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Archiver et communiquer l'image et le son :

les enjeux du 3ème millénaire

Image and Sound Archiving and Access :

the challenges of the 3rd Millennium

CST

CNC

Sous la direction de Michelle Aubert et Richard Billeaud :

ARCHIVER ET COMMUNIQUER L'IMAGE ET LE SON : LES ENJEUX DU 3ème MILLENAIRE

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III LES SYSTÈMES DE GESTION DE L'INFORMATION ET LES STRATÉGIES DE MIGRATION DATA MANAGEMENT SYSTEMS AND MIGRATION STRATEGIES 212

Discours d'ouverture du JTS

Jean-Pierre Hoss, Directeur général du CNC

Mesdames et Messieurs, je suis très heureux de vous accueillir à la 5ème édition du Symposium technique mixte qui se tient, pour la première fois, à Paris.

On m'avait assuré que cette manifestation scientifique et technique serait internationale. Ceci est confirmé puisque vous représentez 42 pays du monde.

A l'aube de ce nouveau millénaire, les questions techniques associées à l'archivage de l'image et du son prennent un nouveau tournant. L'option numérique est incontournable même si la conservation des supports originaux demeure la préoccupation majeure des archives. Cette préoccupation sera évoquée dans la première partie du symposium sous le titre « L'appréciation des risques dans la conservation de l'image et du son ».
L'option numérique est désormais un fait dans tous les plans de transfert de masse des documents. Les stratégies de ces plans et les logiciels utilisés pour traiter les documents endommagés font de plus en plus l'objet de projets communs et des exemples européens vous seront présentés en deuxième partie.
La dernière partie de ce symposium aborde les enjeux communs de la conservation et de la communication. A l'avenir, la valeur d'archive d'une œuvre ou d'un programme n'apparaîtra plus au terme de la production mais elle sera formulée dès la conception de l'œuvre ou du programme.

Ce symposium a été conçu pour susciter le débat et l'échange. Il a été préparé avec le soutien des trois institutions patrimoniales françaises du Ministère de la culture et de la communication qui ont pour responsabilité première d'archiver l'image et le son et d'en gérer les dépôts légaux : la Bibliothèque nationale de France, l'Institut national de l'audiovisuel et le Centre national de la cinématographie. Toutes trois ont lancé des programmes accélérés de transfert et de restauration des supports détériorés de leurs collections. Elles partagent aujourd'hui, les mêmes préoccupations d'une communication élargie des documents archivés.

Les diverses interventions programmées me permettent d'apprécier la complexité des problèmes techniques que vous allez aborder. J'espère que vos échanges seront fructueux et concrets, que les recherches entreprises dans différentes institutions et pays seront encore mieux partagées. Les actes de ce Symposium et les comptes rendus de vos discussions seront édités prochainement et vos travaux rendus accessibles à ceux qui n'ont pas eu la possibilité d'être parmi nous.

Au nom du CNC et de la Commission supérieure technique, je vous remercie de votre présence. Je remercie également les nombreuses organisations européennes et internationales qui ont contribué au programme ainsi que les présidents des différentes commissions techniques qui ont assuré le relais auprès des intervenants et bien entendu, l'Unesco à qui revient l'initiative de ce symposium et qui en assure la permanence.

I

APPRECIATION DES RISQUES DANS LA CONSERVATION DES IMAGES ET DES SONS

RISK ASSESSMENT IN THE PRESERVATION OF IMAGE AND SOUND MATERIALS

Modérateur / Moderator : Bruno Despas, directeur général de Centrimage

Bruno DESPAS

Bonjour mesdames, bonjour mesdemoiselles, bonjour messieurs, bienvenue à cette première session du cinquième JTS qui sera consacrée à l'appréciation des risques dans la conservation des images et des sons. La question de la pérennité des supports utilisés pour l'établissement des éléments de conservation des images et des sons se pose avec de plus en plus d'acuité depuis une vingtaine d'années, et plus précisément depuis la découverte du syndrome du vinaigre qui affecte les films à support en triacétate de cellulose. Contrôler les processus de décomposition des supports, maîtriser les conditions optimales de conservation, en particulier dans les grandes archives, tel est le thème de cette première session. Nous aurons l'occasion d'écouter cinq intervenants, qui comptent parmi les meilleurs spécialistes mondiaux de la question, qui nous apporteront leur lumière et nous feront part de leurs expériences sur ce sujet.

D'un point de vue pratique, cette session durera jusqu'à 12 heures 30. Vous aurez une dizaine de minutes après chaque intervention pour poser quelques questions aux intervenants. La dernière demi-heure de la matinée sera consacrée à une synthèse des interventions de la session. Vous pourrez aussi poser des questions à ce moment-là. Je vous proposerai une pause café aux alentours de 11 heures. Je demanderai instamment aux intervenants de bien vouloir respecter le temps qui leur est imparti, à savoir une vingtaine de minutes, de façon à ce que chacun puisse disposer d'un temps de parole équivalent et que nous respections le programme prévu par les organisateurs de ce JTS.

Le premier intervenant est Jean-Louis Bigourdan, qui nous fera un exposé sur les données expérimentales sur l'efficacité des conditions de conservation pour lutter contre le syndrome du vinaigre. Jean-Louis Bigourdan est chercheur à l'Image Permanence Institute du Rochester Institute of Technology. Il est membre de l'AMIA. Il est spécialiste de chimie, photographie et conservation des éléments photographiques. Il est diplômé de l'Ecole nationale de photographie d'Arles et de l'Institut français de restauration des œuvres d'art. A l'IPI, Jean-Louis Bigourdan a mené des recherches sur la stabilité des films photographiques. Il étudie actuellement les effets des modifications de l'environnement sur la stabilité des matériaux utilisés pour l'enregistrement de l'information.

Effectiveness of storage conditions in controlling the vinegar syndrome: preservation strategies for acetate base motion-picture film collections

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Introduction

Since the evolution of the entertainment industry in the nineteen thirties, the recognition of the cultural value of motion-picture films and the increasing use of photographic film as an archival information-recording medium have stimulated interest in film permanence.[1] Despite the fact that major problems were recognized early on, and that extensive knowledge of film stability has been gained during the past two decades, the preservation of moving images on photographic film is still a major concern today.[2,3] The current challenge for the archival community, however, is not to further understand the film degradation process but rather to formulate practical preservation strategies for film collections.

Photographic film is susceptible to various types of degradation which can be grouped into three major categories: physical, biological, and chemical. Since its beginnings, the technology of photographic film has evolved continuously, and much has been learned about film stability. Nevertheless, photographic film continues to be threatened by the spontaneous chemical decay of its major components, most notably the plastic base and color dyes. Consequently, the control of chemical degradation is a vital challenge for film archivists. They periodically face practical dilemmas regarding climate assessment, enclosure choice, and, more recently, the use of either micro- or macroenvironmental control. The decisions they make may impact the useful life span of film collections in significant ways.

