MAGNETIC TAPE RECORDINGS

AUDIO and VIDEO Cassettes

A primer on their use, handling and storage....

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OVERVIEW

The purpose of this article is to give a better understanding of what affects the performance and longevity of audio and video recordings. It deals primarily with the proper handling and storage of audio and video cassettes to safeguard the recordings for future use. However, no matter how carefully a wrong type of tape and especially inferior quality tape may be handled during use or storage the quality of the recording is still going to be compromised. The physical makeup of the inferior tapes or cassettes are such that they will not withstand long-term storage.

The proper selection, use, handling and storage of magnetic tape for recording of audio or video in any format is extremely important as we are dealing with the preservation of irreplaceable evidence. Careless selection, improper use, handling, or storage can render the recordings useless for submission as viable evidence.

For the purpose of this discussion Audio and Video Magnetic Tape Cassettes will generally be treated the same as they both contain Magnetic Tape of very similar makeups and are manufactured using the same basic processes. Of course differences affecting performance, handling and storage will be addressed separately.

To understand the proper handling and storage requirements, it is important to understand what makes up a magnetic tape, its transport mechanism i.e., the cassette, the materials involved and the environmental effects of both physical and electromagnetic elements etc.

The expertise of the author is in analog audio tapes and cassettes. Therefore information in this document is more detailed in some cases for analog audio cassettes than the other recording mediums.

The Magnetic Tape.

The magnetic tape itself consists of two basic components. The base film and the magnetic coating. Studio mastering reel to reel tapes and higher grade video cassettes use an additional back coating. See Fig.1.

![Figure 1 - Magnetic Tape Layers](image)

Base Films

The base film material is polyester, or more specifically polyethylene-terephthalat/PETP. This material under strain attains stretch values comparable to steel and it is not susceptible to inorganic acids or organic solvents and the content of water is negligibly small.
But, unlike steel the strain curve for polyester follows a curved line. Apart from the purely elastic, reversible strain component, the material also displays a “plastic” behavior. - An irreversible component, the material “flows” just before it ruptures. With too much tension, the sides of the tape pull in and the tape elongates severely, then breaks. Under normal conditions the material is working in the lowest part of the curve.

Magnetic tape used in audio cassettes has to be designed to withstand a continuous 0.44 pound force without any evidence of permanent stretching or elongation. (A modern cassette recorder has the maximum torque of 0.30 lb/inch) whereas the strain required for a 3% stretching (yield strength) is a minimum of 1.46 lbs for material thickness of 12.0 um (60 Min), 1.01 lbs for 7.0 um (90 Min) and 0.78 lbs for 6 um (120 Min).

Video and Digital Cassette Tapes have a typical thickness of 14.3 um down to 8.9 um. The yield strengths are measured for 1 or 5% elongation but the normal working strain is less. To reduce stretching during use the base film is “tensilized” or pre-stretched during its manufacturing process.

Magnetic Coatings

The magnetic coating consists of the oxide particles (needles) and the binder system in which the particles are embedded and attached or “fixed” to the base film

Oxide Particles

The oxide particles are Type I - Gamma Ferric Oxide, Type II - Chrome Dioxide or Type IV- Pure Iron. All have a length of approximately half a micrometer (.5 .um) and a thickness of .05 um. The shape is like a double pointed needle, the sharper the point the higher the quality. The magnetic properties are defined by the so-called hysteresisloop. The magnetic intensity is called coercivity and is measured in units called oersteds. Each oxide particle type is formulated for it’s own magnetic values and designed for a specific recording type.

It is the size of the oxide particle as well as the material that affects the coercivity level of the tape. The unattainable ideal would have particles all of the same size for a specific tape formulation. The smaller the variation in size the higher the quality of the tape and the lower the level of print thru. The stated value of coercivity of any tape is the average value of all the particles on the tape. See Figure 2

![Standard Distribution](image)

**Figure 2 Needle Coercivity Distribution**

This graph shows the distribution in needle sizes of a good tape (narrow curve) and a bad tape (broad Curve)
Binder System

The binder system is a macromolecular plastic like the base film, but, this system only acquires its final structure when the coating is undergoing the drying process in the coating machines. These coatings are divided into the physically drying type and chemically hardening two-component or polyurethane type. This structure is where the cross linking has taken place, the long-chain molecules of the binder form a network around the oxide particles. This interlacing structure is critical for the stability of the magnetic coating during contact with the tape-guiding mechanisms of the recorder, and, also for long term storage.

