Magnetic Carriers

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Typology and history

Magnetic media are essential to modern life. They are used in the form of tape to record sounds and images and to record digital data. In the form of hard and floppy discs they are used to store computer data. When applied in the form of a magnetic strip to a card, magnetic media control our access to money from cash dispensers, entry to doors and to many other things.

The basic principles for recording signals on a magnetic medium were set out in a paper by Oberlin Smith in 1880. The idea was not taken any further until Valdemar Poulsen developed his wire recording system in 1898. Magnetic tape was developed in Germany in the mid 1930's to record and store sounds. The use of tape for sound recording did not become widespread, however, until the 1950's. The BBC, for example, was still using disc recorders until around 1965.

The recording of images on magnetic tape came later. As with sound recording, there were several systems before tape recording came into common use. The first known recordings of images by a non-photographic method were made by John Logie-Baird in 1924. The images were recorded on to 78 rpm discs which are now in the National Sound Archive in London. The first practical recordings of television programmes were made using special film cameras filming video screens. The first video recording machine using tape was made by the BBC in 1955. It used a half inch tape running at 120 inches per second - just over 3 metres per second. This was swiftly superseded by the introduction of the Ampex Corporation's 2 inch video tape system. The arrival of new formats for recording video pictures has steadily increased since then. It has been calculated that, taking the different broadcast standards and electricity supplies into account, images have been recorded on over 100 different formats in the 40 years since video-tape recording started.

Although some dictating machines using a disc coated with a magnetic pigment were in use from the 1950's, disc based media did not develop until computers became widespread. The steady increase in the storage capacity and decrease in physical size of both hard and floppy discs has paralleled the developments in the tapes used for sound and image recording.

Magnetic Tapes

Magnetic media in the form of tapes on open reel or housed in cassettes and cartridges are the most widespread carriers for audio and video data and are widely used for the storage of large quantities of computer data. They are a reliable, low-risk and economical storage medium. Archivists and librarians can rely on a long period of experience in the care and handling of magnetic tapes in archives. If free from production faults, they can be preserved for many years. The oldest audio tapes are now over 60 years old and still perfectly readable.

Types of Magnetic Tape Construction

Early audio tapes used cellulose acetate as the support film material, which is also used for safety film. Cellulose acetate has a tendency to become brittle through hydrolysis caused by the moisture contained in the atmosphere. This brittleness generally causes serious problems when playing old audio tapes. Tapes with severe cases of hydrolysis can suffer from the so-called "Vinegar Syndrome", an auto-catalytic process whereby acetic acid is set free in ever increasing quantities and thus creates an accelerating effect on the decay process. This has been particularly experienced in film archives, especially in hot and humid climatic areas. Affected films become soft and limp, ending up as powder or slime. While, in theory, this may also happen to acetate audio tapes, no disastrous losses similar to those in the film world have been reported. Still, acetate tapes, which were produced until the mid 1960s, are at risk and transfer onto other carriers must be envisaged.

Another group of historical audio tapes used polyvinyl chloride (PVC) as the base film material. As with vinyl discs, these tapes have not exhibited any systematic instability ; the long term prospects are, however, unknown.

Polyester is the base film material which is used for all modern audio and all video and computer tapes. It has the greatest resistance of all base materials to mechanical stress and the influence of humidity. No systematic stability problems have occurred so far but, again, its stability over very long periods (centuries) is unknown.

Many varieties of magnetic materials have been used for the pigment layer, for example the various oxides of iron used from the very first tapes until today and chromium dioxide. Only metal powder, as used in more recent high density tape formats, has given cause for serious concern. Early tapes metal powder tapes suffered from corrosion but this problem now seems to be under control. There is, again, no precise answer to the question of how long metal particle tapes will keep their information undistorted and readable. It must be emphasized, however, that, contrary to layman's expectations, the magnetic information on properly stored and handled tape does not fade away.

The greatest problem related to magnetic tape is the stability of the pigment binder - the glue that holds the magnetic particles together and to the base film. A considerable number of audio and video tapes, especially amongst those produced during the seventies and eighties, are suffering from pigment binder hydrolysis. The atmospheric moisture is absorbed by the pigment binder causing the polymer to hydrolyse and lose its binding property. Tapes of this kind deposit a smear of magnetic particles onto the replay heads. This clogs the heads and swiftly makes the tape unreadable. In extreme cases, the oxide layer the completely delaminates from base in large segments when the tape is played. Processes to render such tapes playable again are available, but the restoration process is cumbersome, time consuming and cannot restore the most severely affected tapes. This problem has been found especially in hot and humid areas where many tapes do not last longer than a few years.