There has been evidence of vinegar syndrome in photographic collections around the world for several decades. The recent availability of tools for surveying acetate film collections may lead to an even darker picture of the extent of vinegar syndrome in film archives. Knowing the magnitude of the problem is fundamental to taking the most efficient steps to preserve our film heritage. In addition, several large-scale research programs have been conducted during the last decade, leading to new strategic approaches to film preservation.

The purpose of this paper is threefold. It will report recent findings on the effectiveness of practical storage situations involving the use of microenvironments. It will suggest a preservation approach for film archivists based on the recognized role of storage conditions in controlling film stability. Finally, it will describe the use of a simple survey tool such as acid-detector strips in assessing the extent of vinegar syndrome in acetate base film collections. The ultimate goal is to define the key points involved in the control of chemical decay in film collections. One of the unique features of this investigation is that recommendations are based on studies lasting up to five years at room temperature. The quality of the storage environment, the state of preservation of acetate film collections, and the required longevity of the film materials are considered to be the major determining factors in implementing a rational preservation strategy.

Background information and data developed at the Image Permanence Institute (IPI) under a research grant entitled *Environment and Enclosures in Film Preservation*[4] funded by the National Endowment for the Humanities are reported. A-D Strips, acid-detector strips designed by IPI as a survey tool for acetate film collections are discussed.

Chemical Stability of Acetate Film Base

Cellulose triacetate (CTA) film base, first introduced in 1948,[5] marked a major advance over cellulose nitrate film base because of its lower flammability. Although its poor chemical stability was not recognized at the time, it has since become a major threat for film collections. The spontaneous chemical decay of CTA film base leads to the deacetylation and chain scission of the polymer. At or near room temperature conditions, significant acetate degradation may occur within three to four decades, or even less if storage conditions are adverse. Polyester film base, first introduced in 1955[6,7] and increasingly used today, provides a significantly more stable film support.[8,9]

The importance of chemical stability prompted an early comparative study of nitrate and acetate film supports using accelerated aging.[10] Over the years, a predictive approach was developed through further studies of the stability of cellulose acetate film base and polyester film base.[8,9] During the past fifteen years, the recognized chemical instability of CTA film base has prompted a number of investigations worldwide. These studies have focused on the impact of either intrinsic factors (e.g., composition and nature of the plastic) or extrinsic factors (e.g., climate conditions and enclosures). The contribution of such intrinsic factors as gelatin, subbing layer (containing traces of cellulose nitrate), and plasticizers has been addressed in several papers.[11,12,13,14,15,16]

The generation of acid has been identified as the first and most sensitive indicator of acetate degradation.[15] This characteristic has made possible the development of a monitoring method for acetate stability studies[17] and has led to the creation of film collection survey tools such as acid detectors. The literature has discussed the degradation mechanism of CTA film base and has emphasized the importance of the autocatalytic mechanism.[18,19,20] Acetic acid, a byproduct of deacetylation, catalyzes further decay of the polymer. The consequences are illustrated in Figure 1, which reflects the rate of degradation of acetate base. The acidity increase faithfully mirrors the advance of chemical decay. This phenomenon is illustrated by the two portions of the curve: (1) an induction period, and (2) a period of fast change beyond the so-called autocatalytic point. Based on this representation, it can be said that the internal acidity level of the film determines the degree of risk that film will become unusable because of shrinkage, physical deformation, or plasticizer exudation. Subsequent large-scale studies have quantified the relationship between climate conditions—i.e., temperature and relative humidity (RH)—and the chemical stability of cellulose acetate film base.[21,22,23] These findings suggest two basic principles for preserving acetate film base:

1. Proper climate control leads to significant improvement in chemical stability. Lower temperatures and dryer conditions slow the degradation rate.
2. Acetate base film that has already started to degrade decays further at an ever-faster rate. The stabilization of decaying film requires improved climate conditions.
3. The removal of acetic acid vapors, a degradation byproduct, retards further degradation by reducing the autocatalytic effect and also limits the risk of infectious behavior.[23,24]

Fifty years after the introduction of CTA film base, partially degraded film is common in a large number of film archives; therefore, all three of these principles are relevant to the articulation of a film preservation strategy.

Climate Control Options

The Macroenvironment

The macroenvironmental approach to film preservation assumes that materials are in equilibrium with the macroclimate. Ambient conditions affect the whole storage area and ultimately control the rate of chemical decay. The relationship between temperature and RH and the rate of chemical decay has been established for both fresh and degrading acetate film base and, more recently, for chromogenic dyes.[22,25] These data sets are of great importance because they provide a quantitative estimate of the impact of a wide range of temperatures, RHs, and their combinations on acetate base and dye stability. In practice, temperature and RH determine the life span of photographic film. Proper control of these two components can greatly improve the chemical stability of acetate base film and color materials. Although the effect of temperature and RH is synergistic, lower temperature provides the greater benefit. These conclusions have been integrated into the ANSI and ISO standard recommendations for storage of photographic film.[26,27] In addition, controlling the air quality in the storage area using adsorbing purification systems minimizes the risk of acid contamination from degrading acetate film.

Microenvironments

Enclosures are used to provide physical protection, but, in a sense, they also create "microenvironments" which may have a positive or negative impact on the stability of film base, primarily by either allowing some ventilation or trapping degradation byproducts. It was this fact that led to the design of vented cans in the 1990s. At constant temperature, the permanence of photographic material depends in large measure on the nature of the air immediately surrounding it. Therefore, the creation of controlled microenvironments in sealed enclosures may be a sound alternative for photographic film preservation. Moisture-controlled microclimates may be used in place of dehumidification equipment. Using an acid adsorbent to remove the acid catalyst from inside a sealed film can is another option.

Several microenvironmental approaches have been suggested in the literature, such as the use of desiccants[28,29] and the implementation of the FICA system proposed by the Swedish Film Institute, which combines the merits of establishing a low moisture content in the film with the benefits of cold temperatures.[30] More recently, Eastman Kodak Company introduced molecular sieves (zeolites) as an aid in controlling vinegar syndrome and dye fading.[31,32] The ability of such crystalline molecular "cages" to trap moisture and acetic acid vapor has prompted a renewed interest in microenvironmental approaches for the preservation of acetate film collections.

Enclosure and Microenvironment Study

Only a few studies have investigated the role of enclosures and microenvironmental alternatives. These studies addressed the potential detrimental effects of enclosure materials on acetate degradation.[12] Until now, considerations for enclosure design have been based on common sense (e.g., open housings promote acid vapor removal) or on experimental data obtained in exaggerated situations (e.g., high incubation temperatures or free-hung samples versus samples in sealed bags).[12,13,18,23] In recent years, data have been obtained which clarify the roles of enclosures and microclimates in minimizing further decay of acetate film base in sheet and roll formats.[4,31,33,34,35] Theoretically, enclosures and microclimates can impact on film stability in several different ways, including facilitating ventilation, neutralizing acid, adsorbing acid vapors, and reducing film moisture content. These are summarized in Table I.