The binder system and oxide particles each make up approximately 40% of the coating. The remaining 20% consists of small air holes in which certain amounts of water are to be found. The air gaps are important as they contribute to the flexibility of the tape. To reduce friction as the tape passes across stationary tape guides a lubricant is added to the coating formula as a wax or oil. In the correct amount it forms a permanent monomolecular layer on the surface of the tape.

Note: After the coating process and prior to drying, the oxide particles “needles” are physically orientated by passing the web (The magnetic tape prior to slitting) over very strong DC magnets. After drying a calendering process may also take place which make the surface mirror smooth. The more the oxide particles are in alignment and the smoother the surface the higher the performance quality of the tape.

Back Coating

Back coatings are normally found on Studio Audio Masters (Reel to Reel), DAT’s, and Higher Grade Video Cassettes. Since the base film has a very smooth surface the reverse side is often supplied with a rough back coating which is non-magnetic but has good electrical conductivity. The surface structure of the back coating is matched to the magnetic coating. This enables good winding characteristics as the individual windings are “interlocked” to each other. The thickness of this coating is usually less than 1 um. The purpose of the back coating for audio is primarily to improve winding characteristics. In DAT’s and Video it is also to reduce scratching of the base film during loading. By sealing the base film it prevents winding debris and foreign materials from becoming imbedded in the main coating thus causing drop outs. The good electrical conductivity also reduces buildup of static electricity which would attract dust etc..that could cause drop outs.

The Cassette Shell...

The Audio or Video cassette shell plays a very important role in the quality of the recording made on the magnetic tape as well as effecting long term storage.

Audio Cassette - Analog Compact Cassette

The analog audio cassette shell consists of two molded plastic halves, tape guide rollers, roller pins, pressure pad, magnetic shield, slip sheets and windows. The assembly is either sonic welded or held together with 5 screws. The difference between sonic welded and 5 screw type of cassette assembly is twofold. The 5 screw assembly allows for repair whereas the sonic welded make for a stiffer cassette with better azimuth tracking and stability. Some cassettes use a combination of these methods therefore enjoying the advantage of both. In the spine of the cassette are knock out tabs to be removed after recording to prevent accidental re-recording. Also located in the spine are molded in indents or holes to identify the type (I, II, or IV) of tape the cassette contains. Some recorders automatically sense these indents and set the equalization and bias accordingly.
The shell halves are high grade high/medium impact heat resistant polystyrene molded to exact tolerances. The final exterior dimensions of the assembled cassette can affect how the cassette physically fits into the recorder. The interior dimensions of the shell are carefully controlled, if the dimension is too narrow the shell can cause the tape pack to bind or drag.

Tape hubs are designed with hub locks to firmly secure the tape leader to the hub, and, with hub center sprockets to fit over the tape machine spindles.

**Figure 3**

**Analog Audio Cassette - Commonly known as a Compact Cassette**

The tape leader is made of the same material as the base film of the magnetic tape. It may be or may not be coated with a magnetic coating for instant start on recording. It also is thicker than the base film and with sufficient length to wrap around the full pack of tape at least 1½ times to prevent the possibility of stretching the recording tape when the cassette reaches the end of a high speed wind or rewind. Note: A leaderless cassette can also be one that has a leader with a magnetic coating. Some leaderless tapes use a shorter leader and one or two are truly leaderless. A cassette with a standard length leader coated or uncoated is more likely to prevent stretching.

The guide rollers keep the tape centered in the cassette. The roller pins are lubricated to reduce friction and prevent squealing. The majority of the cassettes manufactured today use plastic molded in-place pins rather than steel. Providing they are properly lubricated both perform equally well.

