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New Developments on Standards for the Permanence of Electronic Media

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Abstract

One of the major obstacles to the long-term preservation of electronic media is the lack of standards. Existing "industry standards" tend to be distillations of vendor responses to the imperatives of a competitive marketplace. As such, preservation is seldom a priority. Preservation of electronic media is dependent upon the permanence of the media, the hardware and the software. All three are essential for retrievability of information which is only machine readable. Permanence of the magnetic tape or optical disk media is very dependent upon the material as manufactured. Hardware availability requires that parts be obtainable when they become worn out. Consequently format obsolescence is a major consideration.

In the United States, a committee accredited by the American National Standards Institute was formed to address the subject of magnetic tape and optical disk permanence. This committee has been meeting regularly since 1989 and to date two standards have been published and several more are in progress. The first is a test method to establish the expected life of CD-ROM optical disks. Since optical disks do not undergo physical stress when used, the test method was based on an optical readout after accelerated incubation. The second standard concerns the proper storage conditions for magnetic tape. Work in progress on test methods is to determine the useful life of CD-MO and CD-R disks, and recommended storage for optical disks. A document on the care and handling of magnetic tape is in preparation.

The promise of broadly accepted standards is that institutions charged with the preservation of cultural material can embrace new technology while managing the inevitability of equipment and file format obsolescence.

Introduction

There are major gaps in our knowledge on the preservation of electronic images. This includes information on the relative stability of materials, on the recommended conditions for storage and on the means to evaluate the permanence of different media and treatments. This is becoming a serious problem since information is rapidly being recorded using electronic media, primarily in digital form. While electronic imaging has tremendous advantages with respect to access, data compression and transmission, it has some major drawbacks with respect to permanence. This has been recognized as a major concern for the preservation of our cultural records and resulted in a major study by the U.S. Library of Congress in 1996 on the state of our magnetic tape records.

This paper gives an overview of current thinking on the stability of electronic information with particular attention given to published standards and standardization activity on both magnetic and optical disk materials. The focus on standards is emphasized since the preparation of standards is of considerable importance to the industry. Standards offer the following contributions to the conservator, curator, archivist and librarian.

They represent a consensus of the best thinking of those who are most active in the field as well as of individuals having widely different backgrounds, training and interests. This insures that the views of one particular discipline does not predominate. For example, studies by research laboratories might suggest recommended storage and humidity conditions for storage, but the input from archivists is essential to ensure that these conditions are practical to obtain and to maintain.

They resolve differences of opinion and remove the onus of deciding which expert to believe. Consequently standards are a convenient source of unbiased information and they eliminate the need for curators to keep abreast of all the latest publications

Standards improve the quality of products available to the consumer. This is very obvious in some fields such as the permissible tolerance for formats and sizes, allowing materials from different manufacturers being usable in equipment produced all over the world. In the area of preservation, storage conditions are recommended that prolong the life expectancy of the recording media.

The preparation of standards in the preservation field is an involved and complicated process. This is not surprising because technical progress depends upon relating short-term studies with behavior after extended times in storage. The relationship is not always obvious. A basic problem is that although it is possible to obtain anecdotal evidence after long-term storage, there is usually a lack of information about the original state of the material, the enclosures and the storage environment.

Consequently prediction of life expectancy involves the use of accelerated testing with the resulting uncertainty in conclusions. Extrapolation of short term results under high

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stress conditions to long term behavior under moderate conditions is a very difficult analysis.

While laboratory work is usually carried out by manufacturers or government laboratories who have the necessary resources, data interpretation and establishing the specification parameters also includes consumer and general interest participants. This large commitment of time and resources is only made when the stability of the material and its economic importance justify this expenditure. This is the situation with paper and with photographic materials but it has been less apparent with magnetic tape.

Standards Organization

At this time, international standards have not been written on the preservation of electronic images although work had been started a bit more than a year ago. For this reason, this paper will focus on United States standards.