The behavior of a variety of enclosures and microenvironments was investigated at IPI. Results have been presented in several reports.[4,34,35] This paper reports additional related data developed at IPI. The following sections describe the experimental procedure.

Experimental

Test Procedure

The experimental approach was aimed at quantifying the effectiveness of various housing situations in retarding further degradation of partially degraded CTA film in roll form. The film was brought to the point of onset of vinegar syndrome prior to the experimentation. Given this initial acidity level, it was possible to evaluate the effectiveness of acid ventilation, neutralization, and adsorption provided by a variety of storage configurations.

Measurements

Since acidity is the most sensitive indicator of acetate decay, the chemical degradation of the film was monitored by measuring film acidity. Film acidity values are expressed as milliliters of 0.1M NaOH. Brand-new film has an acidity value of about 0.05, while severely degraded film can reach 10.0 or more. The water-leaching method was used exclusively in this study.[17] Duplicate determinations were made at three locations along the length of a 100-foot roll (at 10, 50, and 90 feet).

Acid Diffusion Rate

A high diffusion rate is fundamental to the control of vinegar syndrome by means of catalyst removal. Figure 2 illustrates the impact of film configuration and winding tension on acid diffusion when degraded CTA film was exposed to 21°C, 50% RH. The film was pre-degraded prior to exposure in two formats: 7-inch strips and 100-foot rolls. Film A was tightly wound. Film B was loosely wound. The acid diffusion rate was significantly slower for the film rolls than for the strips for both Film A and Film B. Film A in roll form did not display significant acidity loss after three months of exposure. During the same period of time, the acid content in the Film B roll decreased; it took almost six months, however, for the acidity to reach the level of 0.1, despite the fact that the film was loosely wound and not in an enclosure. These data indicated that the tension applied during the preparation of the rolls altered the acid diffusion rate. This supports the following observations:

1. The slow rate of acid diffusion might limit the benefit of any housing situation.
2. Since acid diffusion is a limiting factor and is very temperature-dependent, the incubation temperature used for microenvironment studies should be as close as possible to room temperature to reflect real-life situations. For this reason, temperatures between 21°C and 40°C were chosen for the study. The importance of this condition was discussed in an earlier paper.[34]
3. Film rolls used for enclosure and microenvironment studies must be wound at a moderate and constant tension.

Microenvironments

Microenvironments were created in sealed metal cans for the purpose of the study. Three basic effects were evaluated: (1) moisture control through use of a desiccant or through moisture pre-conditioning, (2) acid removal through addition of an acid scavenger, and (3) acid neutralization through the introduction of buffered cardboard disks. Activated silica gel grade 43 was used for its moisture adsorption property. Molecular sieves provided by Eastman Kodak Company were used for their ability to adsorb both moisture and acetic acid vapors. Cardboard disks containing calcium carbonate were included to evaluate the way in which buffering contributes to the neutralization of acid vapors.

Results

Effects of Enclosures

The impact of various enclosures was studied by placing 100-foot pre-degraded CTA film rolls in several types of housing. The behavior of enclosure materials (tin-plated steel cans, polypropylene boxes, and boxes made from cardboard containing 5 wt % calcium carbonate) and of different system designs (open versus closed or sealed) was studied. Figure 3 illustrates the acidity of 100-foot rolls kept in various enclosures for one year at 40°C, 50% RH. Significant acidity increases were observed inside unsealed metal cans and unsealed plastic microfilm boxes. Open systems (metal cans without lids, drilled plastic boxes, and buffered cardboard boxes) showed lower acidity levels. Previous data indicated that the lower acidity in the cardboard boxes could be attributed to the porosity of the material rather than to the alkaline buffer in the cardboard.[34] These results demonstrate that tight enclosures have a greater detrimental effect than open ones. However, it was not known if the "ventilation effect" would have a significant role at lower temperatures. This was investigated in a repeat experiment conducted at room temperature for three years.

Figure 4 reports acidity changes in pre-degraded 100-foot film rolls kept at 21°C in various enclosures. Because acidity increase is small at this temperature, each acidity level was corrected by subtracting the initial acidity value of the individual rolls. There was a significant acidity increase inside sealed containers (taped metal cans and taped plastic boxes), while open systems (metal cans without lids, cardboard boxes) showed lower acidity levels. Drilled plastic boxes minimized acidity increase in the film, though to a smaller degree than the open systems. These data confirm the detrimental effect of sealed containers at room temperature. It should be noted that open enclosures did not *lower* the acid content of partially degraded film after three years of storage. These results prompted several observations:

1. Tight enclosures have a detrimental effect on the stability of film that has already started to degrade. This behavior was observed in sealed cans, even at room temperature.
2. At 21°C, pre-degraded film stored in sealed metal cans and sealed polypropylene boxes decayed further at a similar rate.
3. Open enclosures did slow further decay but did not lower the acid content of degraded film to acceptable levels after three years of storage. Enclosures do not provide a definitive method for controlling vinegar syndrome but are a secondary factor.
4. Further decay of partially degraded acetate film base occurs at room conditions. Acidity changes achieved in sealed enclosures through natural aging at 21°C agree with earlier predictions based on accelerated aging. This finding increases the degree of confidence in previously published conclusions regarding the relationship between climate conditions and degradation rate.[22]

EFFECTS OF MICROENVIRONMENTS

There are four approaches that are based on the possible benefits of microenvironments. They are: (1) moisture control by pre-conditioning the film at a low RH; (2) moisture control through the addition of activated silica gel; (3) moisture control and acid adsorption through the use of zeolites; and (4) acid adsorption and acid neutralization through the use of buffered cardboard disks in sealed containers.

For the study, CTA film in 100-foot rolls was pre-conditioned at 50%, 35%, and 20% RH at 21°C and enclosed in sealed metal cans. Film rolls were also pre-conditioned to 21°C, 50% RH prior to being sealed in metal cans with activated silica gel, molecular sieves, or buffered cardboard disks. The rate of degradation was monitored by acidity determination for each pull time. The film rolls were incubated for three years at 35°C. Another series of rolls have been stored for four and a half years.

Study at 35°C

Figure 5 illustrates the effect of moisture pre-conditioning on the stability of degrading CTA film. Comparison of the acidity changes curve with the control curve (i.e., film conditioned to 21°C, 50% RH) shows the marked benefit of low RH pre-conditioning. Figure 6 illustrates the benefit obtained by the addition of activated silica gel (3.6 wt %) and zeolites (2.5 and 5 wt %—approximately the recommended level and twice the recommended level, respectively). Both materials benefited film stability at 35°C. Increasing the percentage of zeolites had a marked impact.

It is of particular interest that two distinct approaches—moisture pre-conditioning at 21°C, 20% RH and addition of 5 wt % zeolites—lead to a similar degree of stability improvement. The moisture pre-conditioning procedure reduces only the moisture content of the film; molecular sieves act as both desiccant and acid scavenger. The benefits of these two mechanisms have been previously assessed and discussed.[34] Zeolites alter the rate of acetate degradation by adsorbing both moisture and acid vapors. The moisture adsorption property of zeolites is recognized as the main factor in retarding further chemical decay of the acetate base.