The slip sheet is designed with ridges that help to keep the tape pack winding smooth during the original loading and during normal use. The slip sheet is lubricated to reduce friction and is also electrically conductive to eliminate static charge buildups that can cause "popping" sounds during recording.
The pressure pad and its pressure spring are designed to apply the correct amount of pressure between the tape and the tape head assembly of the recorder. The pressure pad material is non-linting to prevent audio dropouts.

The interior dimensions and fit of the components are designed so that the required torque to turn the tape pack in a cassette with a 90 minutes of tape does not drag or bind. To assure that cassettes do not exceed these torque limits industry standards were developed. Unfortunately, most modern cassette recorders have a spindle torque much less than the maximum torque value specified in the standards for cassettes. This means that cassettes which meet the industry standards for maximum torque can exceed the torque available in the cassette recorder. The industry specifications are 20 GCM (.11 lbs/in) torque without hold back and 55 GCM (.31 lbs/in) with a 8 GCM hold back force. However, most recorders manufactured today have less than 55 GCM available torque, some even less than 35 GCM (.20 lbs/in) and the hold back torque varies from 2 to 8 GCM. The average cassette torque runs between 35 and 55 GCM with 8 GCM hold back. Any cassette with a torque greater than 35 GCM with hold back may be subject to dragging or jamming.

**Digital Audio and Video Cassettes**

As with analog audio cassettes the precision and fit of the components and proper lubrication is very important. Unlike analog audio cassettes there are no slip sheets since the tape is contained on internal reels. To reduce static charges from attracting dust, internal contact springs are used between the two reels to bleed off any static charge. Spring loaded covers over the tape path are used to protect the tape from damage during handling and storage. Similar to analog audio, 8 mm, and VHS cassettes both have sensing holes molded in the back of the cassette to automatically identify Hi-8 from regular 8 mm, and Super VHS from regular VHS.

Video and digital audio cassettes use internal reels to wind the tape on. The primary reason for this is to assure a smooth and even wind thus preventing edge damage. Edge damage is more critical for video and digital than it is to analog audio.

**Characteristics of Audio - Video Cassettes that affect it usability and survivability**

The characteristics of any tape that can affect its usability are:

- **Print Thru Characteristics of the tape.**
- **Chemical makeup of the Binder System.**
- **Physical characteristics of the Magnetic Coating.**
- **Bonding of Magnetic Coating to the base film.**
- **Lubricants.**
- **Physical characteristics of the base film and finished magnetic tape.**
- **Cassette shell.**

These characteristics can also drastically affect how the tape survives long term or even short term storage and handling and long term storage when done improperly can affect these characteristic.

**Print Thru Characteristics of the tape.**

Print thru is an undesirable phenomenon that causes an echo to be heard when listening to the playback of an analog audio tape. Print thru is a measurable characteristic and is specified by each tape type and manufacturer. Any value of -53 dB or greater (in the negative)for a tape is good and for all practical purposes can not be heard. Such physical effects can also occur in digital recordings. The magnitude of the print thru is far beneath the signal recognition threshold and is therefore unlike analog audio is meaningless.
All magnetic recordings suffer from print thru i.e., the magnetism is transferred from one layer of the wound tape to the adjacent layers. In analog audio tapes this is evident as low level pre-echo and post-echo. Print thru is dependent upon the tapes magnetic properties, the physical properties of the oxide particles, the base film thickness and temperature. Therefore tapes with magnetic coatings of the same magnetic and physical properties but a thinner base film would have more print thru, such as base films for 90 and 120 Minute cassette tapes compared to 60 min cassettes.

The print thru process is complex. The strongest print thru occurs at wavelengths which equal the product (2 * pi * overall tape thickness). On cassette tapes this falls in the 500 Hz frequency range. As stated before not all the oxide particles of the magnetic layer are the same size so that when a tape is said to have a coercivity of 300 oersteds, this is only true for the majority of the particles. Some oxide particles could have a much higher, and some, a much lower coercivity. When the tape is wound on a hub such as in an audio cassette the high coercivity oxide particles on one layer can influence the low coercivity ones of the adjacent layer.

