information Processing Standards |
| FDC | flexible disk cartridges |
| FWHM | full-width-half-maximum |
| g | gram |
| Hg | mercury |
| HRMR | human read/machine read |
| Hz | hertz |
| IBM | International Business Machines Corp. |
| ICST | Institute for Computer Sciences and Technology |
| ID | identification, as in file structure and labelling: volume ID |
| ID | inside diameter (disk dimension) |
| IEC | International Electrotechnical Commission |
| IGES | Initial Graphics Exchange Specification |
| in | inch |
| I/O | input/output |
| IPI | Intelligent Peripheral Interface |
| ISO | International Organization for Standardization |
| ITSMB | Image Technology Standards Management Board |
| JCL | job control language |
| K | kilo ($10^3$) |
| Km | kilometer |
| Laser | Light Amplification by Stimulated Emission of Radiation |
| LSI | large scale integration |
| lpi | lines per inch |
| log | logarithm (base 10) |
| MAC | message authentication code |
| Mb | $10^6$ bytes |
| Mbytes/s | $10^6$ bytes per second |
| MERADCOM | Mobility Equipment R&D Command |
| mi | mile |
| MICOM | Missile Command |
| mm | millimeter |
| mV | millivolt |
| mW | milliwatt |
| MSS | mass storage system |
| MTBF | mean time between failures |
| NA | numerical aperture |
| NARS | National Archives and Records Service |
| NATICK | R&D Labs |
| NBS | National Bureau of Standards |
| NCAR | National Center for Atmospheric Research |
| nm | nanometer ($10^{-9}$ meters) |

| | |
|---|---|
| NMO | number of critical microperations |
| NSA | National Security Agency |
| NTE | not to exceed |
| NTSC | National Television System Committee |
| | |
| OCLI | Optical Coating Laboratory, Inc. |
| OD | outside diameter (disk dimension) |
| $OD^3$ | optical digital data disk |
| ODL | optical disk library |
| OEM | original equipment manufacture |
| OML | Optical Media Laboratories |
| OMU | optical media unit |
| OSU | optical storage units/s |
| | |
| P | power |
| % | percent |
| PH | denotes photographic standards committees |
| | |
| RADC | Rome Air Development Center |
| RAM | random access memory |
| RC | Resin Coated |
| RH | relative humidity |
| RMS | root-mean-square |
| RPM | revolutions per minute |
| R/W | read/write |
| | |
| s | second(s) |
| SCSI | Small Computer System Interface |
| SEM | scanning electron micrograph |
| SMD | storage module drive |
| SNR | signal-to-noise ratio |
| SPARC | Standards Planning and Requirements Committee |
| SPIE | Society of Photooptical Instrumentation Engineers |
| SRM | standard reference material |
| STC | Storage Technology Corp. |
| | |
| TACOM | Tank Automotive Command |
| TAPPI | Technical Association of the Pulp and Paper Industry |
| TBM | Terabit Memory^Tm (registered trademark of AMPEX Corporation) |
| TDP | technical data packages |
| tm | trademark |
| 35 mm | thirty-five mm film (24 x 36 mm format) |
| TSARCOM | Troop Support and Aviation Materiel Command |
| | |
| USAF | United States Air Force |
| USGS | United States Geological Survey |
| | |
| VLSI | very large scale integration |
| | |
| W/R | write/read |

| | |
|---|---|
| YBF | Years Between Failures |
| o | degree |
| oC | degrees Celsius |
| C | Celsius |
| λ | lambda (wavelength) |
| θ | theta (angle) |
| / | per (a.g. pixels/mm read pixels per millimeter) |
| μ | micro ($=10^{-6}$) |
| μin | microinch ($=10^{-6}$ in) |
| μm | micrometer ($=10^{-6}$ m); also referred to as a micron |
| " | inch(es) |

## 5. Appendix B. Optical Digital Data Disk Preliminary Glossary of Terms

**This preliminary glossary has been written and will undergo further development by a task group of the X3/SPARC Optical Digital Data Disk Study Group. It offers a current set of definitions encountered in the OD$^3$ technology, that could be applied to OD$^3$ standardization.**

**NOTE: The text and illustrations in this workshop proceedings were developed independently of this glossary.**

### X3/SPARC Optical Disk Study Group
### Optical Digital Data Disk Preliminary Glossary

**address** (ISO) - A character or group of characters that identifies a register, a particular part of storage, or some other data source or destination.