In the United States, the American National Standards Institute (ANSI) is the umbrella organization which has the sole authority to designate a document as a national standard. Technical Committee IT9 was organized to work on the permanence of photographic, magnetic and optical disk materials. All documents produced by this committee carry the numerical designation IT9, followed by a specific one or two digit number. Two standards on the preservation of electronic materials have been published and two more should be completed within the year.

Technical Committee IT9 includes individuals from diverse backgrounds, which is essential in order to obtain a balanced document. Representatives are active from significant manufacturers, government agencies, archives such as the U.S. National Archives and the U.S. Library of Congress, research institutes such as the Smithsonian Institution, the National Media Lab and the Image Permanence Institute, vendors of services and enclosure materials, and major technical societies. There is also welcome representation from overseas.

Magnetics

Magnetic recording media in the form of magnetic tape, in cassette or cartridge formats, and computer disks is widely used for information storage. The preservation of magnetic recordings is quite different from images on paper or photographic materials since the former are only machine readable whereas information on paper or photographic information can be retrieved without equipment or with a simple magnifying glass. Preservation of magnetic recordings are dependent upon the following four factors.

- The media as produced by the manufacturer.
- The storage conditions which are controlled by the user.
- The hardware which is the product of the equipment manufacturer. The rapid technological advances in electronic imaging and consequent obsolescence of hardware has aggravated the problem of retrievability.
- The software required for proper functioning of the hardware.

Standardization activities on the permanence of magnetic information is much less advanced than in the fields of paper and photographic permanence. In part this is the result of the later two being mature technologies with over 100 years of scientific advances and many years of activity in standards. In contrast, while the age of magnetic tape technology is close to 50 years, work on the permanence of such recordings was only started by ANSI in 1989. To date there is only one published standard and a second is in preparation. The current situation with respect to the important archival factors is reviewed.

Materials

Magnetic media appear quite similar, composed of a base coated with a magnetic layer. The earliest base was paper but in the 1950s this was replaced by cellulose acetate. Since the 1960s all magnetic materials are coated on polyester which has excellent stability. The magnetic particles are generally iron oxides, chromium dioxide, or metallic particles embedded in a polymer binder. The early binders were cellulose nitrate, vinyls, acrylic and epoxy resins. However, today practically all products use a polyurethane binder.

Magnetic tape is used in recorders and players which require it to be transported from hubs and reels over rollers and magnetic heads in a tremendous variety of configurations. There exists a large number of tape thicknesses and widths. Moreover, tape is relatively thin, varying from 10 to 50 μm, the thinner material providing greater data compaction but less physical protection. The net result is that tape life is usually controlled by physical failure, and this physical failure can be manifested in many ways depending upon the format, the recording device and the playback equipment. A critical feature in magnetic systems is the close spacing between the magnetic head and magnetic medium. This is required for optimum output, but it causes either head wear, binder wear, or both. In some situations, tape fails by binder debris clogging the magnetic heads while in others it may be due to high friction and the resulting lack of uniform transport. Consequently a tape specification must include a considerable number of physical tests. Standardization requires agreement on the physical properties to be included, the test equipment and procedure, the means of accelerating the test or incubation conditions in order to estimate life expectancy, and the determination of limits for failure.

During five years of deliberation, the ANSI group recognized that the critical physical properties are binder cohesion, binder-base adhesion, friction, clogging of magnetic heads, dropouts, and binder hydrolysis. Magnetic properties of interest are coercivity and remanence. These decisions in general were consistent with conclusions from individual investigations (1-5). Test procedures for adhesion, friction, hydrolysis were agreed to, but cohesion and dropouts are difficult to measure requiring extensive development work. The latter are also very system dependent. There was also agreement that some of these tests could be used to predict tape life whereas others would specify minimum requirements that tapes must pass.

