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THESES ON THE PRESERVATION AND RESTAURATION OF AUDIOVISUAL MATERIAL

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1. Introduction

1.1 There is no need of dealing here with the present-day necessity for preserving audiovisual recordings in general and films in particular.

It is also well-known that the conventional information carriers using optical or magnetic picture and sound recording are jeopardized so that we can hardly expect them to last several centuries. At present we witness the transition to other information carriers, which are already tested in laboratories, some of them being already marketed. We must be fully aware of the fact that this development entails difficult decisions to be made in the archives. The Preservation Commission is anxious to spread the latest results of scientific research facilitating in this way decisions on the selection of the most appropriate new information carrier.

1.2 At present the following audiovisual recordings can be made:

optic recordings on cine films,
magnetic recordings on tapes,
new video-electronic developments,
new video-mechanic developments.

2. Cine films

All cine films are multi-layer tapes consisting of base, adhesive emulsion and either a black-and-white emulsion or several colour sensitive or filter emulsions. They are very sensitive to temperature and humidity.

Most of these film strips shrink at an excessively low air humidity, and their individual layers have different coefficients of expansion in case of temperature variations.

Therefore they are all exposed to danger physically spoken.

Cine films exist in different sizes (width of film strip).

The most common ones are the following: 8 mm (also super-8-mm-films), 16 mm, 35 mm, 70 mm.

We shall discuss in this context the preservation conditions for 35 mm-films which also hold true for the narrower sizes.

From the physical point of view 70 mm-films are subject to a greater risk because of their bigger mass (shrinkage, peeling off of emulsion), whereas from the chemical point of view they have the same characteristics as films on a triacetate base.

We distinguish according to the

a) base material: nitrate, acetate or polyester films;
b) emulsion: black-and-white and colour films;
c) silent and sound films;
d) sound recording - sound films with optical sound / such with magnetic sound tracks.

Items a) and b) are of overwhelming importance for the preservation of films.

2.1 <u>The base</u>

2.1.1 Nitrate base

2.1.1.1 Nitrate films have a support consisting of nitrocellulose. For this reason they have a low ignition temperature (a new film at plus 130° C, an old film, as proved in the

USA, at plus 41° C) and must be stored at a cool and fireproof place.

2.1.1.2 A nitrate film is subject to a chemical auto-destruction. It constantly releases nitrous gases, which combine with the humidity contained in the air and in gelatine and form nitric or nitrous acids. These acids bleach out the silver image in the emulsion and the base material decays slowly.

Since acetate films have the same emulsion as nitrate films, these nitrous gases exercise their destructive action also on the emulsion of the acetate film.

This is why nitrate film must never be stored together with acetate films. We recommend to store the two types in separate vaults.

2.1.1.3 The decay process of nitrate films can be delayed by optimal storage conditions, but it cannot be stopped.

2.1.1.4 Soviet scientists have most thoroughly studied the possibilities to preserve films. The International Preservation Commission has unanimously accepted the soviet propositions and recommends as the most favourable storage climate for nitrate films

a temperature of + 4° C ± 2° and
a relative humidity of 50% ± 10%.

It is essential to keep this climate constant (see 2.1), and to exhaust nitrous gases when the air is circulated and fresh air is supplied. Such conditions can be provided only by air-conditioning.

2.1.1.5 Insulated metal cabinets for nitrate films like those available in the State Film Archive of the GDR, proved to be a good protection against the fire hazard.

2.1.1.6 Nitrate bases have all the original negatives of old silent films, as well as their duplicated negatives, duplicated positives and prints made before 1950 and the black-and-white sound and colour films manufactured or printed before 1950.

Only the bigger archives still possess considerable quantities of nitrate films which in the interest of their preservation should be copied on triacetate film in the best possible way and at the earliest possible date. Should the original nitrate material be of a remarkably better quality than the acetate prints, the nitrate films should be preserved, provided safe storage facilities exist for them.

2.1.1.7 It should be emphasized that it is necessary in any case to observe all national laws regarding nitrate films in the own interest of the archives.

