Videotape Preservation Handbook

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I. INTRODUCTION

PURPOSE

This handbook is intended to answer the questions of archivists, librarians, and others who have a collection of videotapes they wish to keep for many years. The guidelines offered touch briefly on each appropriate topic, but do not cover any topic in detail. (Refer to the appendix for sources of more detailed information.)

TAPE AS AN ARCHIVAL MEDIUM

Magnetic tape is not considered a good long-term storage medium for archival material. In fact, there is no good archival medium for the long-term storage of video. The archivist is therefore faced with the problems of maintaining obsolete equipment and having to migrate (copy or transfer) material to a newer tape format or a different type of medium.

Nothing is permanent, but properly made magnetic tape stored in reasonable archival conditions has lasted over 50 years. The main archival problems seen with magnetic tape are instability of the binder with some types of tapes, and the rapid obsolescence of the equipment (formats).

Even if there were a convenient and economical long-term storage medium available, it would still be imperative that archivists establish a long-range plan for care of the magnetic tape material in their facility until all of that tape is migrated to the new medium, or to a new tape format. Migration must be considered an element of all long-term archival plans. This handbook is intended to help the archivist in this endeavor.

PRESERVATION FUNCTIONS

Preservation

Preservation broadly encompasses those activities and functions designed to produce a suitable and safe environment that extends the useful life of collections. It includes securing the funds for preservation activities, security, and disaster preparedness, as well as conservation, restoration, examination, documentation, and a long-range plan.

Conservation

Conservation is generally considered to be but one aspect of an overall preservation program. Conservation allows a tape to realize a full life by implementing proper maintenance, handling and storage procedures. This entails suitable storage in proper temperature/humidity conditions, sequestering from use as a service copy, monitoring staff handling procedures, and restoration.

Restoration

a. Physical Restoration

Restoration involves actions to stabilize and return a deteriorated or damaged tape as nearly as possible to its original condition. This means treating a failing tape in a manner that enables the recording to be played at the same level of quality it held when first laid down.

It is assumed that there is intrinsic value in the recorded information or content and little, or no, intrinsic value in the original physical item itself. Thus it is appropriate, for example, to transfer material from an obsolete tape format to a newer format of equal or better quality.

b. Content Restoration

For archival restoration, video and audio enhancement techniques that would be an alteration of the original recording should not be used to process the signal. If enhancement is deemed necessary, enhance a copy but do not alter the original.

Examination and Documentation

Examination involves physically inspecting the tapes and tape containers and/or actually playing the tapes. Examination should include checking documentation that identifies the material recorded on the tape and ensuring that labels and file material agree.

Every archive should have an examination/documentation plan for all incoming tapes.

Examining/documenting all of the tapes already within a collection is usually a much more difficult task. Most collections are too large to examine all of the material at one time. Depending on staff and resources, a systematic sampling of the entire collection may be performed and this may be done periodically.

(Refer to Section III-2, Inspection Criteria, p. 8-9.)

II. VIDEOTAPE

A BRIEF HISTORY OF VIDEOTAPE RECORDING

The first practical videotape recorder was the 2" Quad developed by Ampex in 1956. It was first used only to delay network TV programs for the various time zones.

In 1969, several Japanese companies produced 1/2-inch reel-to-reel video tape recorders to a mutually agreed upon EIAJ (Electronic Industries Association of Japan) standard. These were the first affordable videotape recorder, and were used by schools, companies, and a few special consumers. In 1971, Sony introduced the first successful cassette VTR (Video Tape Recorder) -- the 3/4-inch U-matic, which replaced the 1/2 inch reel-to-reel format.

The first successful VCR (Video Cassette Recorder) format for the home was the Sony 1/2-inch Betamax, introduced in 1975. In 1976, JVC introduced VHS, which overtook Betamax in popularity as the consumer videotape format.

In the professional arena, the one-inch (Type C reel-to-reel) tape was introduced in 1978 and soon replaced most Quad machines. In 1987, the D-1 Digital videotape recorder was introduced, but only "high-end" users (primarily production studios) could afford it. By 1995, new digital videotape recorder formats were priced low enough for the industrial/educational market.

The videotape format charts at the end of the handbook (Figures 1, 2, and 3) include only the more popular videotape formats. There have been many formats introduced that never became commercially successful.

VIDEOTAPE FORMATS

The term "format" is used to describe the physical dimensions of the recording on the tape and also such things as the cassette size, the width of the tape and the speed in which the tape is recorded and played. It

can also refer to the hardware or equipment required to record, play, or edit the tape. The original videotape format was the 2" Quad.

VHS is an analog format developed to make videotape recording affordable to everyone, and it was not designed with high resolution and long life in mind. It should not be used for important archival material. If you must use VHS, then use industrial VHS VCR's, which are much better than consumer models. The S-VHS format is a better format than standard VHS, but it is no longer in production.

Betacam-SP is a popular archival format, and includes equipment that varies radically in price, though be aware that the quality of the audio of the cheaper machines may not be adequate. Type C is another good archival format, but is no longer in production. Both Betacam-SP and Type C are analog.

(Figure 2 illustrates the four categories of videotape formats. Composite and component are defined in the Glossary.)

For videotape recording, the term analog is used to describe a particular method used to record information onto a tape: analog representations are recorded as a continuous signal, while digital representations consist of values measured at discrete intervals. Analog has the advantage of being inexpensive, and the disadvantage of being very susceptible to variations in tape/tape recorder problems.

Digital has the potential of recording the video image at a higher quality then analog, but not all digital formats do this. The high quality professional digital videotape recorders are more expensive than analog recorders, but they are a good archival medium because they solve two of the main archival problems: quantifying any deterioration of the material, and making an exact duplicate of the original.

With high quality professional digital tape recorders, the unprocessed off-tape data error rate can be measured -- which is a measure of the quality of the recording. This takes only a minute or two and can be done periodically. The error rate can be tracked over the years and if it ever reaches a pre-established questionable level, then the tape can be copied. During the copying process error correction circuits are used, and the copy should be a clone of the un-degraded original.

Many digital videotape recorders use compression, that is sophisticated electronics to determine what parts of the video information are redundant and can be eliminated. For example, a blue sky would not be mapped by thousand of data points representing every pixel of entire blue area. Instead, the entire area is mapped, and all points with the same level of blue will be represented by a few bits of data. As a rule, digital tape recorders that use compression should not be used for important archival material because compression throws away some of the information that was contained in the original tape.

Many of the smaller digital videotape formats use very thin tape, which are used to pack more hours of video onto a small cassette. This is not a major benefit for archives, and tapes thinner than about 12 μm are not advisable for archival material. The thinner tapes are both more susceptible to damage and more difficult to restore after being damaged.

A knowledgeable technical person should advise you on whether or not a special converter is required to obtain a high quality digital recording when making a copy,. The different digital tapes formats use different digital “languages” and usually require a "translator" box if you want to keep the information in digital form. If you use the analog video output of the digital recorder, the signal will be inferior, and this should not be used for transferring (migrating) to another digital format.

Two important points to remember about formats are:

1) Choose a format with a large installed base so that the equipment and parts will be available years after the format is no longer being produced.