Unfortunately, involvement by tape manufacturers has recently decreased to the point where there is no longer a critical mass to continue this activity. This lack of activity

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may possibly be due to the general acceptance that magnetic tape has a limited life expectancy (5-8). However, this leaves the consumer without a recognized specification to compare tape products and the manufacturers without a standardized procedure to evaluate tape life. The only option for the user is to purchase tape with recognizable brand names. In my opinion, the consumer of magnetic tape has not been well served.

Storage Conditions

It is a well-accepted fact that good storage conditions will prolong the life of all tapes and there have been many excellent papers written on this subject (9-12). The accepted recommendations have been incorporated into an ANSI document on the storage of polyester base magnetic tape which was published in 1996 as IT9.23. This standard was proposed last year to the International Standards Organization as an international standard and is currently being balloted.

The ANSI document covers relative humidity, temperature and air purity. Additional topics include recommended storage housings, storage rooms, and considerations for fire protection. Two types of storage conditions are specified, one intended for medium-term storage and the second for extended-term storage. The former is for a life expectancy of ten years and the latter is for materials of long-term value. More rigid temperature and humidity conditions are specified for extended-term storage and they should extend the useful life of most tapes to 50 years.

Degradation of magnetic binders is caused by chemical reactions, whose rates are lowered with decreasing temperature and decreasing relative humidity. Consequently, the useful life of film can be increased by lowering either the storage temperature or storage humidity. Moreover, a lower storage temperature can compensate for a higher humidity to obtain the same life expectancy (2,5,13,14). These relationships permit several temperature-relative humidity combinations to be acceptable for extended-term storage conditions and give the storage vault designer a range of options. A greater humidity tolerance is acceptable if the storage temperature is lowered. The lowest recommended temperature is 8°C because below freezing storage may create potential problems with some formulations due to the possibility of lubricant separation in the magnetic layer. Another storage concern is the avoidance of external magnetic fields and the problem of magnetic print-through with analog audio recordings. Other topics covered are acceptable reels, cassettes, cartridges and containers as well as acclimatization times required when ambient temperature and/or humidity is changed.

Work has now been started on recommendations on the care and handling of magnetic tape. Topics covered include cleaning, transportation, use environment, disaster procedures, inspection and staff training.

Hardware and Software Considerations

A major concern in the recovery of information on magnetic tape and disks is the preservation of the necessary hardware and software. Unlike photographic products, magnetic materials can only be machine read and the problem this poses has been recognized for many years (15,16). As equipment is used, parts wear out and must be replaced. Equipment repair is only possible if components are still manufactured or can be cannibalized from other equipment. If past history is any guide, the hardware will become obsolete within a relatively short time. Systems in this field are undergoing constant change and it is very doubtful that replacement hardware will be available after several decades. There are many examples where information on tape has been lost or would be very expensive to retrieve (17). Recent publications by the Smithsonian Institution (18) and the National Archives of Canada (19) suggested that in some cases photographic film may be the material of choice for preservation, while at the same time maintaining electronic images for viewing, editing and distribution.

In the face of the continued evolution and consequent obsolescence of playback hardware and software, consumers might wish that ANSI would create a single readability (i.e., hardware-software) standard that all future magnetic products must adhere to. However desirable this approach may be, it is not practical because it would inhibit the development of technology and would never be supported by the manufacturers. From a users viewpoint, neither the creation of a single readability standard nor the approach of maintaining obsolete playback hardware will guarantee the survival of information on magnetic materials. The only practical approach is a well-managed program of refreshing and migrating stored data from one system to a newer one as obsolescence proceeds.

Optical Disk Materials

Within the last 15 years there has been the development and explosive growth of information distribution and storage using optical disk technology. These materials have been designed in many configurations and for many applications. However, all share the common characteristic that they are read by light and are only machine readable. Hence they share some of the same dependencies and reservations for a storage material as magnetic tape. Preservation of recorded information is dependent upon the same four factors as discussed for magnetics, namely the stability of the material, the storage conditions, the hardware and the software.

Since this is a relatively new technical area, the scarcity of standards on the permanence of recorded information is not surprising. Within the ANSI organization, standardization activity was started in 1989, at the same time as work on magnetic materials. To date, one ANSI standard has been published and work is underway on three additional documents. The existing status will be discussed.