Study at 21°C

Repeat experimentation at room temperature confirmed that storing film with zeolites, with activated silica gel, or after low RH pre-conditioning retards further chemical decay. Figure 7 reports data obtained at room temperature using zeolites or activated silica gel in sealed cans. Using either zeolites or silica gel retarded futher decay of the film. Increasing the percentage of adsorbents increased the benefits. Pre-degraded film rolls stored with 5 wt % zeolites did not display any acidity increase, while the acidity of pre-degraded film stored without adsorbents displayed more than twice the initial acidity level after the same period. It should be noted, however, that the use of zeolites did not reduce the initial acid content in film. Figure 8 indicates the beneficial effect of low moisture pre-conditioning observed at room temperature. These results confirmed previous data obtained at 35°C (Figure 5).

The use of cardboard disks (containing calcium carbonate or calcium carbonate and zeolites) was also investigated. Previously reported data obtained at 40°C indicated a detrimental effect caused by the introduction of additional moisture into the container by the cardboard disks.[34] Repeat experimentation conducted at room temperature using buffered cardboard disks in sealed cans did not support any significant benefit to film stability (Figure 9). Therefore, the use of cardboard disks is not recommended.

Data obtained at room temperature (Figures 4, 7, and 8) indicated that controlled sealed microclimates using either 5 wt % molecular sieves or moisture pre-conditioning at 21°C, 20% RH are slightly more beneficial than open enclosures at 21°C 50% RH.

COMPARISON OF MICROCLIMATES TO MACROCLIMATES

Archivists must consider the relative merits of the macroenvironment approach versus the microenvironment approach. The former has equipment and operating costs, while the latter involves significant material and labor costs.

Based on the information obtained at 35°C shown in Figures 5 and 6, the respective merits of various microclimates can be quantified. Once film reaches the autocatalytic stage of vinegar syndrome (an acidity level of 0.5 or higher), the rate of chemical decay is significantly faster. As a result, film may become unusable within a short period of time. For this reason, an acidity level of 1.0 has been chosen as a relevant end point. However, previous studies have indicated that even at this stage of decay the physical properties of the acetate film base were not significantly altered. Film is still usable for a period of time that is ultimately dependent on the storage conditions. Table II reports, for each microenvironment investigated, the time required for an initially pre-degraded CTA film to double its acid content (an increase from 0.5 to 1). At 35°C, microclimates created by using 5 wt % molecular sieves or by moisture pre-conditioning at 21°C, 20% RH increase the life of the film by a factor of 3 to 3.5 as compared to the control film pre-conditioned at 21°C, 50% RH.

An earlier study quantified the benefits of macroclimate control on film stability, based on data obtained under accelerated conditions and using the Arrhenius method.[21] Table III reports a few of the predictions taken from that study, the results of which were published in the *IPI Storage Guide for Acetate Film*.[22] These data indicate the factor of improvement obtained by lowering the temperature, lowering the RH, or lowering both parameters. The comparison of the effects achievable using either microclimate or macroclimate options led to the following conclusions:

1. The earlier Arrhenius study predicted that an improvement factor of 3 can be gained by lowering the RH from 50% to 20% at 35°C. More recent data verified that pre-conditioning the film at 20% RH leads to a similar improvement in film stability. This increases the degree of confidence in earlier predictions.
2. The improvements that can be achieved with microenvironments can also be achieved by lowering the temperature and/or lowering the RH. (As the experiments showed, there are three ways to increase the film stability by a factor of 3: addition of 5 wt % zeolites, lowering the RH from 50% to 20%, or lowering the temperature from 35° to 25°C.)
3. Microenvironments created by using adsorbents or moisture pre-conditioning can provide a benefit of the same magnitude as that provided by low macroenvironmental RH. The benefit provided by microclimates, like that of low RH, is added to the benefit gained from storage at low temperatures.
4. Most importantly, the benefit of low-temperature storage far exceeds that of either microenvironments or low macroenvironmental RH. Table III illustrates the great potential improvement provided by cold temperature.

Preservation Strategies

The data reported above indicate that open enclosures or sealed microenvironments alone are of less benefit than the macroenvironmental approach using low temperatures. Therefore, the priorities for photographic film storage are clearly defined. Colder temperatures and low RH have been consistently recommended. Almost thirty years after the pioneering paper by P. Z. Adelstein, et al.,[36] recent film stability studies have reinforced the need for cold storage for long-term preservation. Long-term preservation of both new and old film materials requires a climate that is colder than room temperature. This is even more critical if the film is already beginning to degrade.

Monitoring the Extent of Vinegar Syndrome

The potential benefits of the microenvironmental and macroenvironmental approaches discussed in the previous sections depend upon the current condition of the film. A film in an advanced state of decay, i.e., with an acidity level beyond the autocatalytic point (see Figure 1), requires better storage conditions than a non-degraded film to have the same given life span. As degradation progresses, the rate of chemical decay increases, and better storage is needed to further postpone the time at which the material becomes unusable. In addition, contamination of non-degraded film by degradation byproducts (e.g., acetic acid vapors) has been demonstrated in earlier studies.[23,24] This phenomenon has prompted recommendations for either segregation of degrading acetate base film or removal of degradation byproducts in order to avoid contamination. These behaviors emphasize the importance of evaluating the current film condition prior to implementing a preservation plan.

In practice, several actions may be undertaken to extend the life span of degrading acetate base film and to minimize the risk of contamination. Improvement of the macroclimate conditions, segregation of degrading films, implementation of microenvironments using adsorbents, control of air quality using an air-filtration system in the storage area, and duplication are among the options available for film preservation management. Therefore, monitoring the extent of vinegar syndrome is essential for recognizing the problem at its early stages and choosing the option that best fits the situation. Knowing the collection's state of preservation makes it possible to bring about suitable improvements in the storage conditions and to prioritize the duplication of films in an advanced state of decay before they become unusable. Continuous monitoring of film collections for signs of vinegar syndrome recently has been recommended by the European Broadcast Union in their document entitled *EBU Technical Recommendation*,[37] which deals with motion-picture film storage conditions.

The generation of acid is the first and most sensitive indicator of acetate base degradation. Acidity determination methods have been extensively used in laboratory research into film stability. Several diagnostic tools for use in film archives have been developed (e.g., Film Decay Detector Sensor®, Dancan's Danchek®, IPI's A-D Strips). These tools employ various acid-base indicators that change color when exposed to acid vapors.[38,39] These monitors vary in response time, color scale, interpretation, and uses. This paper does not compare these products but focuses on the use of A-D Strips.