2) Buy the best quality equipment available. This does not mean you have to buy the highest priced model, because you may not require features like editing and slow-motion, etc.

TAPE TYPES

(Figure 4 is a cross-sectional representation of magnetic tape.)

Backcoat:

Since the late sixties, most tapes have been made with a thin carbon-black backcoat that serves three functions:

1) It is electrically conductive so that electro-static charges will not build-up when the tape is shuttled at high speed.

2) During high-speed, the layers of tape in the pack cling to each other and create a uniform tape pack.

3) It deters layer-to-layer slippage during shipping as well as during storage.

Basefilm:

The basefilm (or carrier, or substrate) of videotape is **PET** that was about 0.0015 inches thick (0.0015"=1.5 mils=37.5 µm) for the original quad tapes and is about .5 mils thick (12.5 µm) for the most recent tapes. Polyester will change in length in response to changes in tension, temperature, or humidity. Normally, these changes are so minute that they are not a problem.

PET is very stable chemically and has an estimated life of several hundred years, if it is stored at a reasonable room temperature and out of UV light.

Binder:

A binder is mixed in as part of the magnetic coating and adheres the magnetic particles to the basefilm. Depending on the type of binder and the environment in which the tape is stored, some binders can degrade in just a few years.

Magnetic Coating:

The magnetic coating of videotape is usually about 200 micro-inches thick, which is much thinner than the coating on audiotape. The magnetic particles are 10 to 20 micro-inches (1/4 to 1/2 micron) in length.

The magnetic coating of magnetic tape is a complex mix of magnetic particles, binder, lubricant, head cleaning agent, surfactant, and many other chemicals. Each tape manufacturer uses a special magnetic particle, lubricant, etc. that they will not publicize. Some of the formulas stay constant for several years, but they may be modified several times during the life of a given product. This multitude of variables makes it impossible to accurately predict the life of videotape.

Generally, about 40% of the volume of the magnetic coating consists of the magnetic particle itself. The magnetic particle used in the original Quad tape was iron oxide (rust), which had a magnetic strength (coercivity) of about 300 oersteds. Cobalt-doped iron oxide tapes (first used for Type C tape) have a coercivity of 600 to 800 oersteds. The MP (metal particle) tapes used for digital video and Hi-8 are around

1500 oersteds. The higher the oersteds, the more data can be packed into a given volume and the more difficult it is to erase.

MP and ME Tape:

Metal particle (MP) was introduced as a videotape product in 1987. Before that is was used by some audiotape manufacturers, some of whom did not understand that each individual metal particle had to be "armor-plated" to prevent it from oxidizing. As a result, MP had a bad reputation for several years. By the time MP was produced for videotape, the major tape manufacturers had developed techniques for passivating each particle with a protective coating. Battel Institute, Ampex, and Sony performed extensive tests on MP tape and the conclusions were that MP tape has a long life expectancy (see Section IV-Appendices, 4-Reference a, p. 18)

Metal Evaporated (ME) tape was originally developed for the Hi-8 format in 1989. Until 1996, ME tape had durability problems. Recent ME tapes may or may not be acceptable as an archival tape. Adequate testing must be performed to verify their stability and durability.

Tape life

The main factor limiting the life of most videotapes is hydrolysis of their polyester urethane binder. Identifying which tapes are subject to this problem is not easy, so it is recommended that all tapes be stored in a low humidity environment.

Contrary to what many people believe, demagnetization of a tape recording is an infrequent occurrence. Because of the high coercivity of most magnetic tapes, a very large magnetic field is required to erase the recording. However, such a large magnetic field is produced by the erase head on tape recorders: when the "Record" button is pressed, the erase head is turned on, and the portion of tape in contact with the erase head will be erased. To prevent accidental erasure of archival tapes, it is recommended that all tape recorders in the archive be modified so the record function is either disabled or can be activated only by using a special key.

The magnetic fields of motors, transformers, and TV sets are designed to be self-contained, so a tape would have to be within about an inch of the coils of these devices for them to have a noticeable effect on the tape.

Quad tapes are the most susceptible to erasure since they have a magnetic strength of only 300 oersteds. Even so, a field of 20-30 oersteds is required to have an effect on a Quad tape and fields that large are not normally found in an archive. A rule-of-thumb is that a tape can be safely stored in a magnetic field less than 1/10 of the coercivity of the tape. A more conservative figure of 1/20 is recommended for archives.

Some Metal Particle tapes will lose a small percentage of their magnetization if exposed to high temperatures for several months. In 1992, scientists at Sony developed an improved metal particle that has an estimated life of 150 years, if stored at 21 °C (70 °F) and 60% RH. The same metal particle has an estimated life of 700 years if stored at 10 °C (50 °F) and 60% RH. (See Reference 2) This illustrates the effect of temperature on the life of the metal particle. Note that these estimates are for the life of the metal particles in the tape--not for the tape itself.

The polyester basefilm is estimated to last hundreds of years when stored in reasonable archival conditions. The polyester can be temporarily stretched or otherwise deformed but can usually be returned to its original shape by a person knowledgeable in restoration procedures.

To minimize the possibility of damage to the tape, original tapes should be kept in the vault and rarely used. The only time they should be used is for making a copy (a Secondary Master). This Secondary Master should be used to make additional copies.

THE MOST COMMON TAPE PROBLEMS

Sticky-Shed Syndrome

The binder is the weak point of most videotapes. In the late sixties, polyester urethane became a popular binder for videotapes because of its low cost and durability. The problem with polyester urethane is that it can absorb moisture, which changes its molecular structure. High temperature and high humidity accelerate this process.

The first sign of binder breakdown is usually the presence of a powder or a gummy residue on the surface of the tape. When the tape is played, this residue attaches to the playback heads, with results ranging from poor (or no) playback to a jammed machine. If this happens, the tape should be ejected or rewound and all affected tape path parts should be cleaned. The tape can be made playable by using a tape-cleaning machine to remove the powder from its surface or by "baking" the tape. Only a person knowledgeable of the possible problems should do the baking process. The tape baking procedure is discussed in the article "Sticky Shed Syndrome--Tips on Saving Your Damaged Master Tapes," *Mix*, May 1990, p. 148.

Tape cleaning or baking will make the tape usable for a few weeks--until the powder forms on the surface again. After that, the process must be repeated to make the tapes playable again. This hydrolization of the binder will continue unless the tape is stored in a cool, dry environment to reduce the rate of deterioration.

Bad Playback Signal

Sometimes no amount of tracking adjustment will allow high quality video playback. Cleaning the tape guides, adjusting the tape tension, or playing the tape on another tape recorder can often correct this problem. Another possibility is to connect the output of the tape recorder to a Video Processor or a Time Base Corrector. (For more information about this, refer to the Appendix.)

The problem could be that the tape you have is not fully compatible with the machine you are using. Some tape formats have several improved versions that were developed over the life of the format. For instance, High-Band Quad is not compatible with the earlier Low-Band Quad. Some Quad machines have a switch allowing the user to select High-Band or Low-Band.