Figure 4 shows the process of print thru on parts of three adjacent layers of wound tape. If the middle layer (2) contains the original signal then “copies” have been produced in layers 1 and 3. The copy in layer 3 is louder because the distance from the original to the surface of this layer is smaller than to the surface of layer 1. Pre-echo is less than post-echo.

A characteristic of all ferromagnetic materials is magnetostriction. This term refers to the effect on magnetization by the influence of stress to the oxide particles. It occurs as demagnetization in tape as the result of compressive and tensile forces which act on the oxide particles imbedded in the coating when the tape is in contact with parts of the recording equipment. However, the level losses in practice are negligible.

The print thru signal differs from the original signal in one important aspect, the original signal is stable because it is recorded with the aid of high frequency bias. Since the print thru is recorded without bias, it is unstabilized. This means that print thru can be reduced by pressure and tension - magnetostriction. A single wind - rewind can reduce the audible level of the print-thru or echo by several dB's.

It should be noted that print thru occurs immediately upon contact and prolonged storage produces a minimal increase, some reports state approx. 0.5 dB for each year which partly involves irreversible processes. Print thru also increases as the ambient temperature increases.

Chemical makeup of the Binder System.

The chemical makeup of the binder system is made up of several ingredients and mixtures that vary with each manufacturer and are closely guarded secrets. However, this chemical makeup should not deteriorate over time.
in a manner that can increase tape surface abrasion. Increased surface abrasion can lead to head smearing and increased sliding friction, resulting in high frequency loss and physical binding.

**Physical characteristics of the Magnetic Coating**

During the coating and drying process the thickness of the magnetic coating has to be tightly controlled to assure minimal variation. The magnetic properties are directly dependent on the thickness of the coating. These coatings comparatively are very thin, the average thickness is 5 to 3.5 um for audio cassettes (60 to 120 Min), 2.5 um for DAT’s (120 Min), and 3.0 um for VHS (up to 180 Min). See Figure 1. A small variation in the thickness can have a major effect on the magnetic properties, thus, a similar effect on the quality of the recording. It may be noticed that on inferior grade or poorly coated tapes that different sections of the tape the coating will appear to be transparent compared to other sections.

**Bonding of Magnetic Coating to the base film.**

The bonding of the Magnetic Coating to the base film must be permanent in nature and unaffected by normal operating and storage temperatures, and humidity. The bonding of the magnetic coating is primarily the function of the binder material and the tape manufacturing process. A poorly adhered magnetic coating can flake, causing catastrophic loss of recorded material.

**Lubricants**

Lubrication is required for proper operation and reduction of friction, especially across non-rotating tape guides and heads. The type and quantity of lubricant is important so that it forms a permanent monomolecular layer on the surface of the magnetic coating. Too much lubricant can cause a non permanent adherence to the surface allowing for leakage which can be deposited on the record/playback heads. Of course the lack of lubricants increases the surface friction.

**Physical characteristics of the base film and finished magnetic tape.**

The Physical characteristics of the base film and finished magnetic tapes variation in thickness and width as well as the amount of transverse cupping, static longitudinal curvature, wavy edge and longitudinal coiling affect how well any tape winds, records and plays back. The manufacturing processes for the base film, the coating and drying process and the slitting process determine the degree of these characteristics. This is a complicated set of characteristics and is beyond the scope of this discussion. For all practical purposes the less the variation of thickness, width, and the less the amount of cupping etc. the better the usability of the magnetic tape.

**Cassette shell.**

The cassette shell, be it for Analog Audio, Digital, or Video, is as important as the magnetic tape it contains. Since the cassette is designed as the transport mechanism for the tape as well as a convenient storage container it must not cause the tape to drag, jam, apply inadequate tape to head contact or cause poor azimuth tracking or warbling. It also needs to be free of any internal items that can scratch or otherwise damage the tape. It must be free of any materials that can create loose debris or foreign debris than can find its way onto the magnetic tape.