A-D Strips are paper strips coated with an acid-base indicator (bromocresol green) in combination with sodium hydroxide. In practice, a strip is placed with film in a confined environment (e.g., inside a film can). After exposure, the strip's color shift is evaluated using a color-reference scale. Depending on the film condition, the color of the strip may shift from blue (its original color) to green or yellow. These color changes reflect the acid content of the film, i.e., its state of preservation. The strips are calibrated to differentiate four levels: level 0 (no deterioration or 0 to 0.1 acidity), level 1 (deterioration starting or a level of 0.2 acidity), level 2 (advanced deterioration or level of about 1 acidity), and level 3 (critical state or an acidity level equal or greater than 2). In a study done at IPI, determinations performed by various evaluators indicated that A-D Strip level readings may vary by half a level depending on the color perception of each evaluator. Half-level errors are not large enough to cause an archivist to miss the important landmarks in the progress of film decay nor to draw incorrect conclusions concerning the need for improved storage conditions or film duplication. At room conditions, 24 hours is the recommended minimum exposure time to achieve an accurate evaluation. Exposures of a few days to several weeks can be used when needed. Testing at low temperatures and low RH requires longer exposures prior to evaluation. Tests performed at near-freezing temperatures and low RH have indicated that minimum exposure for low temperatures should be extended (e.g., two weeks at 2°C). Further recommendations regarding the use of A-D Strips under various climate conditions will be provided in a revised edition of the *User's Guide for A-D Strips*, the instruction booklet that is packaged with the product.

A-D Strips are specifically designed and calibrated to be a semi-quantitative measure of internal film acidity, and therefore they provide a means not only of detecting the vinegar syndrome in its early stages, but also of determining the state of preservation of the film in a collection. Is the film approaching the autocatalytic point? Has it reached that point or passed it? This information is essential for decision-making about how to preserve the film from now on. Prior to the autocatalytic point, the decay rate is slow. Beyond that point, the rate of deterioration increases greatly, and *action* should be taken to ensure a long life for the film. Together, A-D Strips and the *IPI Storage Guide for Acetate Film* supply the information necessary for obtaining a realistic prediction of film life expectancy, namely, the film's current state of decay and the effect of storage conditions on decay rate. It can be determined, for example, that a film roll that has degraded to the autocatalytic point (half way between levels 1 and 2, i.e., an internal acidity of 0.5) might reach an advanced state of decay (level 2) within a few years, if kept at room conditions. Acetate film collections that have already started to decay may still last for a long period of time if stored at optimum environmental conditions. By reducing the storage temperature from room conditions to 4°C at 50% RH, the life span of acetate base film that has already degraded to the autocatalytic point would be extended by a factor of ten. Moreover, films found to be actively degrading may be earmarked for duplication.

There is now hard evidence that decaying films kept at room temperature will continue to decay at an unacceptable rate. Storage at cold temperatures will stabilize these decaying films, as clearly demonstrated by the results reported in Table IV. After five years, the acidity of film kept at room temperature increased by a factor of 2 to 3. During the same period of time, the acidity of film kept at subfreezing temperatures did not display any significant change. This information is of great practical importance.

An item-by-item evaluation using acid-detectors can identify actively degrading films (i.e. from level 2 to level 3). Such materials should be stored in cold or freezing temperatures while awaiting duplication. Depending on the size of the collection, there are three recommended options:

1. For small collections, it may be practical to store actively degrading films in a separate refrigerated space.
2. A portion of a larger collection could be isolated in individual sealed containers with adsorbents and stored at cold temperature.
3. Institutions with large collections may choose to provide cold temperatures and air-quality control to the entire holdings, thus improving the overall quality of the storage environment and minimizing the risk of contamination by removing degradation byproducts from the air.

Key Points in Implementing a Preservation Strategy

It is well established that preservation of photographic film is much more cost-effective than restoration, and frequently restoration is not possible. The only way to protect film from chemical decay is control of storage conditions. This can be accomplished by control of either the macroenvironment or the microenvironment. A film archivist must decide which approach is the most suitable for the institution, with respect to equipment expenditure, maintenance, accessibility and labor cost.

Macroenvironmental control has much greater potential for stability improvement if low temperatures are employed. Maximum longevity is obtained through the use of cold storage at subfreezing temperatures. This option maximizes the benefit of climate control on film base and chromogenic dye stability. The macroenvironmental approach using low temperatures can extend the useful life of acetate base film by a factor of one hundred even for film that has already started to degrade. This approach is recommended to preserve either old or new film materials.

At room temperature, tight enclosures have a detrimental effect on film stability. However, open enclosures do not significantly reduce the acid content of decaying acetate base film. Enclosures do not provide a definitive method of vinegar syndrome control.

The microenvironmental approach utilizes sealed containers. Using activated silica gel, molecular sieves, or low pre-conditioning RH can extend the longevity of film by a factor of three to four. The benefit provided by microenvironments, like that of low RH, is added to the benefit of storage at low temperatures.

Monitoring the extent of vinegar syndrome throughout the collections is believed to be an essential part of a proactive preservation strategy. Acid-detectors provide a simple way to identify degrading materials and evaluate the state of preservation of acetate film collections. With this information it is possible to estimate the remaining life span of film, and subsequently (1) to determine the required improvement in terms of storage conditions, and (2) to prioritize duplication of film in an advanced state of decay.

Risk of contamination may be addressed either by segregating actively degrading films or by controlling the concentration of acidic vapors in the air. Cold storage is the only alternative for stabilizing actively decaying acetate film base prior to duplication.

Acknowledgements

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Table I: Potential functions of unsealed enclosures and microenvironments in sealed cans.

Functions	Unsealed Enclosures	Microenvironments in Sealed Cans
Reduce moisture content	No effect	Addition of desiccants (zeolites, activated silica gel), or initial moisture pre-conditioning
Facilitate ventilation	Vented enclosures or porous enclosure material	No effect
Neutralize acid	Enclosure material containing alkali fillers (e.g., calcium carbonate)	Addition of cardboard disks containing alkali fillers (e.g., calcium carbonate)
Adsorb acid	Enclosure material containing acid adsorbents (e.g., zeolites)	Addition of acid adsorbents (e.g., zeolites)

Table II: Approximate time required at 35°C to increase the acidity of 100-foot pre-degraded CTA film rolls from 0.5 to 1 and time factor of improvement for various microenvironments.

Microenvironments in Sealed Cans	Time (Months)	Time Factor
Film conditioned to 21°C, 50% RH (control sample)	7	1
Film conditioned to 21°C, 35% RH	11.5	1.5
Film conditioned to 21°C, 50% RH with 2.5 wt % molecular sieves	10	1.5
Film conditioned to 21°C, 50% RH with 3.6 wt % activated silica gel	10	1.5
Film conditioned to 21°C, 50% RH with 5 wt % molecular sieves	21	3
Film conditioned to 21°C, 20% RH	25	3.5

Table III: Benefit of macroenvironmental control. Effect of temperature and relative humidity on further CTA chemical decay from acidity of 0.5 to 1.0. Predictions based on accelerated aging.[22] Approximate time factor of improvement versus temperature and RH.