Types of Magnetic Tape Housing

There are three basic methods for the immediate storage of tape : open spool, cassette and cartridge. The tape on an open spool has to be threaded on to the machine and the free end secured on a second spool by hand - a time consuming task and easily performed incorrectly. Tape in a cassette is enclosed in a shell and the two ends of the tape are securely fixed to captive spools. A cartridge is also fully enclosed but the tape is in the form of a continuous loop. Cassettes and cartridges are easier to load on to a machine than open spool tapes and are also suitable for use in robotic storage systems. Cassettes are common for modern video and computers but relatively few are used for professional audio. Cartridges are most commonly encountered with data but some are used for audio - particularly for short items such as station idents and commercials.

– Open Spool Tapes

Open spools were until recently the main form of tape used for professional audio recordings. Continental European tradition generally uses professional tape on flangeless hubs only, a practice that requires additional care when handling the tapes. Some expensive professional digital audio formats like DASH and PD (ProDigi) use reel-to-reel tape and stationary head technology. Early video and many data tape formats also used tape in open spool form.

– Cassette Tapes

Cassettes are used for many purposes. They range from the Compact Audio Cassette or Musicassette through the many types of video cassette to the latest Digital Audio Tapes with rotary heads (R-DAT). They are probably the most widely used form of tape used in modern systems.

The Compact Audio Cassette was originally designed for use with dictating machines. Its convenient size led to it becoming used for the issue of commercial music recordings and for home recording. Except as an access tape, it was not normally used for professional work. In addition to the Compact Cassette, there have been several other cassette tape formats used for dictating machines.

Many types of cassette have been used for analogue video recordings both professionally and in the home. The commonest is the ubiquitous VHS cassette. Other formats include the 3/4 inch U-Matic - a

semi-professional format - and the 1/2 inch BetaCam used by many broadcasters around the world. All video tape formats, analogue and digital, use rotary head technology. Some of these digital video formats were also adapted for the storage of general computer data.

Rotary head technology is used for the digital audio format R-DAT, while stationary head technology is employed for the DCC (Digital Compact Cassette), a data-reduced digital consumer audio format designed to replace the Compact Audio Cassette, but without success.

A variety of cassette formats are used in the computer world as back-up tapes for the information held on hard discs as well as carriers in mass storage systems - the so-called streamer tape formats. These include linear formats like QIC- 80, Exabyte or DLT as well as various rotary head formats, derivates of R-DAT (DDS) and of various digital video formats.

The R-DAT format potentially makes an ideal data backup media. However, there is little experience of their long-term storage qualities. Opinions are divided. Some experts say that a five year re-copying term is appropriate, others claim that DAT are not suitable for long-term storage. For safety reasons, a two year recopying term is advisable until more is known of the long-term performance of these formats.

– Tape Cartridges

The primary use for cartridges is for storing computer data but a variant was extensively used to record short sound sequences for commercials, station identifications and the like. These audio cartridges were either monophonic or stereophonic (two tracks). The cartridges used for computer data, however, use 24 tracks which permits a storage capacity of 12 700 bpi. Due to the sequential recording, the average access-time is relatively long.

Magnetic Discs

There are two types of magnetic disc - the hard discs and the floppy discs. While reading and writing, the disc is rotating around its centre. The data are recorded in circular tracks, sector by sector. Because of the sectorial access to the data, the average access- time is relatively short.

Floppy discs are thin, flexible plastic plates covered with a magnetic oxide layer and protected by a firmly fastened square plastic jacket. At present, the common format is the 3.5 inch disc. The older 3.0, 5.25 and 8.0 inch discs are no longer in use and it is difficult to find drives for them. The storage capacity of a 3.5 inch disc is 1.4 MB. 3.5 inch discs with a capacity of 2.88 MB have been developed but are not very common.

Data interchange on floppy discs usually causes no media problems provided that a drive for the physical format of the disc is available. Discs are not suitable for long-term storage. They can deform because of the instability of the plastic material and damage the drive. They should, therefore, only be used for a limited period of time.