Edge Damage or Warped Tape

Since polyester can be deformed and "reformed", a tape that appears to be unplayable because of polyester deformation can often be restored to a playable condition. First, the tape should be fast forwarded to the end. Then it should be rewound to the beginning and played to the end. Carefully observe how the tape is packed on the takeup hub. If the pack is flat, than bake it at 110 F-120 F for a few hours. After the tape has cooled for a few hours, rewind and play it. Baking a tape should not be done unless you know how to do it.

If the tape did not pack flat, rewind it and play it on another tape recorder. The tape may pack flat on the second tape recorder.

Unstable Video

If the video tears, rolls vertically, or jiggles, use a video processor or a time base corrector (TBC) to make the video stable. (Refer to Section IV. Appendices, 2, Video Processors/TBCs, p. 13.)

III. Preservation Management

1. ENVIRONMENT

ENVIRONMENTAL CONDITIONS

To minimize the risk of developing problems, tapes should be stored at a humidity of around 25% RH and at a temperature less than 22 C (70 F). Around 8 C (46 F) is the best long-term storage temperature, but tapes should not be stored below 8 C. Figure 4 illustrates what is meant by a cool and dry environment--which is the area to the lower-left. Humidity variation should be less than ±5 % RH and a temperature variation of less than ±2 C.

The primary enemy of tape life is high humidity. Several studies have demonstrated that an environment of 20 % RH to 30 % RH is necessary to prevent or decrease the deterioration of the tape binder. Installing a dryer in your air conditioner system is one possible way of controlling humidity. If the tape storage room is well insulated, a relatively small dryer can be used. The room should be able to retain the proper environment for about two days, in case of a major power failure.

The air in many urban areas contains many contaminants that can harm archival material. In these cases, the air should be filtered with a 99.5% HEPA filter

TAPE STORAGE AND USE ROOMS/AREAS

- The room must be fireproof and not contain wooden boxes, cardboard boxes, or wooden shelving. If an overhead sprinkler system is used, design the shelves so that sprinkler water will not contact any tapes. Do not store tapes on the floor. Shelving should provide for air circulation around the tapes. Circulating air and low humidity prevents mildew.
- The walls, floors, and ceiling must be made of dust-free, easy to clean material. Carpet should not be used. Use a "water" vacuum cleaner, or one with a hose that exhausts outdoors, or a vacuum cleaner with a 95% HEPA filter or better.
- The room should be well insulated and without windows.
- The floor must have a large drain in case a water pipe breaks or the sprinkler system discharges. The drain should have a flapper valve rather than the normal J-Trap, because a J-Trap must have water in it.
- A clean room sticky floor mat should be placed in the doorway of the entrance to the tape storage room. This will prevent debris from shoe soles from being tracked into the room.
- Prevent the exposure of tapes to dust by providing a clean area where boxes of tapes can be opened.
- As a strategy to enhance storage security, all tapes should be copied and stored in a separate part of the building, or, preferably, stored in another building.

2. CARE AND HANDLING

INSPECTION CRITERIA

- Type of container the tape is in (cardboard, cheap plastic, shipper, etc.)
- Check physical container for damage that compromises the structural integrity of the container itself. Does the container need to be replaced?
- Check the interior of the container and the edges of the tape for patterned black, brown, or mustard colored contamination that can indicate the presence of fungus.
- Is the tape in a plastic bag? Sealed or unsealed?
- Determine the tape format. If it is an unknown format, it should be identified as unknown.
- Does the label on the tape match the label on the container.

- Note the brand of the tape.
- Note anything unusual.
- For open reel tapes; is the end-of-tape secured? Special holddown tape is made for this purpose.
- Check the tape edge for white powder or crystalline residue and check the interior of the container for black/brown flakes of oxide. The presence of such debris indicates that the tape needs restoration work.
- Check the condition of the tape pack. A loosely packed tape or a tape that is distorted should be rewound.
    a. For open reel tapes; pull on the end-of-tape and notice if the tape pack slips. If the pack rotates, the tape is packed too loose.
    b. For a cassette tape; rotate the two hubs in opposite directions and observe if the pack slips severely.
    c. Alternatively; look for any space between layers. Any noticable space indicates a loose pack.
    d. Look at the tape pack and notice if there are any pack distortions radiating out from the hub.

CLEANING MAGNETIC TAPE

Normally, tapes do not need to be cleaned, except when they have powder shed or a gummy residue. In these cases, the tape can be cleaned (or baked) to make it playable. Only a person who understands the potential problems should bake tapes.

The best method for cleaning is by using a long-fiber paper wipe, commonly called Pellon, which can be bought from archival supply companies or at a Fabric store. A good technician can convert an old tape recorder into a tape-cleaning machine. Both surfaces of the tape must be cleaned.

Some tape cleaning machines have a razor-sharp blade for cleaning tapes. This type of blade must be kept clean or it can damage tapes. Also, tapes with a splice should not be run over a cleaner blade because the splice can get caught on the blade and damage the tape. It is rare to find spliced videotape but many audiotapes have splices.

Moldy tapes must not be cleaned or baked until the fungus has been killed. (Refer to Section 5, Emergency Preparedness, Fungus, p. 12.)

TAPE HANDLING AND PRECAUTIONS

- Always wind a cassette tape to one end before ejecting.
- Never touch a tape except at the end/beginning of an open reel tape.
- Handle open reel tapes by the hub. Do not squeeze the flanges.
- Do not handle a cassette tape by the movable door.
- Always place reels of tape and cassettes on a clean, flat area.
- Keep tapes away from direct sun.
- Do not place tapes near a heat source, an electric motor, or a transformer.

TAPE RECORDER MAINTENANCE

Proper maintenance of your tape recorders is critical. A misaligned or dirty tape recorder will produce unusable recordings. Clean your recorders weekly if they are used often--monthly if lightly used. If you play a dirty tape, clean the recorder before playing another tape.

Tape cleaning cassettes using a white or green long-fiber paper material named Pellon are the best way to clean cassette recorders. A properly trained technician should clean reel-to-reel recorders.

If your recorders are used several times a week, they should be thoroughly cleaned and checked for alignment by a tape recorder technician on an annual basis.

ORIGINALS AND COPIES

The television industry and the archival community use several terms for an original tape. For this paper, original applies to the earliest generation in the archive.

1) Originals, Masters, and Edit-Masters

- Store in an environment of 20-30 % RH and as low a steady temperature as possible, but not below 8 C.
- The storage area should be well insulated, of fireproof construction, and have restricted access.
- Originals, masters, and edit-masters tapes should be stored in a different building then the copies of these tapes.
- Do not allow an Original to be used except to produce a Secondary-Master.
- Duplicate the Original tapes and store the duplicates at a separate site.
- Break the record tab off the cassettes.
- Label tapes with a distinctive label, e.g. ORIGINAL--Do Not Record!
- The person using this tape must be very knowledgeable about tape handling and tape recorder care.