**axial acceleration** - The peak apparent acceleration of recording layer in a direction normal to the reference plane (meters per second squared) at the operating rotational speed (rpm).

**axial total indicated runout (TIR)** - Maximum peak-to-peak apparent axial displacement (micrometer) of the recording layer perpendicular to the reference plane at the operating rotational speed (rpm).

**baseline reflectivity** - The reflectivity of unwritten, ungrooved media.

**beam diameter, $1/e^2$** - The diameter of a gaussian beam, measured at a distance of $1/e^2$ from the baseline intensity.

**beam diameter (FWHM)** - The diameter of a gaussian beam measured at a distance where the beam intensity is one half of the peak intensity.

**bi-refringence** - see double-pass optical retardation

**bit error** - see error

**bit error rate (BER)**

**carrier** - the rms carrier level in dBm in a specified bandwidth signal centered at the fundamental (carrier frequency) of a monotone recording. The input is a 50% duty cycle square waveform.

**carrier-to-noise ratio (CNR)** - The ratio of the carrier to the noise level in dB.

**cartridge** - A device containing an optical disk which serves to protect the disk from damage due to physical handling and to facilitate disk interchange. The cartridge may also provide space for physical labeling, features for write protection, provisions for automatic handling, and temperature and humidity sensors.

**concentricity** - The difference in the mechanical center locations of the centering feature of the disk and any contour on the disk (such as a pregrooved track).

**cyclic redundancy check character (CRC)** - A character used in a modified cyclic code for error detection and error recovery.

**dBm** - Decibels referenced to a one (1) millivolt level.

**decibel (dB)**

1. A unit to express the magnitude of a change in signal levels.
2. The difference in decibels between two signals is 20 times the common logarithm (base 10) of the ratio of their voltages.

**diode laser** - see semiconductor laser

**disk size** - The nominal outside diameter of the disk without cartridge including a rim or ring (if any) (mm).

**double-pass optical retardation** - The maximum optical path difference (in wavelengths) between any two coincident optical beams with orthogonal polarization propagating twice through the protective layer at normal incidence.

**entry face** - The disk or cartridge face on which the read or write beam first impinges.

**environment, operating** - May include the temperature (degrees C) and relative humidity (%RH) ranges for writing and reading disks with a specified maximum gradient for temperature (degrees C per hour) and humidity (%RH per hour); maximum dew point (degrees C); range of altitude (meters); and minimum conditioning time when taken from an environment outside the operating environment (hours).

**environment, shipping** - May include the temperature (degrees C) and relative humidity (%RH) ranges for shipping recorded or unrecorded disks with a specified maximum gradient for temperature (degrees C per hour) and humidity (%RH per hour); maximum dew point (degrees C); range of altitude (meters); allowable levels of shock (g's); and allowable duration.

**environment, storage** - May include the temperature (degrees C) and relative humidity (%RH) ranges for storing recorded or unrecorded disks with a specified maximum gradient for temperature (degrees C per hour) and humidity (%RH per hour); maximum dew point (degrees C); and range of altitude (meters).

**error** (ISO) - A discrepancy between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value or condition.

**error correction code (ECC)** - see error detection and correction code

**error ratio** - The ratio of the number of data units in error to the total number of data units.

**error detection and correction code (EDAC)** - A family of methods in which redundancy is added to a message in known fashion which is recorded with the message. Upon readback, a decoder removes the redundancy and uses the redundant information to detect and correct erroneous channel symbols.

**fill factor** - The $1/e^2$ diameter of a gaussian beam at the entrance pupil divided by the entrance pupil diameter.

**full-width-half-maximum (FWHM)** - see beam diameter (FWHM)

**imbalance** - The product of the total mass of the disk and the distance in the plane of the disk between the center of gravity of the disk and the axis of rotation of the disk (gm-cm).

**index of refraction** - The ratio of the phase velocity of light in a vacuum to that in a specified medium. The index of refraction is invariably a function of the frequency or wavelength of the optical radiation.

**laser** - An active electron device that converts input power into a intense beam of coherent optical radiation. An acronym for Light Amplification by Stimulated Emission of Radiation.

**laser diode** - see semiconductor laser

**noise level** - The level of rms electronic noise in dBm measured over a defined noise bandwidth.

**optical path length** - The sum of the products of the index of refraction (n) and the thickness of each layer (micrometer) between the entry face and the recording layer.

**protective layer** - The material between the entry face and the recording layer provided for mechanical protection of the recording layer and to defocus surface dust and scratches.