2.1.2 <u>Acetate film</u> (safety film)

2.1.2.1 The base of these films consists of acetyl cellulose, for more than 20 years triacetate has been used in general. Triacetate film bases have a much higher ignition temperature than nitrate films; it is similar to that of paper. As regards the fire hazard, they do not entail bigger problems than the storage of books in a library.

2.1.2.2 The triacetate base does not eliminate any harmful gases which could bleach out the image and result in the decomposition of the base as such.

2.1.2.3 For this reason triacetate base in particular and triacetate film in general are much more durable than nitrate film. But the triacetate base is not completely safe, either. This is due to the fact that a plasticizer is constantly escaping, particularly at low atmospheric pressure and in a dry climate. Under these circumstances acetate film will also shrink and become brittle and thus useless. At excessive air humidity the plasticizer will recrystallize.

Despite these negative properties triacetate base is more stable than nitrate base and easier to preserve.

2.1.2.4 The most favourable climate for the storage of all safety films is the following

temperature: + 6 to + 12° C
relative humidity: 50% ± 10%.

Also in case of these films it is important to keep the climate constant.

2.1.2.5 In most countries the transition from nitrate to acetate films took place in the fifties. As from the midfifties one may assume that new negatives or duplicated films and prints were made on a triacetate base.

2.1.3 Polyester film

2.1.3.1 Polyester base is insensible to both the temperature variations in the course of the day and the humidity. It is not inflammable and do not eliminate harmful gases. It cannot be attacked by moulds, fungi and bacteria.

2.1.3.2 It would be the ideal base material if there were not considerable difficulties in attaching the light sensitive emulsion on it. These difficulties increase as the width of the film strip grows.

2.1.3.3 This is why only super-8-mm-films on polyester base are marketed for the time being. For special purposes small quantities of 16 mm polyester films are produced. 35 or 70 mm films on polyester base are not manufactured.

2.1.3.4 Polyester film can safely be stored at the temperature indicated for the triacetate base (2.1.2.4). Due to the emulsion air-conditioning is necessary.

2.2 The emulsion

is a light sensitive layer which is linked with the film base by an adhesive layer. It consists of gelatine in which finely dispersed microcrystalline light sensitive substances are incorporated. Gelatine is a culture medium for fungi and bacteria. At high temperatures and high humidity we can safely expect that they will exercise their damaging action. Even at the indicated optimum temperatures damages caused by fungi and bacteria may occur, since certain fungal and bacterial species may adapt themselves to climates that were originally not suitable for them.

2.2.1 Black-and-white films

2.2.1.1 In black-and-white films silver halogenides are embedded in the gelatine as light sensitive elements. After the exposure and processing they produce the black silver image. Upon the action of acids (industrial waste gases, nitrous gases, processing resuidues) the silver image fades until the film becomes useless. Fading occurs mainly before the decomposition of the base begins.

2.2.1.2 These damages can be repaired by a complicated redevelopment process, which, however, does not only require development facilities but also qualified staff.

2.2.1.3 The storage climate for black-and-white films is determined by the respective film base (see 2.1.1.3, 2.1.2.4 and 2.1.3.4).

2.2.2 Colour film

2.2.2.1 The colour in the film can be produced according to two different optical principles:

- the additive principle in which the three spectral regions of blue, green and red are superimposed on each other (are added), and
- the subtractive process in which the primary colours are filtered out from the white light by means of filters in the complementary colours yellow, purple and cyan.

2.2.2.2 The additive process was used for negatives and positives for a short period only, particularly by Technicolor and Gasparcolor. At the present time only Technicolor copies are made according to this process, while all other colour raw films including Technicolor negatives, are produced according to the subtractive process.

2.2.2.3 There are three techniques for producing colour in the film:

a) the technique of chromogenous development, in which the colour of the negative is produced by dyes (colour cupplers) embedded in the various colour layers;

b) the printing process in which 3 colour separations are dyed in the primary colours and are printed one above the other on one film strip (at present used only for Technicolor prints);

c) the bleaching process which is no longer used (formerly particularly by Gasparcolor); the colours were differentiated by means of bleaching out.

2.2.2.4 The colours produced by printing or bleaching are considerably more stable than the ones obtained by chromogeneous development. Since for decades the majority of the colour films has been produced according to the simpler and easier chromogenous development process, it follows that the colours in the film are extremely sensitive and will disappear after a certain time even when they have been stored in the dark.