2) Secondary-Masters (Sub-Masters or Copy-Masters)

- Store in an environment below 50 % RH and below 20 C--but not below 8 C.
- The storage area should be well insulated, of fireproof construction, and have restricted access.
- These tapes are used as a substitute for the Originals and should be handled like masters.
- These tapes are used to produce copy tapes.
- Break the record tab off the cassettes.
- Label tapes with a distinctive label, e.g. SECONDARY MASTER--Do Not Record!
- The person making these tapes must be very knowledgeable about tape care and tape recorder care because this person will be handling Original tapes.

3) Copy/Duplicates

- Store in an environment below 50 % RH and below 22 C--but not below 8 C.
- The storage area should be controlled access but not necessarily restricted.
- When shipping tapes, pack them in a well-insulated package to reduce the temperature and humidity variations encountered during shipment. Also, ship by one-day or two-day delivery service to minimize the possibility of the package being exposed to high heat, rain, snow, or severe cold while sitting on a loading dock or in a delivery van. Ship on a Monday or Tuesday to be sure the tapes are not held over a weekend.

3. RISK MANAGEMENT

Monitor your vault area temperatures and RH. This can be done with a chart recorder that keeps a record for a month. Some recorders (loggers) can be connected with a computer to plot the results on a monthly basis.

Hire an expert to evaluate your archive, look for potential problems, and write a report recommending how to improve your facility.

Analyze your collection to determine what is needed to make it both usable and viable, and to justify funding demands. Try to determine the format of each tape, the manufacturer and the date of the recording and the condition of both the tape and its container. If you have old audiotapes, open the container and sniff. If it smells like vinegar, then the tape should be copied.

(If your risk assessment includes playing the tape, then look for splices, edge damage, and any other problems listed in Section III-2, Inspection Criteria, p. 8-9.)

4. REFORMATTING

Film-to-Tape and Tape-to-Film

For archival purposes, tape should not be copied to film and film should not be copied to tape. Both tape and film have archival problems. The two media have different color spectra and different frame rates, so a transfer from one medium to the other will not be a faithful reproduction. Any film format can be transferred to any videotape format and vice versa--for a price. Cross-media transfers should only be done as a last resort for preservation purposes, or for a special event or distribution.

Tape to Tape

Making a copy that is difficult to distinguish from the original is not easy, which is the reason video labs usually charge so much for their work. A professional tape technician is the person most likely to have the necessary knowledge and skills. For instance, some tape machines are known to be poorly made, while some are known for their durability and quality. The tape recorder, including the tape guides, used to record the new tape must be cleaned as described in the maintenance manual. It must also be checked for proper alignment by using an alignment tape.

A professional person will also know which tape types to use and which ones not to use. Buy the tape you choose in quantity and sample a couple for dropouts. Always copy to a new tape. Do not copy a valuable recording to a used tape.

When making a new recording, always start with about a minute of color bars and a 1,000 cycles per second tone on both audio tracks.

Tape tension differences between record and play show up as the top few horizontal lines of the video being shifted to the right or left (hooking). This problem can be corrected by using a time base corrector.

Ethics in Copying Tapes

Anyone who copies original tapes for archival purposes must be careful not to change the original content. The copy must be as close to a clone of the original as possible. Tape produced for viewing, distribution, specials, etc., can be processed or enhanced to make the picture and/or sound better than the original. BUT, archival tapes must always be as faithful a reproduction of the original as possible.

5. EMERGENCY PREPAREDNESS

Fire suppression

A fire and smoke detection system with two different temperature sensors is recommended. One set of temperature sensors should be set at the temperature required by the local fire code, the other set to a lower temperature. A fire will trigger the lower temperature sensor, which will set off a local alarm but not turn on the sprinklers. If the fire is stopped before one of the higher temperature sensors is triggered, no water will damage any tapes.

It is possible to use a chemical fire retardant rather than a water based system, but these special are very expensive.

Fungus

There are thousands of different types of fungi, and some are deadly. Also, it is usually very difficult to remove all of the fungus on tapes. For these reasons, it is best to have fungus decontamination done by a professional.

To prevent fungal growth, tapes must be stored in an environment less than 50 % RH and the room air should circulate. Every tape in the vault should be exposed to at least some degree of circulating air.

Disaster recovery

1) Water

Any tapes that have been soaked in water should be submerged in cold water until someone who knows how to dry them properly can dry them. The water can be kept cold by adding ice or by placing the container in a refrigerator (not a freezer). If the water temperature is kept between about 8 Celsius and 12 Celsius, the tape will not deteriorate while in cold water.

Call a company that specializes in tape disaster recovery.

2) Exposure to dampness

If the tapes have been exposed to moisture but water did not actually contact the tape, than they should be kept in a cool and dry area for a few days--NOT hot and dry. The cool, dry environment will counter the effect of any hydrolysis that occurred.

Magnetic Fields

Magnetic fields are not a major problem for magnetic tape. This is because a very large field is required to affect the signal on the tape and such a large field is not very common. The field a few inches from a large motor or transformer is so small that it will not affect a magnetic recording.

The rule-of-thumb is that a tape can tolerate a field about one tenth the amount of the coercivity of the tape. Quad tapes and old audiotapes had the lowest corcivity (about 300 Oersteds). Therefore, they can withstand a field of about 30 Oersteds. 20 Oersteds is being conservative.

Keep magnets and iron away from tape.

IV. Appendices

1. Comparison of Bytes and Volume

Figure 6 is an attempt to compare the storage capacity of paper, tape, film, and CD-ROM. 40 Mbyte for a frame of 35mm is what the Kodak Cineon system uses.

2. Video Processors/TBCs

Many analog tape playback problems can be "cleaned up" by using a Video Processor or a Time Base Corrector (TBC). Most video labs will have this equipment and know how to use it. Depending on several factors, a video processor or a TBC can actually introduce unwanted artifacts into the copy tape. The two most common are over-enhancement and velocity errors.

Over-enhancement is seen as ghost images to the right of a vertical line. The proper level of enhancement will produce a single, sharp vertical line, a mild over-enhancement will produce a faint ghost and severe over-enhancement a clear ghost.

Velocity errors usually show up as several horizontal "bars" on the video screen. These "bars" are alternating dark and light bands and consists of several horizontal lines each. They are caused by a mismatch between the playback video heads and the video heads which made the recording. These velocity errors can be suppressed or eliminated by finding a video recorder with a better match of video heads or a TBC that can suppress the velocity errors.

A video processor can also be used to correct black-white level problems, color problems and horizontal/vertical sync problems. A good video processor is a necessity for anyone planning to copy videotapes.

3. Simple Dos and Don'ts

DO:

- Store tape in a COOL and DRY place: 40 °F to 70 °F @ 20% to 30% RH.The environment should not vary more than ±3 °F and ±5% RH.
- Use only new, brand-name tape when recording a tape for long-term storage.
- Clean all tape-path components after playing a damaged tape.
- Protect the tape machine and tapes from dust.
- Follow the recommended maintenance practices for the VCR.
- Record at Standard-Speed with VHS. (VHS is not recommended for long-term storage)
- For long-term storage of Consumer formats, leave the tape on the take-up hub after it has been in record or play.
- Before recording or storing non-consumer archival tapes, shuttle the tape to the end and back.
- Always eject tape at the beginning or the end.
- Break off the Record tab to protect the recording.