**radial acceleration** - The peak radial acceleration of any track on the recording layer relative to the axis of rotation of the disk (meters per second squared) at the operating rotational speed (rpm).

**radial total indicated runout (TIR)** - Maximum peak-to-peak radial displacement (micrometers) of any track on the recording layer.

**recording layer** - The disk layer on or in which the digital data is recorded.

**recording layer read exposure** - The maximum continuous read power (milliwatts) at the readout wavelength at the full-width-half-maximum (FWHM) read spot diameter allowed in the recording zone during readout at a specified linear velocity of the recording layer (m/s).

**recording layer reflectivity** - The reflectivity (%) of the disk at a specified wavelength measured through the protective layer (if any) at normal incidence.

**recording layer reflectivity uniformity** - The peak-to-peak variation of the recording layer reflectivity (% absolute) over the recording zone.

**recording layer sensitivity** - The minimum energy per mark (nanojoules per micrometer squared at the FWHM diameter) required to produce marks meeting specified carrier level using a specified nominal writing wavelength (nm) with a specified pulse length (ns) and a specified linear velocity of the recording layer (m/s).

**reference plane** - The plane normal to the axis of rotation of the disk drive spindle defined by the contact surface with the disk drive.

**second harmonic carrier** - The rms carrier level in dBm in a specified bandwidth centered at 2X the carrier frequency.

**semiconductor laser** - A laser in which stimulated emission of coherent light occurs at pn junction when electrons and holes are driven into the junction by carrier injection, optical exitation or other means.

**signal-to-noise ratio** - The ratio of the time averaged signal power to the total noise power (dB) over a defined bandwidth.

**static deflection** - The maximum distance a surface of the disk deviates from the reference plane (mm) in a static condition.

**strehl ratio** - The peak irradiance of a real spot divided by the peak irradiance of an aberration free (ideal) spot.

**thickness, apparent** - The thickness of an object as measured by optical means. The apparent thickness equals the physical thickness divided by the index of refraction of the object being measured.

**thickness, physical** - The thickness as measured by physical means (e.g., micrometer, calipers, etc.). The physical thickness is considered the real or actual thickness.

**unobstructed access** - Access is termed to be unobstructed when the recording zone may be accessed by the read/write optical head scanning in from outside the outer disk edge without raising or lowering the optical lens assembly, with the disk mounted to the spindle.

**warping angle** - The maximum angle (milliradians) between the axis of the disk and the normal to the reference plane when the disk is properly clamped to the spindle. The measurement should be made with the disk at a specified rotational speed (rpm).

**working distance** - The distance from the entry face to the closest point on the read/write head objective lens assembly.

**zone, clamping** - A region of the disk which may be in contact with the spindle and a clamping mechanism.

**zone, handling** - A region of the disk which may be physically contacted by a handling mechanism.

**zone, mechanically accessible** - The annular zone on and surrounding the disk which the optical head and can access, unimpeded by the disk or cartridge structure, with the disk mounted on a spindle.

**zone, optical beam accessible** - The annular subset of the mechanically accessible zone on the disk which can be accessed by the read or write beam.

**zone, recording** - An annular subset of the optical beam accessible zone available to the user for data storage.

## 6. Appendix C. Participants

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11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report constitutes the proceedings of the National Bureau of Standards/National Security Agency jointly-sponsored Workshop on Standardization Issues for Optical Digital Data Disk (OD$^3$) Technology, held in Gaithersburg, Maryland, June 1-3, 1983. The objective of this workshop is to promote discussion and interchange among current and potential OD$^3$ users and suppliers, regarding the prospects for OD$^3$ data interchange standardization.

The workshop presentations include definitions of the physical, dimensional, optoelectrical, quality and data transfer characteristics of OD$^3$ media, as related to the drive performance. A range of OD$^3$ applications and their standards' requirements are also described. The various methods currently used for estimating media life expectancies and the potential for standardized terminologies and procedures for such assessments are discussed.

Many workshop participants noted that there were numerous complexities associated with OD$^3$ data interchange among systems. Data interchange parameters include the optical media sizes, their reflection and transmission characteristics, error detection and correction schemes, and numerous other parameters that are incorporated in the functional design of OD$^3$ media and systems.

The participants also noted the timeliness and importance of OD$^3$ data interchange standardization activities and gave priority to the development of an optical digital data disk lexicon. Many of the workshop participants also expressed an immediate need for standardized test and evaluation procedures for OD$^3$ media responses, life expectancies, and environmental requirements.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)
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