Comprehensive investigations have been carried out so as to determine the most favourable parameters for the preservation of colour films (the latter being important also for distribution). In the Soviet Union temperatures lower than -50° C were used for these scientific researches.

2.2.2.5 Different data are recommended by the producers for long-term storage. They vary between +20° C and -18°C. Such differing statements cannot be correct. Scientists agree on the fact that only in region below zero there is a chance for the colour films to be preserved over a longer period.

2.2.2.6 After lengthy discussions the Preservation Commission has accepted the proposal to preserve colour films in the following climate:

temperature not more than -5° C and
relative humidity not more than 30%.

Lower temperatures are quite possible, but they are much more expensive to achieve and result only in an inconsiderable increase in life.

2.2.2.7 The decay of the colour in the film is a chemical process in which not only the original colours are destroyed, but new colours are formed (mainly yellow and brown).
The destruction process takes place more rapidly than the bleaching out of black-and-white film. This is why colour film is the audiovisual information carrier that is most difficult to preserve.

2.2.2.8 For the preservation work carried out in the archives it is very important to know that at the present time colour films constitute approximately 90% of the raw films produced by the biggest film producing countries (Northern America, Europe and Japan).

2.2.2.9 There are only two possibilities for prolonging the life of colour films:

optimum air conditioning of the storage facilities or

resolving the colour image in black-and-white colour separations of the three primary colours.

In the latter case the principles governing the storage of black-and-white material should be applied for preservation.

2.2.2.1o If the colour separations are stored on three different strips according to the primary colours, the different degree of shrinkage will create considerable difficulties in re-assembling the separations to make a colour film. The individual images can no longer be superimposed.
It is possible to photograph the three colour images one below the other or even side by side on one film strip or to print them in this way. In so doing the problem of shrinkage will be reduced to the degree which is common for cine films. The first equipment

for such a process is being installed in Paris at present (Service des archives du Film).

2.2.2.11 The damaging factors having for colour films are in general the same ones as for black-and-white films, the only difference being that they have a stronger effect on the classes of dyes formed during chromogenous development.

We have already mentioned that prints made by the printing process have considerably more stable dyes. In no case, however, the stability is better than that of the black-and-white image.

2.2.2.12 There are several auxiliary processes by means of which the durability of the colours can be prolonged in such archives that are not equipped with air-conditioning plants creating temperatures below zero (automatic defroster devices, sealing up in polyethylene bags). But it should be emphasized that these are just makeshift solutions designed to delay the destruction process for a short period only.

2.2.2.13 It is possible to restore the colour in the film by

chemical means or by
corrective printing.

Chemical regeneration is an extremely complicated process in which the individual colours are selectively reduced or intensified.
The corrective printing offers best possibilities particularly in making colour separations, but we must not overlook the fact that with the usual archival and laboratory equipment no success will be obtained. All methods of colour regeneration are still being tested. For the time being it is not possible to use more stable dyes.

2.2.2.14 The most recent and so far optimum possibility for preserving the colour is to use electroning recording techniques, i.a. television techniques.

3. Magnetic image and sound recording

The audiovisual recordings on magnetic tapes differ from the optical film. Not images are recorded but symbols which may be retransformed into images.

This means on the one hand that the problems related to the preservation of the optical recording in the emulsion of the cine film are no longer applicable, on the other hand certain new difficulties occur with regard to the magnetizable layer.

3.1 The base

In the archives the bases can be used as important indicators of the age of a tape. The oldest tapes have a base of triacetate or polyvinylchloride (PVC).

At the present time both triacetate and polyester are used as base material.

3.1.1 When we dealt with cine film we mentioned already the advantages offered by polyester tape as compared with triacetate tape. In case of magnetic tape a negative property must be taken into consideration: when being exposed to strong tension polyester tape will be readily extended.
For this reason one uses tapes that were exposed to tensioning in longitudinal and transversal directions, because they are not as flexible.

3.2 The layer

The layer consists of organic varnishes as binding agent and magnetizable particles (iron oxide, chromium oxide).