DON'T

- Don't leave tapes or tape machines in the sun or in a hot vehicle.
- Don't store tapes in a basement, where there is the possibility of being flooded.
- Don't store tapes in a room with wood shelves or other combustibles.
- Don't use Extended-Play tapes for long-term storage.
- Don't store the tapes in cardboard sleeves/boxes (acid) or vinyl boxes (chlorine).
- Don't allow food, drinks, or smoking in either the tape storage or use areas.

4. References

a. "Accelerated Life Testing of Metal Particle Tape" by John Corcoran and Frazer Morrison, SMPTE Journal, Jan 1994.

b. Y. Okazaki, K. Hara, T. Kawashima, A. Sato, and T. Hirano; SONY Corporation Sendai Technology Center; "Estimating the Archival Life of Metal Particle Tape"; IEEE Transactions on Magnetics, Sept 1992.

c. C. Denis Mee and Eric D. Daniel, Magnetic Recording Technology, publ. McGraw-Hill, (1995)

d. John Van Bogart, National Media Laboratory, "Magnetic Tape Storage and Handling: A guide for Libraries and Archives", The Commission on Preservation and Access, 1400 16th Street, Suite 740, Washington, D.C. 20036-1000, June 1995

e. SMPTE RP-103

f. ANSI IT9-5.23

5. Related organizations

a. FIAT: International Federation of Television Archivists

b. FIAF: International Federation of Film Archivists

6. Websites Related to Archiving Film & Videotape

a. Organizations

American Film Institute:www.afionline.org

Canadian National Film Board: www.nfb.ca

Academy of Motion Picture Arts and Sciences: www.ampas.org/ampas

Association of Moving Image Archivists: www.amianet.org

Note: AMIA also has a Listserve for questions and announcements.

International Federation of Television Archivists (FIAT):www.nbr.no/fiat/fiat.html

International Federation of Film Archivists (FIAF): www.cinema.ucla.edu/fiaf/fiaf.html

b. National Archives

U.S. National Archive (NARA): www.nara.gov

U.S. Library of Congress: http://lcweb.loc.gov

Australia National Archive: www.aa.gov.au

Canada National Archive; www.archives.ca

c. Standards Organizations

Society for Motion Pictures and Television Engineers (SMPTE): www.smpte.org

American National Standards Institute (ANSI): www.ansi.org

Audio Engineering Society: www.aes.org

d. Resources

Library of Congress Internet resource page: lcweb.loc.gov/film/orgs.html

Library of Congress Publications and Resource Guides: lcweb.loc.gov/film/pubs.html

Utah State Archives Internet Resources for Archives:
http://utstdpwww.state.ut.us/~archives/referenc/!archive.htm

U.S. Film Preservation Board: http://lcweb.loc.gov/film

Library of Congress Television/videotape Study for Congress: lcweb.loc.gov/film/tv.html

National Media Lab: www.nta.org

National Association of Broadcasters (NAB): www.nab.org

V. GLOSSARY OF TERMS

Access storage: Storage conditions at or near room ambient conditions that allow tape collections to be readily accessed for immediate playback.

AES: Abbreviation for Audio Engineering Society.

Analog recording: A recording in which continuous magnetic signals that are representations of the voltage signals coming from the recording microphone or the video camera are written to tape.

Analog-to-digital: The process in which a continuous analog signal is quantized and converted to a series of binary integers.

ANSI: Abbreviation for American National Standards Institute.

Archival storage: Storage conditions specifically designed to extend or maximize the lifetime of stored media. Generally involves the use of temperatures and humidities lower that access storage conditions. Temperatures and humidities are also tightly controlled within a narrow range, and access by personnel is limited.

Backing: See substrate.

Binary number: A number that can be represented using only two numeric symbols, O and 1. Binary numbers are used by computers because they can easily be represented and stored by hardware that utilizes switches, magnetic fields, or charge polarities that are normally in one of two states. The on/off, north/south, or positive/negative states can easily represent the 1s and Os of a binary number, respectively.

Binder: The polymer used to bind magnetic particles together and adhere them to the tape substrate. Generally, a polyester or polyether polyurethane based system. See polymer.

Bit: A single numeric character. Each bit of a binary number can either be 0 or 1. An e-bit number is composed of exactly n numeric characters. An e-bit binary number can have 2n distinct values. For example, an 8-bit binary number has 28 = 256 distinct values, namely all the numbers between 00000000 (0 in decimal) and 11111111 (255 in decimal), inclusive. 8-bit quantization would discretely sample a signal and assign each sampling a value from 0 to 255, permitting 256 possible values.

Blocking: The sticking together or adhesion of successive windings (layers) in a tape pack. Blocking can result from (1) deterioration of the binder, (2) storage of tape reels at high temperatures, and/or (3) excessive tape pack stresses.

Cinching: The wrinkling, or folding over, of tape on itself in a loose tape pack. Normally occurs when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of slip. Results in large dropouts or high error rates.

Coercivity: The level of demagnetizing force that would need to be applied to a tape or magnetic particle to reduce the remanent magnetization to zero. A demagnetizing field of a level in excess of the coercivity must be applied to a magnetic particle in order to coerce it to change the direction of its magnetization. Coercivity is the property of a tape that indicates its resistance to demagnetization and determines the maximum signal frequency that can be recorded by a tape. Hc is the common abbreviation for coercivity.

Cohesive force: The force that holds a material together. The force that holds a material to itself.

Cohesiveness: See cohesive force.

Component: A Component TV system keeps the signals separate and requires two or three cables.

Composite: Composite is the combination of sync, black/white video and color video signals and uses only one cable. Consumer TV and VCRs are composite.

Copy: See transfer, migrate, refresh.

Curvature error: A change in track shape that results in a bowed or S-shaped track. This becomes a problem if the playback head is not able to follow the track closely enough to capture all of the information on the recorded track.

db: See decibel.

Decibel: The unit of measure used to indicate relative changes in signal intensity or sound volume. The actual expression for calculating the difference in decibels between signal A and signal B is: Decibel (dB) = 20 logbase 10 (signal A amplitude/signal B amplitude)

+6 dB represents a doubling of the signal or a 100% increase

+1 dB represents a 12% increase

+0 dB represents no change-signals are equal

1 dB represents a 11% decrease

6 dB represents a halving of the signal or a 50% decrease

Digital recording: A recording in which binary numbers that represent quantized versions of the voltage signals from the recording microphone or the video camera are written to tape. On playback, the numbers are read and processed by a digital-to-analog converter to produce an analog output signal.

Digital-to-analog: The process in which a series of discrete binary integers is converted to a continuous analog signal.

Dropout: A term used with analog videotape recorders. A brief signal loss caused by a tape head clog, defect in the tape, or debris that causes an increase in the head-to-tape spacing. Missing magnetic material can also cause a dropout. A video dropout generally appears as a white spot or streak on the video monitor. When several video dropouts occur per frame, the TV monitor will appear snowy. The frequent appearance of dropouts on playback is an indication that the tape or recorder is contaminated with debris and/or that the tape binder is deteriorating.

Flange pack: A condition where the tape pack is wound up against one of the flanges of the tape reel.