Hard discs are usually found installed permanently in computer systems and used for very fast access, short term storage. Removable hard discs exist but they are not common. Although hard discs are reliable, it is advisable to make back-up copies of data stored on them. Storage capacities in excess of 8 GB are now common and, when hard discs are used in an array (RAIDs), very large storage capacities can be achieved - albeit at greater cost compared with other storage formats. Hard discs in RAIDs will be in continuous use and have a life expectancy of several years.

Data Density versus Data Security

The history of magnetic storage media is the history of ever increasing data density. This has been achieved by the steady decrease in size of the elementary magnetic structure - from iron oxide via chromium dioxide to "pure metal" as used in metal particle tape and hard discs. In parallel with this, has come the development of ever smaller gaps in the reading heads, very thin base films (some R-DAT tapes are only 9µm "thick") and very narrow tracks widths (13µm on R-DAT). By use of these developments, ever increasing quantities of information can be recorded on ever decreasing sizes of carriers.

The danger is, however, that the recorded information becomes increasingly vulnerable. It is generally true to state that, because of their increased data density, modern formats are less reliable than older formats with their less dense storage capacities. Correct recording and reading of information onto or from modern magnetic formats is highly dependent on the physical and chemical condition of the recording medium being in pristine condition, the replay equipment functioning perfectly and an environment free from disturbing factors such as smoke, dust, and other pollutants.

Typology of magnetic tape carriers (audio and video) - synopsis

carrier	date of manuf.	media	type of recording	record. proced.	composition
magnetic tape	1935- 1960	sound	analogue	magnetic	base : cellulose acetate magnetic pigment : Fe_2O_3 formats : open reel audio
	1944 - 1960	sound	analogue	magnetic	base : PVC magnetic pigment : Fe_2O_3 formats : open reel audio
	1959-	sound / video	analogue	magnetic	base : polyester magnetic pigment : Fe_2O_3 formats : open reel audio, compact cassette IEC I 2 inch ("quadruplex") open reel video
	1969-	sound / video	analogue / digital	magnetic	base : polyester magnetic pigment : CrO_2 formats : compact cassette IEC II, DCC 1 inch open reel video, VCR, U-matic; VHS, Betamax, Video 2000, Betacam, D1
	1979-	sound / video	analogue / digital	magnetic	base : polyester magnetic pigment : metal particle (MP/ME) formats : compact cassette IEC IV, R-DAT ; video8/Hi8, Betacam SP, M II, all digital video formats (except D1)

Causes of deterioration and Preventive Measures

The stability of magnetic carriers

The main factors that affect the stability of carriers and the retrieval of information can be summarised as :

- humidity and temperature,
- mechanical deformation,
- dust and dirt of all kinds,
- magnetic stray fields.

Humidity

Humidity is the most dangerous environmental factor. Water is the agent of the main chemical deterioration process of polymers : hydrolysis. Additionally, high humidity values (above 65 % RH) encourage fungus growth, which literally eats up the pigment layer of magnetic tapes and floppy discs and also disturbs, if not prevents, proper reading of information.

Temperature

Temperature is responsible for dimensional changes of carriers, which is a particular problem for high density tape formats. Temperature also determines the speed of chemical processes : the higher the temperature, the faster a chemical reaction (eg hydrolysis) takes place ; the lower the temperature, the slower the chemical reaction.

Recommended Climatic Storage Conditions						
	temperature	±/24h	±/year	RH	±/24h	±/year
	°C	°C	°C	%	°C	°C
preservation storage	between 5 and 10	±1	±2	30	±5	±5
access storage	around 20	±1	±2	40	±5	±5

Fluctuations of target temperature and humidity values should be kept to a minimum. Operational areas (studios) should, therefore, have the same climatic condition as the access storage areas. Tapes must be allowed to slowly acclimatise to the change in conditions when brought out of or returned to the preservation storage.

It is of utmost importance that both temperature and humidity are controlled simultaneously. Damage to tapes can occur if attempts are made to cool the storage environment without dehumidification. Such action will normally lead to an excessive rise in relative humidity.

Mechanical Integrity

Mechanical integrity is a much underrated factor in the retrievability of data recorded on magnetic media : even slight deformations may cause severe deficiencies in the play back process. Most careful handling has, therefore, to be exercised, along with regular professional maintenance of replay equipment, which, if it malfunctions, can destroy delicate carriers such as R-DAT very quickly. With all tape formats, it is most important to obtain an absolutely flat surface of the tape pack to prevent damage to the tape edges which serve as mechanical references in the replay of many high density formats. All forms of tape - open reel, cassettes and cartridges - and floppy discs should be stored upright.