Materials

Unlike magnetic media, optical disks are manufactured not only in a variety of sizes, but they can also be composed of very different materials. The most common substrates are either polycarbonate or glass. The image recording layer features various organic or inorganic coatings since they can operate by several different mechanisms. For example, write-once disks can record information by ablation of

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either a thin metallic layer or a dye/polymer coating, by phase change, by metal coalescence or by change in the surface texture. Read-only disks have the surface modulated by molding of the polycarbonate substrate and erasable disks are based on magneto-optical or phase change properties. Despite this vast dissimilarity in composition, optical disks have an important advantage over magnetic materials with respect to predicting their life expectancy. Optical disks are recorded and read by light and do not come into contact with moving or stationary parts of equipment. Therefore their useful life is mainly determined by the properties of the material itself and unlike magnetic tape, physical wear and tear is less of an issue. This has resulted in the use of the Arrhenius method to predict the longevity of disks by several investigating laboratories. All these studies used an electronic readout signal to mark the course of disk degradation.

The Library of Congress (20) employed the uncorrected bit error rate as the primary measure of degradation after incubating the disks at elevated temperatures. Care was taken that the maximum temperature used was lower than the softening temperature of the substrate. A similar approach was suggested by the National Institute of Standards and Technology (21,22). The life expectancy of read only CD-ROM was studied at 3M (23,24) using block error rate as the signal and incubation was at several combinations of elevated temperature and humidity. A very similar methodology was employed by Kodak (25) in a study of writable CDs. The 3M procedure has been standardized by Technical Committee IT9 to predict the useful life of CD-ROMs and was published as IT9.21. This test method has been proposed to ISO for consideration as an international standard. It is currently in the balloting process. It should be noted that this test method predicts the effects of temperature and humidity only and is not a material specification. The difference is that the latter gives test requirements for all aspects of permanence that a material must meet to be given a life expectancy rating, while the former is only a single test procedure.

Optical disks can fail by a number of different mechanisms, such as relaxation of the substrate causing warping, changes in the reflecting layer by corrosion, cracking or pinholes, changes in the reflection of any dye layers by light, pressure or crystallization, or breakdown of the disk laminate by adhesion failure and layer separation. The CD-ROM test method is quite explicit in stating that it is only valid if the dominant failure mechanism at the accelerated conditions in the test method is the same as during usage. It also does not address material changes due to light or to exposure of corrosive gases.

Another property of concern in the stability of disks, not addressed in the ANSI test method, is the effect of temperature and humidity cycling. Temperature cycling may be critical because the different component layers have different thermal coefficients of expansion, resulting in large stresses between layers with the possibility of cracks, adhesion failure or deformation. Humidity cycling is likewise important because of differences in dimensional changes due to moisture absorption. Potential problems due to humidity cycling are more important for disks than for magnetic tape because of the greater thickness of optical disks and consequent greater times for moisture equilibrium. The importance of temperature-humidity conditioning times has been recognized (26) in the CD-ROM test method and staging (i.e., conditioning) times are specified. Environmental cycling tests are useful to determine disk behavior under high stress conditions, however, they cannot be used for predictions of life (20,27).

Technical Committee IT9 has now started work on a test method to evaluate the stability of writable CDs and magneto-optical (MO) disks. These are companion documents to the CD-ROM test method. It is expected that the test method for MO disks will be completed in 1997.

Of particular interest to the consumer is how long optical disks will last. Most of the published information is based on the test method described above. Some manufacturers (23,24,28) predict life expectancies greater than one century. The National Media Lab (8) reported a very wide range from 5 to over 100 years depending on the product. It can be concluded that although an ANSI specification for the life expectancy of optical disks does not exist, considerable progress has been made in standardizing the methodology on which to base predictions.