Digital audio and video cassettes by the nature of the recording must protect against foreign debris and edge damage more than analog audio cassettes.
Handling of Audio and Video Tapes

Service life of a magnetic tape depends to a decisive extent on the base film and the coating. This not only applies to storage life, but also - possibly even more so - the handling during use. The cassette obviously is also a factor but once the recording has been made, subsequent problems that can occur with or damage to the cassette housing itself, providing it has not damaged the tape, can be remedied by simply replacing the housing.

The following outside factors can influence the usability of or even the quality of the recording on a cassette tape during handling, use, and long or short term storage. This is because of their degrading effect on the magnetic tape (base film and coating) and/or cassette housing.

- Poorly maintained equipment.
- Foreign particles.
- External Magnetic and other Fields
- Temperature and Humidity.
- Tape deformation.
- Tape winding.

Since most of the recordings are of the surveillance type, which means the recordings are usually if not always done under adverse conditions. (Loosely defined as the lighting for video is far from ideal, the subjects are uncooperative, the ambient noise level for audio is too high, the placement of the equipment is far from ideal and the content or spoken language is not usually clear and concise.) The influence of the outside factors listed above can have even more of an impact than when recordings are made under "ideal" conditions.

- Poorly maintained equipment.

Outside of inferior grade tapes, poorly maintained equipment is responsible for 95% of the problems encountered with recordings that are poorer in quality than they should be even when taking into effect the adverse recording conditions.

The most important maintenance that needs to be performed on any Audio or Video Recorder or Playback machine is CLEANING. All tapes leave residue (Minute particles of the coating material.) to some degree or another. Inferior grade tapes are known to leave excessive residue. The residue collects on the tape guides, capstan, pinch roller and heads. The residue not only can then dislodge itself and become imbedded in the magnetic coating causing drop out in analog, digital and video tapes. But, it can build up on the head in sufficient thickness to drastically reduce the quality of the recording. For analog audio this reduction appears as a loss in frequency response and in amplitude. In video or Digital audio with helical scan heads the residue and other foreign debris tends to be thrown off due to the speed of the head spin. This material however then becomes entrapped in the magnetic coating of the tape causing drop outs during playback. Equipment used only for playback causes the same problems and can damage a critical tape beyond usability. One that may have been originally only a poor recording the adverse recording environment.

Analog audio machines can be safely cleaned using cleaning fluids designed for this purpose. Denatured alcohol and lint-less swabs can also be used if done with extreme care. Do not allow excess fluid to get on any components other than the heads, capstan, pinch roller and guides.

Digital and video are best cleaned using cleaning cassettes either wet or dry. There is no evidence that the dry type of cleaning cassette, if used according to instructions, damages heads. (Trying to clean these machines with a swab is basically impossible unless the outside case of the machine is removed in order to access all of the moving and stationary components.)

The second most important maintenance that needs to be performed on audio equipment is the
recording/playback head azimuth alignment. The azimuth alignment affects how the gaps in the head are aligned with the recorded tracks on the tape. This alignment is done using Calibration tapes or cassettes designed for this purpose and assures that a tape recorded on one machine can be played back on any other machine. In time due to the handling of the equipment or accidently hitting the heads they become misaligned. (If the same machine is always used for recording and playback, unfortunately not a viable possibility, the alignment would normally be unnecessary.)

The third most important maintenance is to verify that the pinch rollers are not excessively worn causing tape slip and that the drive and take up belts are not worn or slipping.

Of course overall performance can be and should be tested periodically using Calibration & Alignment and Reference tapes/cassettes to determine the recording and playback characteristics of the machine. The result of these tests will determine if equalization or bias signal levels need to be adjusted or other repairs made to bring the machine back to optimum performance.

**Foreign particles.**

Mechanical damage to the magnetic coating is one of the worst things that can happen to a tape. A burr on a tape guide or head that touches the tape surface may cause a scratch so large in comparison with the recorded track dimensions in an audio tape that it is damaged beyond recovery or a video tape will play back with severe disturbances.

Dirt or foreign particles can also cause serious damage during use, handling and storage. The sources of foreign particles are tobacco smoke, fingerprints, dust particles, residual cleaning agents, human hair and tape residue. To better understand the affect these can have on an audio or video tape we need to compare the size of the particles to the thickness of the magnetic coating and the size of the head gap. See fig. 5.