Dust and Dirt

Dust and dirt prevents the intimate contact of replay heads to media which is essential for the retrieval of information, especially with high density carriers. The higher the data density, the more cleanliness has to be observed. Even particles of cigarette smoke are big enough to hide information on modern magnetic formats. Dust may also be responsible for "head crashes" of computer hard discs and of rotary head formats, which inevitably leads to irretrievable loss of data. It goes without saying that in addition to the mechanical problems caused by dust, fingerprints and smoke, chemical pollution caused by industrial smog can accelerate chemical deterioration. The effective prevention of dust and other kinds of dirt and pollution is, therefore, an indispensable measure for the proper preservation of magnetic media.

Magnetic Stray Fields

Magnetic stray fields, finally, are the natural enemy of magnetically recorded information. Sources of dangerous fields include dynamic microphones, loudspeakers and head sets. Also magnets used for magnetic notice boards etc, possess magnetic fields of dangerous magnitudes. By their nature, analogue audio recordings, including audio tracks on video tapes, are the most sensitive to magnetic stray fields. Analogue video and all digital recordings are less sensitive. For the safeguarding of analogue audio recordings it is necessary to keep to the following maximum magnetic stray fields :

- AC fields : 5 Oe (Oersted) = 400 A/m (Ampere per metre)
- DC fields : 25 Oe = 2000 A/m.

It should be noted that normally a distance of 10-15 cm is enough to diminish the field strength of even strong magnets to acceptably low values.

Summary

Although magnetic media are generally quite stable and analogue magnetic tape has been in existence for over 60 years, none of the magnetic media are designed with longevity in mind. Even if all recommended standards and practices for the preservation of original magnetic carriers are carefully observed, it not possible to preserve them for long periods. Sooner or later copies will have to be made. Because of the increasing deterioration of audiovisual information when copying in the analogue domain, a preservation policy based on copying can only be successful in the digital domain. For digital documents, audiovisual as well as computer data, the problems related to the preservation of the carriers are increasingly overshadowed by the problems of the obsolescence of hardware and associated software. The management of future migration is, therefore, becoming the central issue of audiovisual as well as of general data preservation. Self-checking and self-regenerating digital mass storage systems are likely to become a powerful tool in future preservation policy.

The digitization of analogue carriers and the migration of information already in the digital domain are gigantic tasks. Because these will take time to complete, digitization/migration projects must be arranged in a hierarchical order. Priority must be given to those documents which are in frequent demand and to those which are at immediate risk. Meanwhile, those documents which are in good condition can wait. They must, however, be stored with all possible care in order to keep them in the best possible physical condition until their turn for digitization or migration comes.

Standards

– **International**

ISO/IEC 11172	MPEG-1 - Video compression system.
ISO/IEC 13818	MPEG-2 - Video compression system.

– **National**

ANSI X3.14-1983	American national standard for information systems : recorded magnetic tape for information exchange.
BS 4783:1972	Recommendations for the care and transportation of magnetic tape.
BS 4783:1988	Recommendations for storage, transportation and maintenance of magnetic media for use in data processing and information storage. Part 2 : Recommendations for magnetic tape on open spools.
BS 4783:1988	Recommendations for storage, transportation and maintenance of magnetic media for use in data processing and information storage. Part 3 : Recommendations for flexible disk cartridges.
BS 4783:1988	Recommendations for storage, transportation and maintenance of magnetic media for use in data processing and information storage. Part 4 : Recommendations for magnetic tape cartridges and cassettes.

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Website Directory

Records and Information Management Resource List
Links to Records and Information Management (RIM) and other related Websites.
A list of resources created by Alan S. Zaben.
http://home.earthlink.net/~survivoraz/infomgmt/medstr_f.htm

Electronic Storage Media
A list of information resources on the CoOL website.
http://palimpsest.stanford.edu/bytopic/electronic-records/electronic-storage-media/

Audio/Video Glossary
Searchable alphabetically and by subject.
http://www.soundsite.com/glossary/glossary.html

European audiovisual Conference
Speeches, papers and reports from the Conference. Birmingham (UK), 6-8th of April 1998.
http://europa.eu.int/eac/bg-intro_en.html