3.2.1 The particles irregularly arranged in the past, have now in the raw tape a uniform shape (needle form) and direction. The trend is to further minimize these tiny particles (maximum length 1/1000 millimetre), because this will reduce the background noise. This applies particularly to the low noise tapes.

3.3 Preservation conditions

3.3.1 There are some specific properties and some external effects that can jeopardize the preservation of magnetic tapes.

3.3.2 A common characteristic of all types of magnetic tapes is that they require a constant climate for their preservation, room temperature is generally recommended by the manufacturers. But there are no objections either to store the tapes (especially triacetate tapes) at the same conditions as triacetate films. This is why a special type of vaults for the storage of magnetic tapes is not required; but care must be taken that in the storage room itself electric interference fields are avoided.

3.3.3 In contrast to image recordings magnetic ones cannot be fixed; this is a considerable disadvantage. Until recently scientists were of the opinion that a magnetic recording can be stored for one hundred years as a maximum, because the level will decrease from 60 dB to 52 dB over this period, thus making the tapes useless. But now it was observed that the level will not decrease so strongly, so that we can reckon to store image and sound recordings over even longer periods. Magnetic image recordings are anyhow more stable than magnetic sound recordings.

3.3.4 The fact that magnetic recordings cannot be fixed explains why electric interference fields produced in the vicinity of the tape stored will change the orientation of the particles and thus the recording as such.

This risk can be countered in a relatively easy way. The most powerful interference fields are effective only within a distance of 2 m from the tape.

3.3.5 Comprehensive scientific experiments have shown that lightnings and DC motors do not erase recordings.

In modern tapes the loss of plasticizers does not have a particularly dangerous effect. Polyester does not contain any plasticizers.

Although the layer does contain plasticizer at any rate, a loss can largely be avoided by keeping the temperature constant and providing a slight excessive atmospheric pressure.

3.3.6 After the recording each magnetic tape has a certain background noise, the volume of which depends on the size of the oxidic particles. This is why one began to manufacture special tapes, socalled low noise tapes, especially for hi-fi techniques.

Compared with the normal tapes these tapes have the disadvantage that in case of polyester tapes the fastening of the layer on the base material is more difficult. This and other disadvantages are the reasons why they are not very suitable for long-term preservation.

3.3.7 During each recording a print-through effect occur, which can be measured, but will not always be audible. This effect depends on

1) the thickness of the base material
2) the wave length
3) the intensity and the duration of the magnetic effect
4) the ambient temperature.

As a result of the short wave length of the video signals, video tapes do not exhibit any disturbing video print-through effects, but due to the low thickness of the tape, their sound part is very susceptible to the print-through effect.

By rewinding the tapes several times an existing print-through effect can be reduced in most cases to an acceptable degree.

3.3.8 In old tapes the memory effect, i.e. the coming through of old erased recordings, can play a role. In tapes manufactured after 1960 the memory effect was no longer observed. It can safely be avoided when fresh tapes without old erased recordings are used for the recording.

3.3.9 Polyester tapes are not subject to shrinkage, but triacetate tapes. Here the same applies as what was mentioned with regard to cine films; it should be mentioned, however, that the shrinkage in the image can more easily be compensated than the shrinkage in the sound part which often is irreparable.

3.3.10 Especially at low humidity electro static charge may be produced by friction on the sound head when recording or playing the tapes. This attracts dust which will result in disturbances both during the recording and the reproduction; in case of sound recordings this manifests itself by a cracking noise.

The friction of the tapes on the tape guides can be countered by the manufacturer's admixing to the layer charge shunting substances, such as carbon black.

For storage in archives it is appropriate not to rewind the tapes after they have been used. The strong tension which usually occurs during rewinding is avoided in this way, the tapes are loose and more uniform, i.a. the edges are not jeopardized to such an extent.

When rewinding for replaying or checking the tape, defective splices can be spotted and repaired and moreover the tape can rest in most cases for 24 hours, thus reducing a possible print-through effect.

4. Development of video electronic devices

Video electronic facilities are still in the state of development, although some of them have already been introduced into the recording and reproduction technique. All of them have one thing in common; they are based on television and the quality is therefore determined by the number of scanning lines of television (approximately 560) and not by the quality of the film image which correspond more than twice the number of lines.