![Figure 5](image)

Comparison of foreign particle size to tape and Video Head Gap

When foreign debris becomes imbedded into the magnetic surface drop outs or loss of signal occur. This is more critical in video and digital audio recordings which work with very short wavelengths, but it is still noticeable in analog audio. The cause of the drop out is the lifting of the tape from the record/playback head by the distance of the foreign particle that is imbedded in the tape or caught between the tape and head. See Figure 6 below.
As can be seen from the above chart all of the video and digital audio formats record at wavelengths less than 1 um. DAT’s are the most susceptible to foreign particles causing drop outs due to its shorter wavelength.

The loss of signal is directly related to the law of damping distance which states that if the tape is lifted from the head by the distance which equals the recorded tape signal wavelength, the signal can be weakened by approx 54 dB. The chart below shows the effect for analog audio, video and digital audio. See figure 7

The lifting of a tape a minuscule amount can cause a drastic reduction in signal level at the spot where the foreign material is imbedded. In analog audio in severe cases it can sound like clipping. In video it results in horizontal lines and in digital it results in clipping.

![Wavelengths](image)

**Figure 6**

**Wavelengths for different type of recordings.**

Leaving cassettes in any recorder when it is not in use should be avoided at all costs. A video recorder is the worst because when the cassette is in the recorder the tape is exposed to any dust particles in the air. Most analog and digital audio recorders have lids that close over the cassettes to prevent dust from settling on the cassette or tape.

All cassettes should be kept free from dust and dirt. Video and digital cassettes should be kept in their protective sleeves when not in use.

**External Magnetic and other Fields**

**External Magnetic Fields**
External magnetic fields can erase any tape to the extent dependent upon the magnetic field strength and the tape coercivity. The coercivity of audio cassettes (Type I) is about 380 oersteds, for VHS approx. 680 oersteds and DAT's around 1500 oersteds.

There is some disagreement as to the external magnetic field level applied at the tape surface that is required to completely erase the tape. It falls somewhere between one to three times the coercivity of the tape. Much lower levels are required to cause some erasure or damage. Studies done by NIST (What used to be the National Bureau of Standards) on a computer tape and of a Computer diskettes of 300 oersteds show differing results. The computer tape lost 18% of its signal with an external force of 100 oersteds and almost 95% at 300 oersteds. The computer diskette shows a 50% loss at just under 300 oersteds. It appears that only levels over 60 oersteds had effect on these items. This level of some airport x-ray machines fall between 20 and 60 oersteds, which would indicate that they are truly not harmful to audio or video cassettes. However, there are many other sources of external magnetic fields that can destroy or damage the recording on a tape.

One characteristic of magnetism that works in your favor is that the magnetic field from a magnetic source decreases rapidly with distance, approx. by the square of the distance. The further away the cassette is from the magnetic source the safer. A magnet with a force of 2000 oersteds therefore drops to 60 oersteds in just 4 cm (1.57 in). So for a magnet or magnetic device to affect the tape it has to be within close proximity to the tape or cassette. See figure 8.

![Graph](https://example.com/graph.png)

**Figure 8**

Reduction of Magnetic Field Strength vs Distance in centimeters.

The common sources that can be dangerous within a close range are magnets of loudspeakers, power transformers, degaussing coils in color TV sets, electric motors, refrigerator or small bar magnets, magnetic latches found on pocket books or wallets (these have field strengths of 500 to 650 oersteds which depending on the media can result up to a 95% loss of signal. Magnetic mounts for roof lights, portable van lights or tool holders all contain very strong magnets.

**Other fields**

Exposure to X-rays, Gamma Rays, Etc. NIST and other agencies performed tests to determine the effect of various rays on recorded data and found the following:

Nuclear Radiation: No data loss was observed after media/data was subjected for 1.5 hours to about 3.0 megarads of gamma-rays.