Temperature	Time Factor at 50% RH	Time Factor at 20% RH
35°C	1	3
25°C	3	15
15°C	10	45
5°C	45	200
-1°C	110	540

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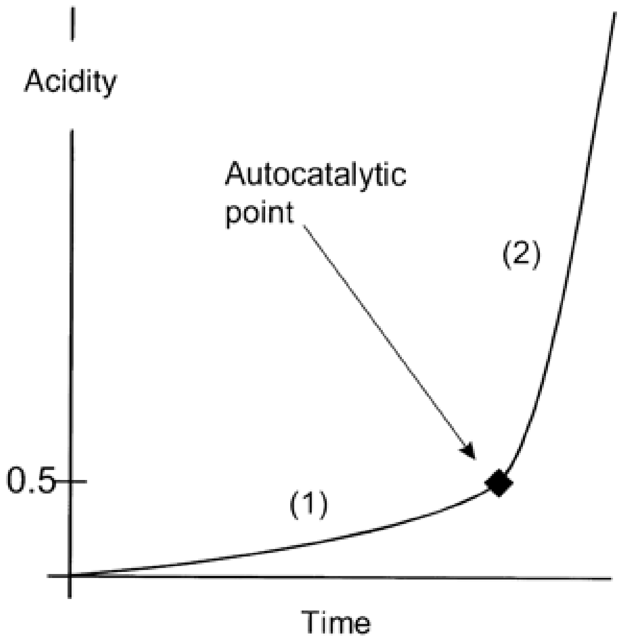
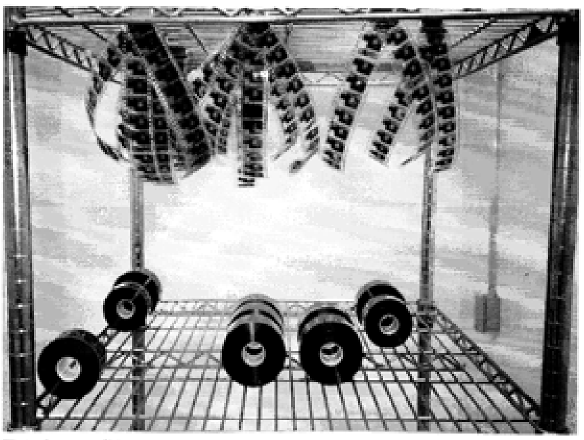
Figure 1: Free acidity change versus time for





Pre-degraded CTA base film exposed to 21°C 50% RH in two formats : roll and strip

Figure 2: Acidity of degraded CTA film exposed to 21°C, 50% RH in two formats (100-foot roll and 7-inch strip). Film A was tightly wound. Film B was loosely wound. Film samples were exposed without enclosures.

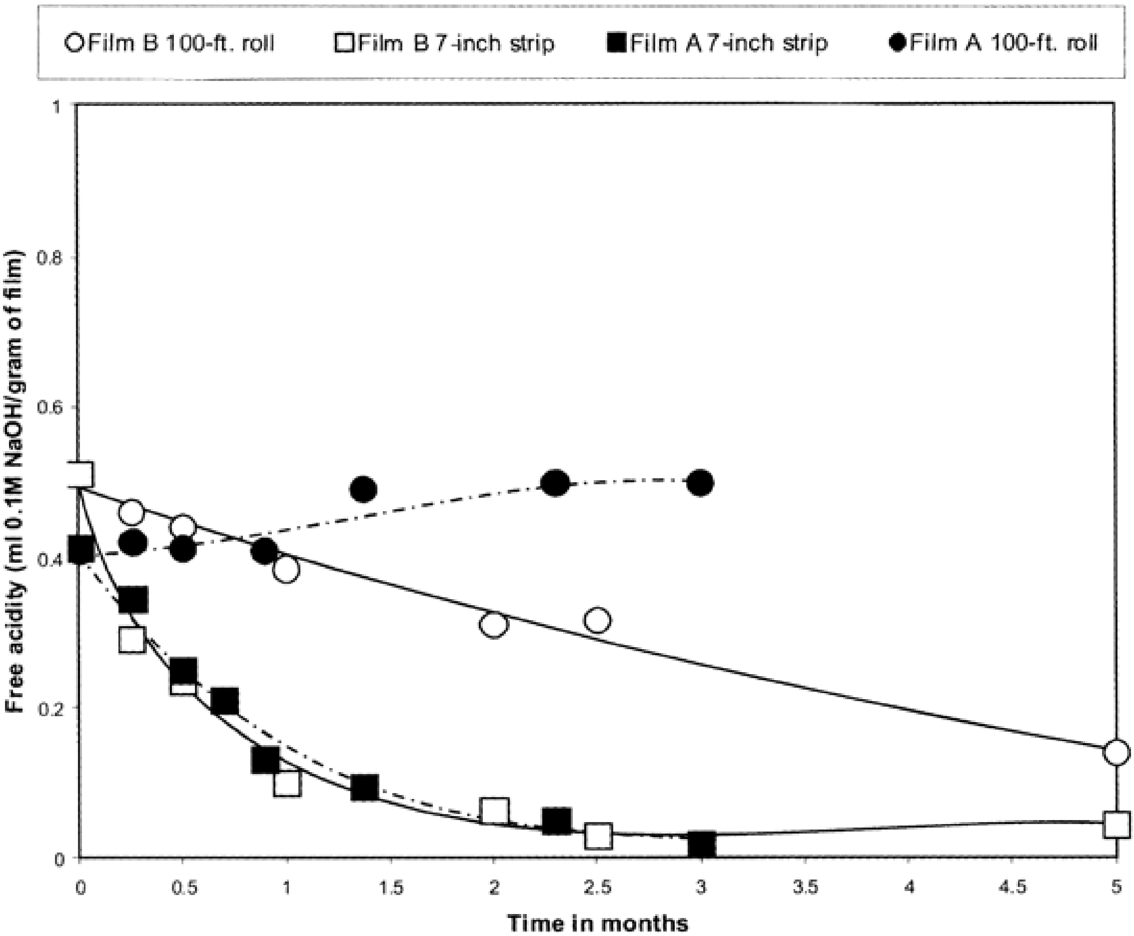


Figure 3: Acidity for 100-foot rolls of pre-degraded CTA film incubated at 40°C, 50% RH in various enclosures. Film initially conditioned to 21°C, 50% RH.