Format: The arrangement of information tracks on a tape as prescribed by a standard. The two most common categories of recording formats are longitudinal and helical scan.

Head clog: Debris trapped in the playback head of a video recorder. Clogging of the playback head with debris causes dropouts.

Helical scan recording: The recording format in which a slow moving tape is helically wrapped around a rapidly rotating drum with small embedded record and play heads. The tape is positioned at a slight angle to the equatorial plane of the drum. This results in a recording format in which recorded tracks run diagonally across the tape from one edge to the other. Recorded tracks are parallel to each other but are at an angle to the edge of the tape.

Hydrolysis: The chemical process in which scission of a chemical bond occurs via reaction with water. The polyester chemical bonds in tape binder polymers are subject to hydrolysis, producing alcohol and acid end groups. Hydrolysis is a reversible reaction, meaning that the alcohol and acid groups can react with each other to produce a polyester bond and water as a byproduct. In practice, however, a severely degraded tape binder layer will never fully reconstruct back to its original integrity, even when placed in a very low humidity environment.

Hygroscopic: The tendency of a material to absorb water. An effect related to changes in moisture content or relative humidity. The hygroscopic expansion coefficient of a tape refers to its change in length as it takes up water upon an increase in the ambient relative humidity.

Longitudinal recording: A recording format in which a slow or fast moving tape is passed by a stationary recording head. The recorded tracks are parallel to the edge of the tape and run the full length of the tape.

Lubricant: A component added to the magnetic layer of a tape to decrease the friction between the head and the tape.

Magnetic particles: The magnetic particles incorporated in the binder to form the magnetic layer on a magnetic tape. Iron oxide, chromium dioxide, barium ferrite, and metal particulate are various examples of magnetic pigment used in commercial tapes. The term pigment is a carry-over of terminology from paint and coating technology--the magnetic coating on a tape is analogous to a coat of paint in which the magnetic particle is the paint pigment.

Magnetic pigment: See magnetic particles.

Magnetic remanence: The strength of the magnetic field that remains in a tape or magnetic particle after it is (1) exposed to a strong, external magnetic field and (2) the external field is removed. The property of a tape that determines its ability to record and store a magnetic signal. Mr is the common abbreviation for magnetic remanence. Magnetic remanence, Mr, and magnetic retentivity, Br, both refer to the ability of the tape to retain a magnetic field; however, the latter is expressed in units of magnetic flux density.

Magnetic retentivity: See magnetic remanence.

Migrate: See transfer, refresh, copy.

Mistracking: The phenomenon that occurs when the path followed by the read head of the tape recorder does not correspond to the location of the recorded track on the magnetic tape. Mistracking can occur in both longitudinal and helical scan recording systems. The read head must capture a given percentage of the track in order to produce a playback signal. If the head is too far off the track, recorded information will not be played back at a level adequate for proper reproduction.

NARA: The abbreviation for National Archives and Records Administration.

NTSC: The 525 line/60 Hz television system used in the U.S., Canada, Japan and several other countries. Stands for National Television Standards Committee. European countries use either PAL or SECAM standards.

Pack slip: A lateral slip of selected tape windings causing high or low spots (when viewed with tape reel laying flat on one side) in an otherwise smooth tape pack. Pack slip can cause subsequent edge damage when the tape is played, as it will unwind unevenly and may make contact with the tape reel flange.

Passivate: A chemical process which forms a protective coating on a metal..

PET: Abbreviation for polyethylene terephthalate. The polymeric substrate material used for most magnetic tapes.

Pixel: The smallest bit of a picture/video.

Polymer: A long organic molecule made up of small, repeating units (literally, many more). Analogous to a freight train, where each individual unit is represented by a freight car. At very high magnification, a chunk of polymer would resemble a bowl of cooked spaghetti. Plastic materials are polymers. The strength and toughness of plastics is due, in part, to the length of its polymer molecules. If the chains (couplings in the freight train) are broken by hydrolysis, the shorter chains will impart less strength to the plastic. If enough polymer chains are broken, the plastic will become weak, powdery, or gooey. See binder.

Popped strand: A strand of tape protruding from the edge of a wound tape pack.

Print through: The condition where low frequency signals on one tape winding imprint themselves on the immediately adjacent tape windings. It is most noticeable on audio tapes where a ghost of the recording can be heard slightly before the playback of the actual recording.

Quantization: A process in which a continuous signal is converted to a series of points at discrete levels. The quantized version of a ramp, a continuum of levels, would be a staircase, where only certain distinct levels are allowed.

Refreshing: This term can refer to periodic retensioning of tape, or the rerecording of recorded information onto the same tape (or different tape) to refresh the magnetic signal. In the audio/video tape community, refreshing generally refers to retensioning of the tape, but it can also refer to the copying of one tape to another. See transfer, copy, migrate.

Relative humidity (RH): The amount of water in the air relative to the maximum amount of water that the air can hold at a given temperature.

Restoration: The process where a tape degraded by age is temporarily or permanently restored to a playable condition. The tape cleaning or baking are examples of tape restoration procedures.

Retensioning: The process where a tape is unspooled onto a takeup reel and then rewound at a controlled tension and speed. In performing this procedure, tape pack stresses are redistributed and, thus, the tape is retensioned. This has sometimes been referred to as exercising the tape.

RH: The abbreviation for relative humidity.

Room ambient conditions: The temperature, humidity, and air quality of the surrounding conditions. Those conditions generally found in a library, studio, or office facility with a controlled environment (heating and air conditioning).

Scission: The process in which a chemical bond in a molecule is broken either by reaction with another molecule, such as water, or by the absorption of a high energy photon.

Signal-to-noise ratio: The ratio of the recorded signal level to the tape noise level normally expressed in decibels. Commonly abbreviated as S/N.

SMPTE: Abbreviation for the Society of Motion Pictures and Television Engineers.

Stick slip: The process in which (1) the tape sticks to the recording head because of high friction; (2) the tape tension builds because the tape is not moving at the head; (3) the tape tension reaches a critical level, causing the tape to release from and briefly slip past the read head at high speed; (4) the tape slows to normal speed and once again sticks to the recording head; (5) this process is repeated indefinitely. Characterized by jittery movement of the tape in the transport and/or audible squealing of the tape.

Sticky shed: The gummy deposits left on tape path guides and heads after a sticky tape has been played. The phenomenon whereby a tape binder has deteriorated to such a degree that it lacks sufficient cohesive strength to prevent the magnetic coating from sheding during playback. The shedding of particles by the tape as a result of binder deterioration that causes dropouts on VHS tapes.

Sticky tape: Tape characterized by a soft, gummy, or tacky tape surface. Tape that has experienced a signficant level of hydrolysis so that the magnetic coating is softer than normal. Tape characterized by resinous or oily deposits on the surface of the tape.

Stress: Force per unit area, such as pounds per square inch (psi). A tape wound on a reel with high tension results in a tape pack with a high interwinding stress. See tension.

Substrate: Backing film layer that supports the magnetic layer in a magnetic tape. PET is currently the most commonly used tape substrate.