Radar Signals: There was no observable signal loss after exposure to L, C, and X-band radar beams, having up to 50,000 watts peak power, at a distance of about 10 feet.
Microwave Ovens: No measurable data erasure was observed after the media/dat was exposed for a time sufficient to heat the casing.

X-Rays: Media exposed to X-ray energy as applied for dental examination and in airport surveillance systems did not have any loss of data. The magnetic field emitted from airport metal detectors is only in the 5-10 Oersteds range. (Note: Depending on the source of information in this document the level of airport detectors ranges from a low of 5-10 as from this NIST report and as high as 60 Oersteds from other sources.)

High Voltage: Arcs produced by ignition coils that struck plastic cards directly and recorded media exposed to more that 15,000 volts did not show any data loss (Note: However static buildup in an analog audio recorder can cause “Pops”.)

Light and Laser Beams: Recorded media was subjected to light sources ranging from infrared to an intense ultraviolet light source with no resultant data loss. It should be noted, however, that an intense focused light might create sufficient heat that could destroy the data or the medium/cassette.

Temperature and humidity.

Temperature influences on the oxide particles is irrelevant as ferromagnetism does not disappear until the Curie point is reached (1000 °F for iron oxide and 266 °F for chrome dioxide.) However the base film and cassette components are susceptible to damage at much lower temperatures. For example at 230 °F the base film already begins to deform significantly and audio and video cassette housings have been known to deform when left in direct sunlight in an automobile where temperatures of 158 °F can be reached. Other damage to the base film can occur in temperatures as low as 132 °F.

Recommended Normal Operating Temperature and Humidity.

The normal operating temperatures are dependent on the tape and cassette manufacture specifications. But they should fall within the following guidelines.

The desired operating temperature and humidity for both audio and video cassettes is 68 °F to 86 °F at 30-50% relative humidity.

The maximum operating temperature and humidity range varies depending on the cassette type. For analog audio cassettes it is between 32 °F to 95 °F at a non condensing relative humidity of 0-95%. For VHS it is between 40 °F to 105 °F at 40-60%, 8 mm and DAT’s from 60 °F to 90 °F at 20-80%.

The effect of changes in temperature also have a significant effect on digital and video cassettes more so than analog audio cassettes. Video and digital tapes are sensitive to changes in temperatures that are greater than about 36 °F. The changes affect the roll of tape rather than the recording itself. The tape hubs in these cassettes have expansion and contraction properties different than the tape itself. Under the influence of considerable cooling, such as in the trunk of a car on a cold day, or in a cold storage room, contraction of the hub causes the tape windings to become loose and the tape layers can be subject to rubbing against each other (due to vibration) as well as with windings becoming uneven. When the cassette is brought back to normal or warmer temperature the uneven tape pack will cause irregular distortion of the tape causing lines of video noise in the recording. Any foreign debris can cause more abrasions to the magnetic layer causing additional drop outs.

When extremes of temperature cannot be avoided and the cassette has been transported the cassette should be brought back to normal temperature and left to stabilize for at least 8 hours - if there is evidence of condensation then 24 hours is preferred. The cassette should then be wound and rewound to form an even and smooth tape pack.

Tracking errors can occur if the temperature of the recorder and tape when recording is greater than about
18 °F from the temperature when playing.

If video or any tensilized tape, i.e., pre-stretched during manufacturing, is kept for any length of time at temperatures in excess of 132 °F the tape will shorten as the pre-stretching is removed. If the reduction in length is only 1% a recording previously made cannot be played back without serious degradation. (Disturbed lines in the upper part of the picture.)

Temperature affects analog audio in a different way, however it is just as serious as increased temperature causing an increase in print thru.

**Storage Temperature - Non Recorded**

The non-recorded storage temperatures are dependent on the tape and cassette manufacture specifications. But they should fall within the following guidelines.

The normal storage temperature and humidity for both audio and video cassettes should be the same as the temperature that they will be recorded and played back in. The preferred ranges is 68 °F to 86 °F at 30-50% relative humidity.

The maximum non-recorded storage temperature and humidity range varies depending on the cassette type. For analog audio and video cassettes it is between 5 °F to 130 °F at a non-condensing relative humidity of 0-95%. For 8 mm and DAT’s from 40 °F to 105 °F at 0-80%.

