General Comments on the Stability of Videotape

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As the Principal Investigator for Media Stability Studies at the National Media Laboratory, I have investigated the stability of magnetic videotape used for both analog and digital recording. The National Media Lab (NML) is an industry resource supporting the U.S. Government in the evaluation, development, and deployment of advanced storage media and systems. The NML endeavors to provide a broad perspective of current progress in storage issues, both from a commercial and a government perspective.

Videotape poses a special challenge to archivists, librarians, historians, and preservationists. As an information storage medium, videotape is not as stable as photographic film or paper. Properly cared for, film and paper can last for centuries, whereas most videotapes will only last a few decades.

Videotape recording technology consists of two independent components—the magnetic tape medium and the recorder. Neither component is designed to last forever. Images recorded on a videotape can be lost because of chemical degradation of the tape. However, access to images recorded on a tape can also be disallowed because the video format has become obsolete and a working recorder cannot be located.

Videotape Components

Videotape consists of several components. The layer which is responsible for recording the magnetic signal consists mainly of magnetic particles held together by a binder polymer. Lubricants, carbon black, head cleaning agents, and other components are also added to this layer to reduce wear, facilitate tape transport, dissipate static charge, and reduce dropouts. This relatively thin, paint-like, magnetic layer is supported on a thicker, stronger substrate film. A thin back coat layer can also be added to the other side of the substrate film to improve tape wind, facilitate transport, and dissipate static charge.

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Over time, videotape properties can change unfavorably. Hydrolysis of the binder polymer can result in a less durable, more gummy magnetic layer resulting in an increase in dropouts. Loss of lubricant over time can result in increased wear of the magnetic layer during playback. The magnetic pigment can lose some of its magnetic signal resulting in poorer color reproduction and contrast on playback of analog recordings and dropouts in digital recordings. The backing film can creep and deform in improperly wound tape packs resulting in mistracking on playback.

Binder Polymer

The binder polymer has the function of securing the magnetic pigment to the tape backing and providing a smooth surface to facilitate transportation of the videotape through the recording system. Other components are added to the binder to help with tape transport and facilitate playback. A lubricant is added to the binder to reduce friction, which reduces the tension needed to transport the tape through the recorder and also reduces tape wear. A head cleaning agent is added to the binder to reduce the occurrence of head clogs which result in dropouts. Carbon black is also added to reduce static charges which attract debris to the tape.

The binder is responsible for holding the magnetic particles on the tape and facilitating tape transport. If the binder looses integrity—through softening, embrittlement, loss of cohesiveness, or loss of lubrication—the tape may become unplayable. Sticky tape and sticky shed are commonly used terms to describe the phenomenon associated with deterioration of the magnetic tape binder.

The binder polymers used in magnetic tape constructions are subject to a chemical process known as hydrolysis. In this process, long molecules are broken apart by a reaction with water to produce shorter molecules. The shorter molecules do not impart the same degree of integrity to the binder system as do the longer molecules. Water must be present for the hydrolysis reaction to occur. Videotapes stored in a high humidity will undergo a greater degree of hydrolysis that tapes stored in low humidities. Binder hydrolysis can lead to a softer than normal binder coating, higher friction, and/or gummy tape surface residues. Tape binder debris resulting from binder deterioration may result in head clogs which may produce dropouts on a videotape when played back.

Lubricant

Lubricants are normally added to the binder to reduce the friction of the magnetic top coat layer of videotape. A lower friction will facilitate tape transport through the recorder and reduce tape wear. In a videotape recorder, where the tape is usually

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wrapped around a rapidly rotating head, low friction is important as it prevents overheating of the tape.

Over time, the level of lubricant in videotape decreases as lubricants are partially consumed every time the tape is played. Lubricant levels also decrease over time even in unplayed, archived tape as a result of evaporation and degradation. The lubricants used in some tapes are oily liquids which are volatile and slowly evaporate away over time. Some lubricants are also subject to degradation by hydrolysis and oxidation, just like the binder polymer, and will loose their essential lubrication properties with time.

Magnetic Pigment

The magnetic pigment is responsible for storing the recorded video signal. If there is any change in the magnetic properties of the pigment, recorded signals can be irretrievably lost. The magnetic remanence is the property of a pigment that enables it to retain a magnetic field. A decrease in the magnetic remanence of the pigment over time can result in a lowered output signal. The coercivity characterizes the pigment's ability to resist demagnetization. A magnetic tape with a lower coercivity is more susceptible to demagnetization and signal loss.

Magnetic pigments differ in their stability—some particles retain their magnetic properties longer than others. So some videotapes will retain initial image quality longer than others. Iron oxide and cobalt-modified iron oxide pigments are the most stable pigment types of those used in videotapes. Metal particulate (MP) and chromium dioxide (CrO_2) pigments provide a higher tape signal output and permit higher recording frequencies than the iron oxide pigments, but are not as stable as the iron oxide pigments. A loss in signal will manifest itself as a loss of hue and reduction in saturation for an analog video recording.