All these methods have one common characteristic feature, i.e. instead of dyes they use signals for colour transmissions. This means that they are at any rate considerably more durable than films.

Differences exist with regard to the purpose. There are methods designed for the transformation of film to electronic recordings and other methods representing independent electronic recordings.

At any rate, this orientation is more promising than the development of the optical film till now.

4.1 Methods already in use

4.1.1 The methods which are used at present in television employ electric signals received by a television camera or another video-electronic system which by remanent magnetic induction are produced on a magnetic tape. In this way a magnetic image is produced which contains the visual image in coded form. These recordings are produced on a tele-projector as a visual image (e.g. Ampex system with 4 revolving picture heads and a tape width of 50,8 mm).

When using these systems developing and printing are no longer necessary, the recordings can be used without delay. When using the same recording and reproduction times respectively the quantity of tape used corresponds to that of a 35 mm-film.

With regard to storage, the same regulations as for magnetic recordings or triacetate film are applicable.

4.1.2 In case of electronic-photographic picture recording the electronic image is transferred by means of an electron beam to a film with fine grain and recorded.

The Electronic Video Recording System (E.V.R. - C.B.S.) based on this method is no longer marketed. It was used for cassettes containing images in the size 2.5 x 3.3 mm and in which the light signals (the proper image) were recorded in one track and the chrominance signals (colour) in the adjacent second track.

They were reproduced by means of an intercalated device which is connected to a tv apparatus.

With these very small size the quantity of film base used equals 2% of 35 mm film and 10% of 16 mm film.

4.1.3 The holographic process

By way of example holotape should be mentioned which was developed by the R.C.A. Corporation for video cassettes.

By electronic methods a print of the film to be projected is produced on a light sensitive 16 mm film. This print contains separately the information on light and chrominance. This print is copied in laser light on a cronary tape with a width of 12.7 mm, which is coated with a material which, under the action of laser beams, softens to a varying degree. After chemical treatment of the surface of the tape a relief in the form of elevations and recesses appears (maximum distance 1 μ = 1/1000 mm). This relief contains the light and chrominance informations. This holographic matrix is used for the mechanical multiplication of the prints for video cassettes by pressing suitable tapes.

By using a special reading laser the relief variations are transformed to visual images on the picture tube of the television set.

The most important advantages of the holographic images are

their high reliability,
the fact that damages and dust can hardly exercise adverse effects on them,
the storage capacity which largely exceeds that of the classical film (approx. 20 times the capacity of 35 mm film).

4.2 The video record

Various manufacturers (Philips, 3M and AEG Telefunken) have developed a video disc the first version of which should now be available commercially.

The light and chrominance signals of the moving picture are received by a video-electronic system and transferred to the surface of a matrix record either by means of very close grooves (approx. 140 per millimetre) or by forming microscopic cavities. As in the case of records, multiplication is effected by pressing. The image is decoded by means of special scanners and reproduced on the picture tube of the television set.

4.3 Critical examination of the new possibilities

With regard to the long-term pressrvation of audiovisual recordings two of the above mentioned systems have properties which appear to make them much more suitable for long-term storage than the materials used up to now:

the holographic process and the
video disc.

As in the case of magnetic recordings, the common characteristic feature of these two methods is that they do not store light and colours in the form of silver particles or dyes, but in the form of coded signals. In contrast to the magnetic recordings they have the advantage that they can be fixed, i.e. will not be changed by magnetic influences. In both cases the material of the information carriers is much more stable than optical film. The video record, at least the matrix, is advantageous in that it consists of a material which can easily be preserved i.e. glass and anticorrosive metal.

This means that it could be permanently (i.e. probably over centuries) be preserved in a constante climate or even in a slightly varying climate, for instance in occupied rooms without air-conditioning.

For the time being the two systems cannot yet be used in archives. Once this is possible, this will mean at any rate an adaption to the new materials by the large archives which will take several decades. This will also mean a complete technical change-over of the archives which, however, would help to reduce the economic expenses for storage.

These possibilities just appear in outlines. They must be further observed and investigated and we may safely assume that one day they will be basis for new preservation techniques used in audiovisual archives.

Already now one should take into account that the settlement of this problem will sooner or later become imperative.