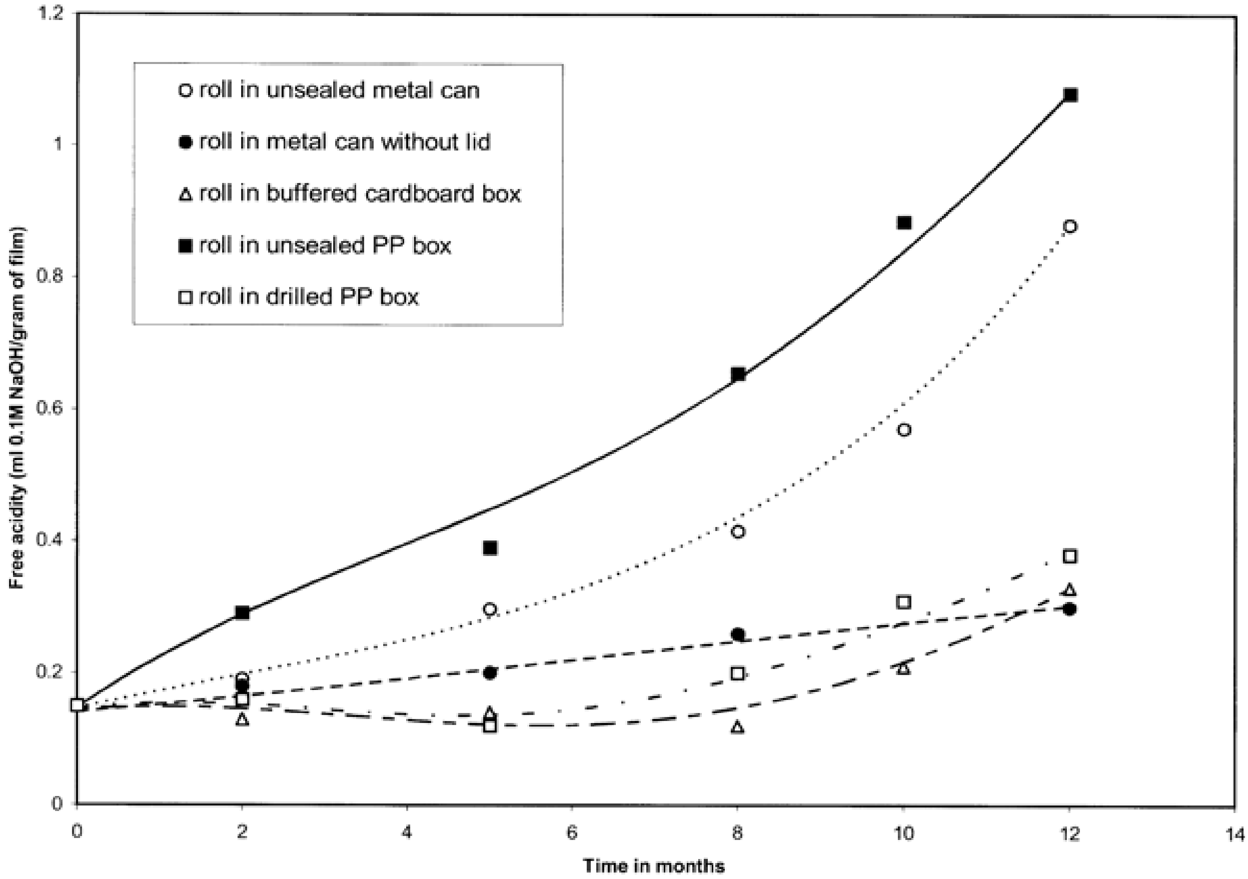


Figure 4: Effect of enclosures at room temperature. Acidity change for 100-foot rolls of pre-degraded CTA film stored at 21°C, 50% RH. Initial film acidity 0.4 to 0.6. Film initially conditioned to 21°C, 50% RH.

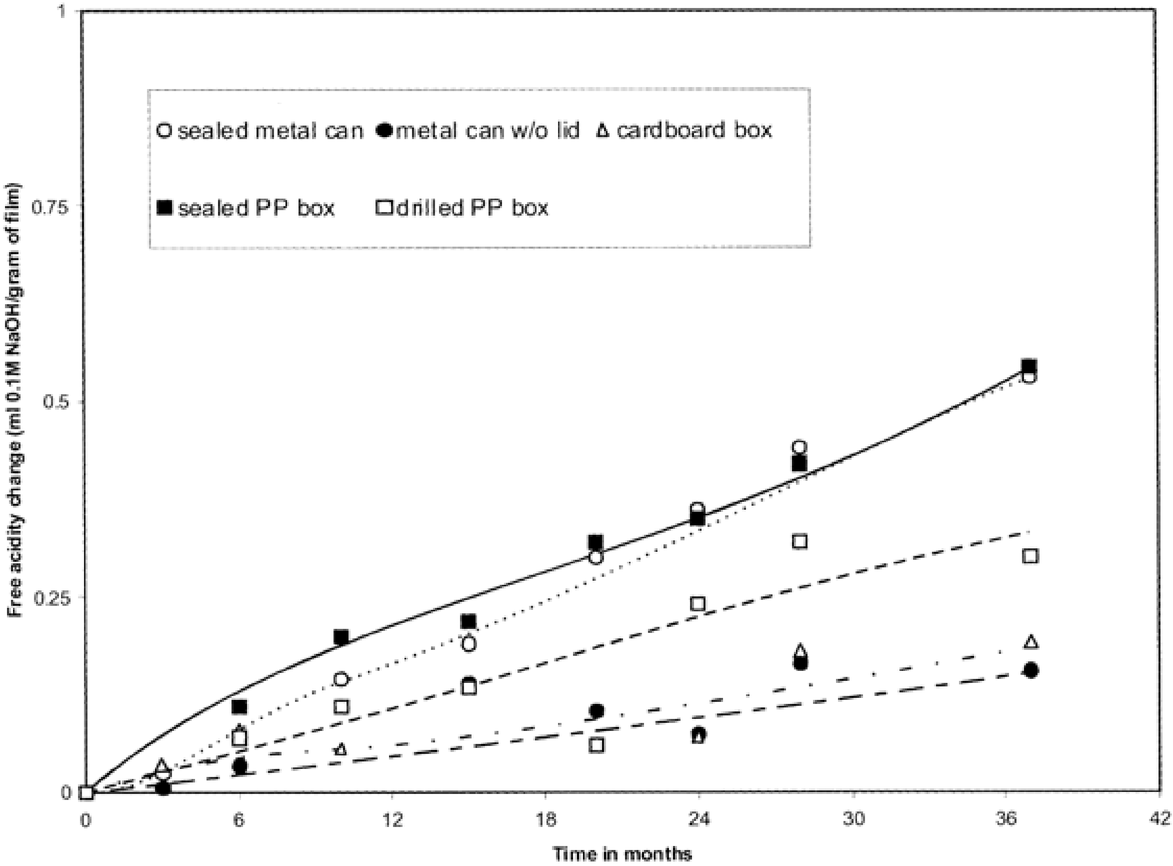


Figure 5: Effect of moisture pre-conditioning. Acidity for 100-foot rolls of pre-degraded CTA film incubated at 35°C in sealed cans. Film initially conditioned to 50%, 35%, and 20% RH at 21°C.