Tape baking: A process in which a magnetic tape is placed at an elevated temperature for a brief time in order to firm up the tape binder. This procedure is recommended as a temporary cure for the sticky shed or sticky tape syndrome. The tape baking procedure is discussed in the reference, "Sticky Shed Syndrome--Tips on Saving Your Damaged Master Tapes," Mix, May 1990, p. 148.

Tape noise: A magnetic signal on the tape resulting from the finite size and nonuniform distribution of magnetic particles in the magnetic layer of the tape. Tape noise is inherent in any magnetic tape but can be reduced by using smaller pigment sizes in tape formulations. The iron oxide pigments found in less expensive tapes have the largest tape noise level. For analog, the noise increases each time the tape is copied (each generation).

Tape pack: The structure formed by and comprised solely of tape wound on a hub or spindle; a tape reel consists of a tape pack, the metal, plastic, or glass hub, and flanges.

Tape transport: The mechanics used to guide and move the tape through the recording system and past the read and write heads of the recorder. The tape transport consists of the tape guide pins, capstan, rollers, tension controllers, etc.

TBC: Time-Base-Corrector. An electronic unit that reduces the video errors created by changes in the head-to-tape speed.

Tension: Force, or force per tape width. The force on a tape as it is transported through a recorder. A tape wound on a reel with high tension results in a tape pack with a high interwinding stress. See stress.

Thermal: An effect related to changes in temperature. The thermal expansion coefficient of a tape refers to its change in length upon a change in the ambient temperature.

Track angle: The angle that the track of a helical scan recording makes to the edge of the tape. This should correspond with the scan angle of the helical recorder--the angle that the tape makes to the equatorial plane of the rotating drum head. If the track angle and scan angle do not correspond, mistracking will occur.

Transfer: The process of copying all of the information on one tape to another tape of the same or different format. The term refreshing is commonly used by some archivists and librarians to refer to the process of copying information from one tape to a newer tape of the same format (e.g., VHS to VHS). When the information is copied to a different format (e.g., BetaMax to VHS), the terms reformatting and converting have been used.

Vinegar syndrome: Characteristic of the decomposition of acetate based magnetic tape where acetic acid is a substantial byproduct that gives the tape a vinegarlike odor. After the onset of the vinegar syndrome, acetate tape backings degrade at an accelerated rate--the hydrolysis of the acetate is catalyzed further by the presence of acetic acid by product.

NOTICE

The information contained in this report is based on experience, theoretical investigations, and accelerated tests. By following the recommendations made in this report, it is the experience of many archivists that the life of the information recorded on tape will be increased, but there is no guarantee that all information recorded on the tape will be permanent.

Figure One:

ANALOG VIDEOTAPE FORMATS

Year *	Tape Width	Cassette/ Open Reel	Use **	Obsolecence Rating ***	Originating Company	Comments ****
1956	2"	OR	P	CE	Ampex	2" Quad
1962	2"	OR	IE	CE	Ampex	First popular helical
1963	2"	OR	IE	Ext	Sony	2" Helical
1964	1"	OR	IE	Ext	Sony	
1965	1"	OR	IE	CE	Ampex	SMPTE Type A
1965	1"	OR	IE	Ext	PI	Precision Instruments
1965	1/2"	OR	IE	CE	Sony	CV--First low cost VTR
1968	1"	OR	IE	EXT	IVC	
1968	1/2"	OR	IE	Ext	Sony	
1969	1/2"	OR	IE	End		EIAJ-1
1969	1/4"	OR	IE	Ext	Akai	Small portable
1970	1/2"	C	IE	Ext	Phillips	First Cassette VTR
1971	3/4"	C	IE	T	Sony	3/4" U-Matic
1972	1/2"	C	C	Ext	Cartravision	Consumer VTR
1972	1/2"	C	IE	Ext	Sanyo	V-Cord
1973	2"	OR	IE	Ext	IVC	2" Helical
1975	1"	OR	P & IE	End	Bosch	SMPTE B
1975	1/2"	C	C	CE	Sony	Betamax--Firs consumer
1976	1"	OR	IE	Ext	Sony	
1976	1"	OR	P & IE	CE	Ampex	SMPTE A with Slo-Mo
1976	1/2"	C	C	ok	JVC	VHS
1978	1"	OR	P	End	Ampex/Sony	SMPTE C
1983	1/2"	C	P & IE	Ext	Panasonic	SMPTE M
1984	1/2"	C	P & IE	Ext	Sony	Betacam
1984	8 mm	C	IE & C	Ext		8 mm (.315")
1986	1/2"	C	P & IE	End	Panasonic	M-II
1987	1/2"	C	P & IE	T	Sony	Betacam-SP
1987	1/2"	C	IE & C	ok	JVC	S-VHS
1988	1/2"	C	P & IE	Ext	Sony	ED-Beta
1989	8 mm	C	IE & C	T		Hi-8 (.315")

Figure One Notes:

Only the more popular formats are listed here out of a total in the region of 50-100.

* Indicates when the product was first publicly available.

** P = Professional, IE = Industrial/Educational, C = Consumer

*** Obsolecence ratings:

Ext=Extinct: Only one or two playback machines MAY exist at special laboratories.

CE=Critically Endangered: Only a small population of machines are available with few (if any) spare parts available.

End=Endangered: Manufacture of the machines has ceased.

T=Threatened: The machines are still being manufactured, but a competing format makes this one unlikely to survive.

Note: Most of these ratings are from the COOL website.

**** All formats are Helical except when noted as Quad (1956-1971). There were several versions of quad formats.

Figure Two:

DIGITAL VIDEOTAPE FORMATS

Name	Year *	Makers	Tape Width	Tape Thick-ness	Hours per Cassette	Tape Type	Comp-ression	Bits	Quantiza-tion
D1	1986	Sony BTS	.75"	13 µm	Medium=1/2 Large=1 1/2	Iron	No	8	4:2:2
D2	1988	Sony Ampex Hitachi	.75"	13 µm	1/2, 1, 3	MP	No	8	Composite
D3	1992	Panasonic	.5"	11 µm	4	MP	No	8	
"	"	"	"	13 µm	2	"	"		Composite
DCT	1992	Ampex	.75"	13 µm	1/2, 1, 3	MP	2:1	8	4:2:2
Digital Betacam	1993	Sony	.5"	13 µm	Small=1 Large=3	MP	2.3:1	10	4:2:2
D5	1994	Panasonic	.5"	11 µm	4	MP	No	10	4:2:2
"	"	"	"	13 µm	2	"	"		
HD-D5	1999	Panasonic	.5"			MP	5:1	10	
D9 - Digital-S	1995	JVC	.5"	13 µm	1 1/2	MP	3.3	8	4:2:2
Digital Beta SX	1995	Sony	.5"	13 µm		MP	10:1	10	4:2:2
D6	1996	Toshiba							
D7 - DVCPRO	1996	Panasonic	.25"	8-9 µm	Medium=1 Large=2	MP	5:1	8	4:1:1
DV/ Mini-DV	1996	Consortium	.25"	7 µm	4	ME	5:1		4:1:1

* Indicates when the product was first introduced.