Storage Conditions

As with all materials, improvements in storage conditions will result in improved life. This is regardless of the inherent stability of the material. In other words, good storage conditions will prolong the life of even less than optimum disks. Unfortunately, storage temperatures and storage humidities have been recommended in some optical disks standards issued by the International Standards Organization (ISO) that are now considered in some quarters to be much too high. Technical Committee IT9 has recently initiated much needed work in this field and it is expected that a standard will be ready within the year. The recommended environmental conditions are 23°C and a relative humidity between 20 and 50%. As with magnetic tape, lower levels provide increased stability, with the lowest specified conditions being -10°C and 5% RH. This document also covers magnetic fields, enclosures, labeling, housing, storage rooms and acclimatization. These recommendations are consistent with those of the National Archives and Records Administration (29). Particular care should be given to maintaining a low dust and dirt environment. Another important consideration for optical disks is the avoidance of large temperature and humidity variations (26) as discussed previously. Protection from light is vital for many writable CDs.

Hardware and Software Considerations

The situation with optical disks is similar to that described for magnetic tape. Machine readable media require the necessary hardware and software to recover the information. This situation was recognized since the initial development of this technology (16). Hardware wear and particularly hardware obsolescence are serious concerns. There is no activity underway within Technical Committee IT9 to standardize on hardware and software for optical disks for the reasons discussed for magnetic materials.

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Because of obsolescence concerns, a very negative future was recently predicted for the permanence of information stored on CD-ROMs (30). However, this was based on the assumption that data on this material would remain untouched and not copied during its storage life. This is not the currently accepted viewpoint. There are two approaches to the long-term preservation of information on optical disks.

For many years it has been understood that preservation of information on optical disks means refreshing from obsolete onto newer systems (31). Digital preservation depends upon this reformatting and not on preservation of the physical media. D.J. Waters (32) expressed this concept as a change to thinking in terms of life cycles. Permanence of digital storage should be considered as a measure of the length of the renewal period. Unlike analog information, digital recordings can be copied without any loss in quality. This lead to the optimistic conclusion (33) that digitized information can be preserved forever provided attention is given to periodic recopying. However, a recent report by the Commission on Preservation and Access (34) indicated that the cost and complexities of refreshing digital information presents a real threat to information life. Deliberate or inadvertent failure to do so because of expense or difficulty can result in data loss and there have been many anecdotes where this has occurred. Lesk (35) indicated that refreshing will be a recurring cost which should be considered in operating a library or archive. Consequently, extending the life of the media as long as possible will reduce this cost.

As discussed under the magnetic section, an alternate approach is to use photographic film as the preservation media for stored digital images (18,19,31) and digital recordings for display and transmission. H. Weber (36) stated the firm conclusion that optical disks are to be recommended as an access media but they are not reliable for storage because of the doubtful incompatibility of future systems, microfilm being the superior material. Undoubtedly different archives will use different combinations of the recopying or the photographic procedures, depending on such factors as the size of the collection, the quantity of existing microfilm records, the demands for access and cost considerations. For example, a recent recommendation (37) to law librarians was not to digitize the vast quantities of existing microfilm but only to digitize on demand.

Conclusions

In the field of magnetic recordings, there has been limited standardization activity. Although some work was done in an ANSI committee on various test methods to evaluate stability, there does not exist a material specification. Likewise there are no standards on hardware and activity is not planned. However, a positive accomplishment has been the publication of a magnetic tape storage document and work is underway on recommendations for the care and handling of tape.

Permanence standards on optical disks are somewhat further advanced than with magnetics. Optical disks are not subject to physical abuse as magnetic tape and this simplifies evaluation. A test method to evaluate temperature and humidity effects on CD-ROMs has been published and a companion document on MO discs is nearing completion. The importance of the storage environment is also recognized and a storage recommendation should be published shortly.

It makes economic sense to prolong the life of imaging media as long as possible so that hardware obsolescence and not media life is the controlling factor. Permanence standards for electronic materials are therefore of considerable benefit to control costs and finite progress has been made in this area.

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