**Humidity**

![Humidity chart](image)

The influence of relative humidity in very low and high levels can affect how the tape physically performs. This is especially true when condensation takes place. Condensation will penetrate into the vacuoles of the coating and form a skin on the surface. The result is that the tape blocks or sticks (as the result of increased abrasion) to the head and other smooth tape guides and damage to the coating may also occur.

A temperature of 130 °F and relative humidity of 85% will cause the individual layers of tape to stick together,
playback may be impaired because of increased tape abrasion and if Video or Digital the clogged heads.

The lower humidity (below 30%) has a negative effect because the dryer atmosphere aids static charging of the polyester base film. This leads to the attraction of dust and dirt that gets trapped and imbedded into the magnetic coating.

Another aspect of humidity is the possibility of binder hydrolysis during long term storage. Binder hydrolysis is formation of a deposit on the tape surface. Hydrolysis means the decomposition of a chemical substance by water. There is always a balance between the substance and its reaction products and this balance depends on humidity and temperature. In recent years cases of hydrolysis have in practice only been observed in very rare instances with no recognizable connection. According to current knowledge unusual conditions must have occurred during transportation use or storage of the tape, whereby acidic vapors, industrial gases and fingerprints are clearly the principal factors which have a catalytic effect.

**Tape Deformation.**

Tape deformation means that the tape no longer lies flat, so that tape-head contact is no longer guaranteed across the full width. Tape deformation can be caused by the manufacturing process and is often evident in inferior grade tapes. Tape deformation also result from plastic distortion of the base film, which occurs as an effect of storage. Such deformations is mostly the result of bad windings to loose or too tight. Such as caused by only partially rewinding a cassette, or having made many fast forward or reverse searches without going thru a complete rewind at the end.

Deformations that primarily affect video and digital recordings are those of length changes in the micrometer range which can lead to skew with helical scan. This can be caused by the very slow release of stresses which have been produced in the base film during the manufacturing or during the drying process. The use of tensilized polyester reduces this phenomenon.

Deformations are normally caused by winding problems and other than what is mentioned above occur primarily in open reel to reel tapes that are more subject to over tight windings causing an increase in print thru, and deformations of the magnetic coating whereas to loose of a wind causes clinching and other problems.

All cassettes except analog audio have automatic locking of the hubs to prevent the tape reels from loosening during handling. The standard audio cassette requires the use of a separate hub lock or to be in a Norelco box. These types of cassettes that stored without hub locks can develop an “S” loop which can cause an immediate jam upon attempting to record or playback. It is recommended that these cassettes are stored in working Norelco boxes (as not all Norelco boxes have hub locks that lock the hub.) or use an external hub lock.

**Tape winding.**

Tape winding is more of a major problem in reel to reel tapes than with cassettes. However cassettes can also cause damage if they are not handled correctly. A cassette should never be left partially wound. After use prior to storage either short or long term the cassette should be fully rewound (If the tape was subject to much jogging then it should be completely wound first.) to insure that the pack wind is smooth and even and with even tension preventing tape deformation damage.
Summary

There are many outside factors that can cause a poor recording or loss of recorded material during use, handling and storage, from poor equipment maintenance to poor handling and storage techniques. These include severe temperature and humidity environments, dust or foreign debris, stray magnetic fields and poor winding practice. If one understands that the recording equipment and cassettes are precision items and applies common sense to the use, handling and storage most if not all of the problems causing the loss of recorded information can be avoided.

Reference materials utilized in the preparation of this document: “When Tapes Are Aging” by Erik Hendrup V/MT, “On the problems of Long-Term Storage of Magnetic Video Tapes” by Brian Jenkinson, “When Tapes Start To Feel Their Age” by Dr. Andreas Merkal, “Long-Term Stability of Audio and Video Magnetic Tape Recording” by D.I. Werner Singhoff, BASF, “Video Care” by BASF USA, “Effects of External Sources on Recorded Magnetic Media” by BASF USA.