There is not much that can be done to prevent the magnetic deterioration that is inherent in the metal particulate and chromium dioxide pigment types. However, the rate of deterioration can be slowed by storing the tapes in cooler temperatures. The level of humidity has little direct effect on the deterioration of magnetic pigments. However, by-products of binder deterioration can accelerate the rate of pigment deterioration, so lower humidity would also be preferred to minimize the degradation of the magnetic pigment.

Tape Backing

The backing film, or substrate, is needed to support the magnetic recording layer, which is too thin and weak to be a stand-alone film layer. In some tape systems, a back coat is applied to the backside of the tape substrate layer. A back coat reduces tape

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friction, dissipates static charge, and reduces tape distortion by providing a more uniform tape pack wind on the tape reel.

The tape backing, or substrate, supports the magnetic layer for transportation through the recorder. Since the early 1960's, most videotapes have used an oriented polyethylene terephthalate (PET, DuPont Mylar™) film as a tape substrate material. PET has been shown, both experimentally and in practice, to be chemically stable. PET films are highly resistant to oxidation and hydrolysis. In archival situations, the polyester tape backing will chemically outlast the binder polymer. The problem with polyester backed videotapes is that excessive tape pack stresses, aging, and poor wind quality can result in distortions and subsequent mistracking when the tapes are played.

The Longevity of Videotape

The National Media Laboratory has been investigating the stability of magnetic tape since 1989. Several key magnetic, physical, and chemical properties of magnetic tapes aged in accelerated environments have been studied as a function of time. The experimental data collected have been modeled using relevant kinetic expressions. Once established, these models allow the estimation of life expectancies assuming that the videotapes are stored at specific temperatures and humidities.

There are several analog videotape formats—quadruplex, U-matic, Betamax, VHS, 8mm. Likewise, there are several digital videotape formats—D-2, D-3, D-5, digital BetaCam. Videotape longevity is determined in part by the design of the system used to play them. Furthermore, analog and digital videotapes differ in the way in which they fail. There are also several manufacturers of videotape who may have changed formulations several times over the years of production.

Videotape longevities are highly dependent on the particular recording format used, quality of the videotape, conditions under which the tapes are stored, care with which the tapes are handled, and the number of times the videotape is accessed over its lifetime. As such, it is very difficult to make a general statement regarding the life expectancy of videotape. However, extrapolation of kinetic models points to the benefit of proper storage conditions in increasing the longevity of videotape.

Storage and Handling

Individuals who are responsible for videotape collections must be aware of the specific care and handling requirements for magnetic tape. The instability of videotape, relative to film and paper, requires that special practices be implemented to ensure that the recorded images will be preserved. Storage recommendations such as those from SMPTE RP-103 (1982) of 70°F ± 4°F and 50% ± 20% are based on what is convenient for immediate playback of tapes and economical from an environmental control standpoint. Special storage environments may be required if the videotapes are to be preserved for longer than 10 years. For collections which must be preserved indefinitely, transcription from old media to new media is inevitable, both for reasons of media instability *and* obsolescence of the recording technology.

Storing videotape in a clean, controlled environment is the single, most important thing one can do to extend its life. High temperatures, high humidity, and the presence of dust and corrosive elements in the air all affect the physical components that make up magnetic tape and can result in videotape signal loss through decreased magnetic capability and deterioration of the binder or backing of the tape.

An understanding of videotape degradation mechanisms makes it clear as to how proper storage and handling can increase the life of videotape. Cooler storage temperatures slow the rate at which tape binders degrade and thus extend the life of the videotape. Lower relative humidities also reduce the rate and extent of binder hydrolysis.

All videotapes, regardless of format will last longer if the tape packs are wound properly and the tapes are stored at reduced temperatures and humidities. Models for binder hydrolysis prepared by the National Media Laboratory indicate that some videotapes will last twice as long when stored at 68°F & 30% RH rather than at 72°F & 50% RH. Be advised, however, that too low of a storage temperature may result in the migration of lubricants to the surface of some videotapes which can interfere with proper playback.

The best way to reduce the degree of tape backing distortion which can result in mistracking is to store videotapes in an environment that does not vary much in temperature or humidity. Each time the temperature or humidity changes, the tape pack will undergo expansion or contraction. These dimensional changes can increase the stresses in the tape pack which can cause permanent distortion of the tape backing. Mistracking can also arise if the tape experiences non-linear deformation as a result of non-uniform tape pack stresses. This normally results if the tape pack wind quality is poor as indicated by popped strands of tape—one to several strands of tape protruding from the edge of a wound roll of tape.

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Analog versus Digital Videotape

The chief advantage of an analog recording for archival purposes is that the deterioration of the recording over time is discernible. This allows the aging videotape to be copied to a new tape before it reaches a point where the recording quality has degraded to an unacceptable level. Even in instances of severe tape degradation, where video quality is severely compromised by the presence of a high rate of dropouts, a portion of the original image will still be perceptible.

A digital videotape will show little, if any, deterioration in quality up until the time at which catastrophic failure occurs—large sections of recorded information will be completely missing. None of the original material will be detectable in these missing sections.