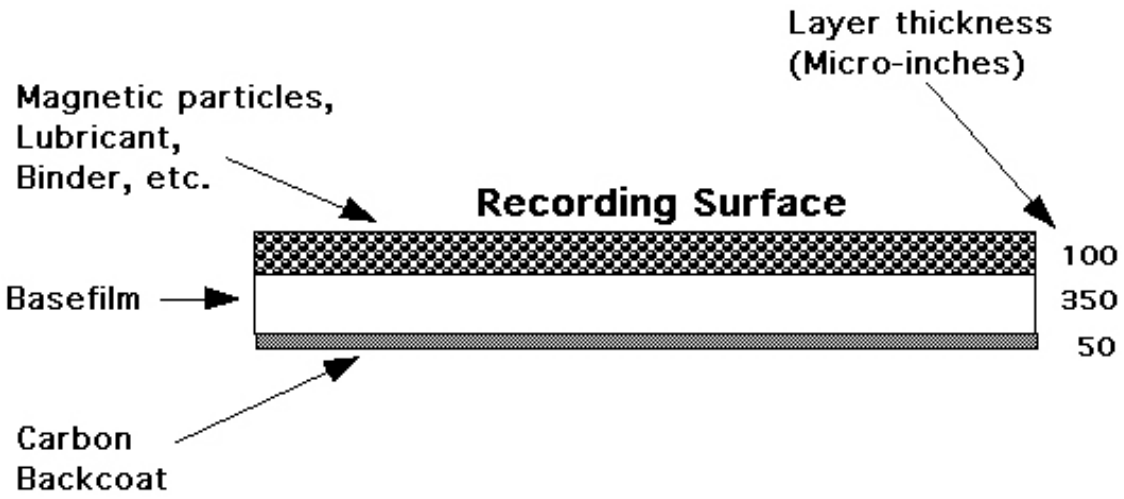
Figure Three:

FORMAT CATEGORIES

	ANALOG		DIGITAL
	Professional	**Consumer**	
COMPOSITE	QUAD 3/4" U-MATIC C	VHS	D2 D3
COMPONENT	M-II BETACAM-SP HI-8 S-VHS		D1 DCT (Compressed) D5 DIGITAL BETACAM (Compressed) Digital-S (Compressed) DV (Compressed) DVC-PRO (Compressed)

Figure Four:

CROSS SECTION OF MAGNETIC TAPE



Cross-section of Magnetic Tape

Notes:

1. Magnetic particles comprise about 40% of the recording layer.

2. Each magnetic particle is about 10 micro-inches long. As a comparision, the wavelength of green light is 18 micro-inches and the thickness of a human hair is around 2,000 micro-inches.

3. Until 1986, all videotapes used iron oxide particles. With the introduction of digital, metal particle (MP) tape has become the dominant particle. Metal-Evaporated (ME) is also used.

Figure Five:

HUMIDITY CURVES

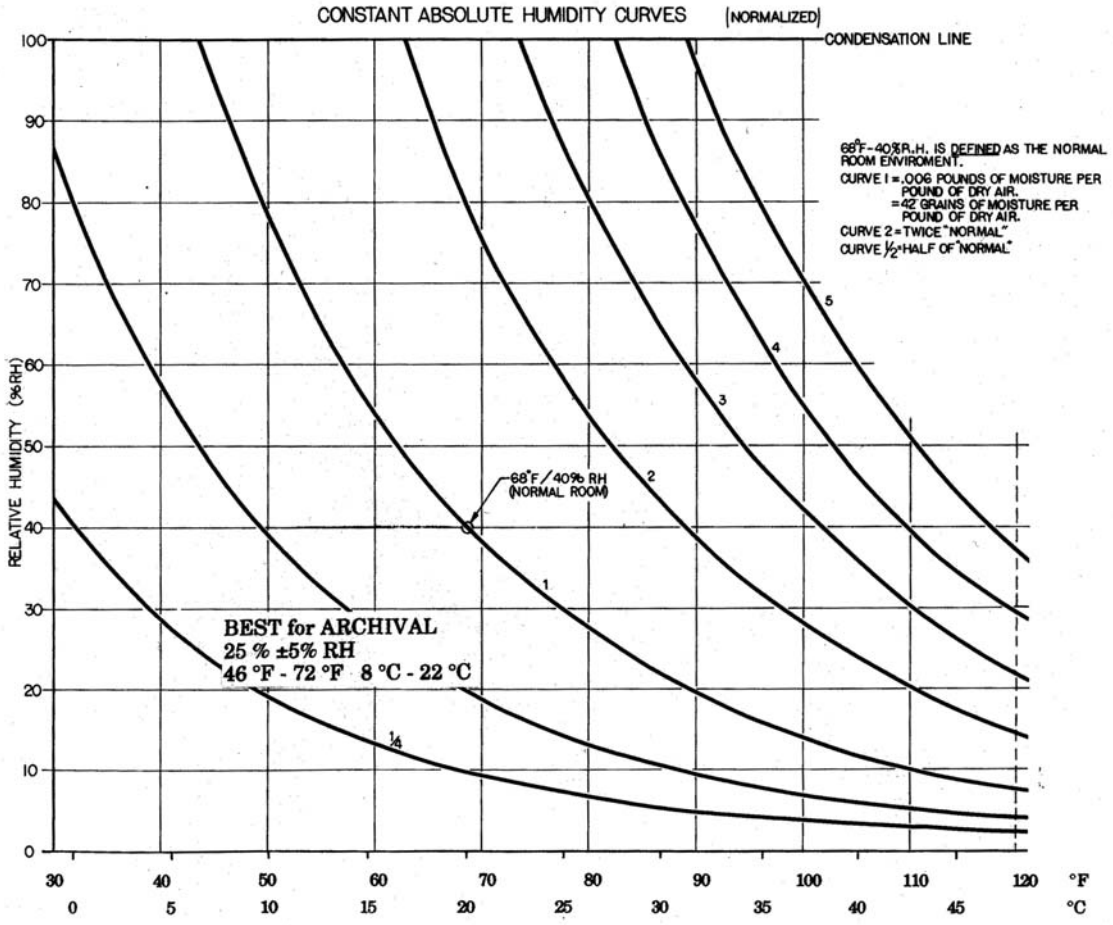


Figure Six:

COMPARISON OF BYTES & VOLUME

	1 Frame	1 Second
35 mm Color Film	40 MByte*	1,000 MByte*
NTSC Video (525 x 60)	1 MByte	30 MByte

1 average page of text equals approximately 2,500 characters.

400 pages of text = 1 MByte (1.8 inches / 4.6 cm thick stack)

1 small DST cassette (VHS size) = 50,000 MByte = 20 million pages = 7,500 foot stack

1 CD-ROM = 650 MB

1 DVD-ROM = 4.7 GB (one-layer, one-sided)

1 Hard Drive = 100 to 400 GB ($3 per GB)

1 Datatape = 100 to 200 GB

Notes:

1 Byte = 8 bits = 8 pixels

M = Mega = Million

G = Giga = One thousand million

256 GB is required for 2 hours of uncompressed NTSC video

* Cineon system