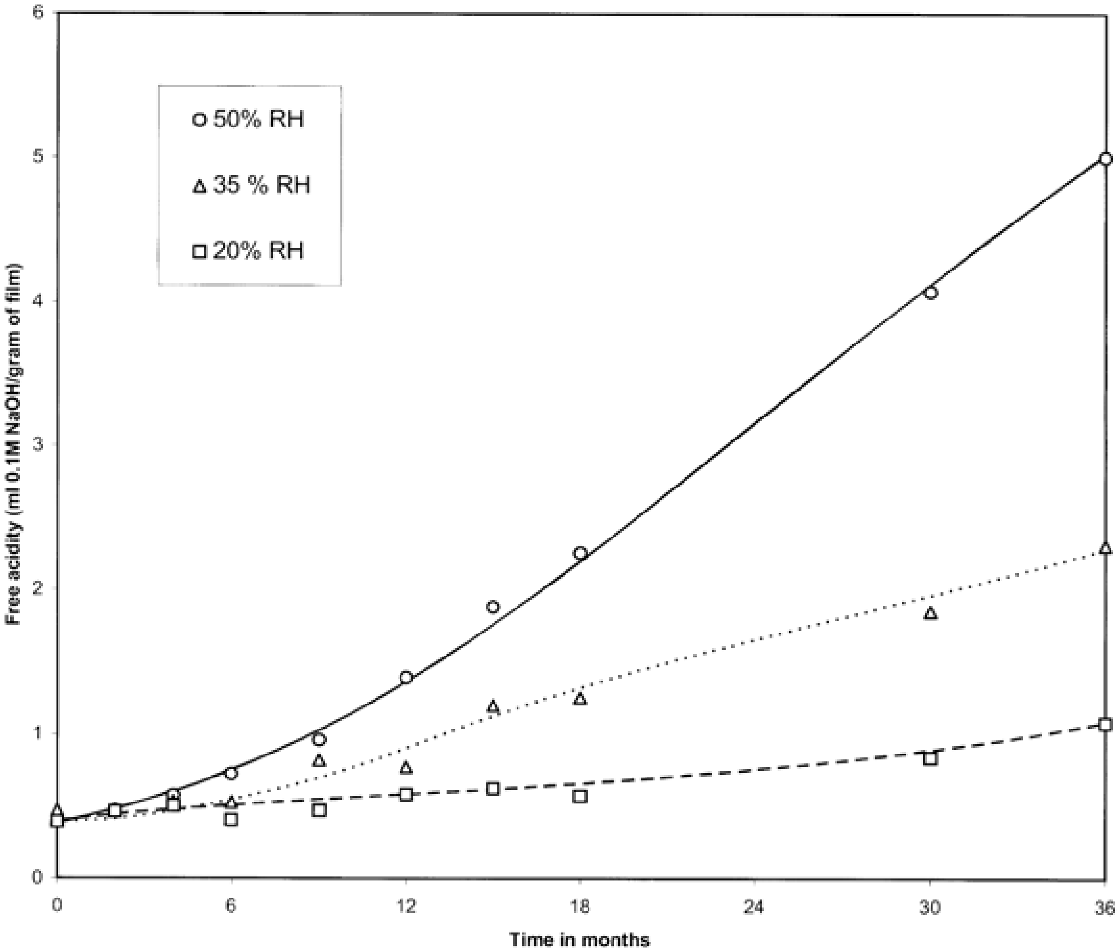


Figure 6: Effect of adsorbents. Acidity of 100-foot CTA film rolls incubated at 35°C in sealed cans with zeolites or activated silica gel or after moisture conditioning at 21°C, 20% RH. Film conditioned to 21°C, 50% RH prior to addition of adsorbents.

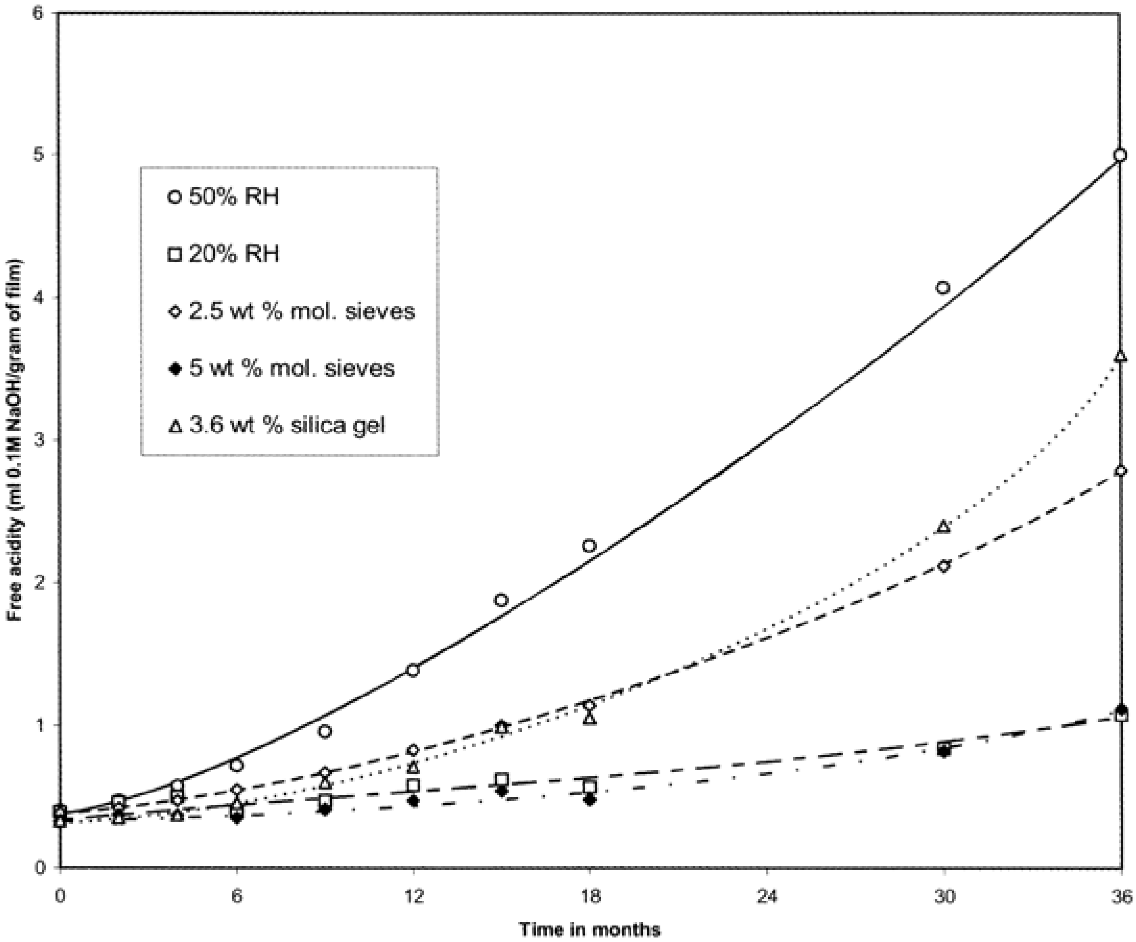


Figure 7: Effect of adsorbents at 21°C. Acidity change of 100-foot CTA film rolls stored in sealed cans with molecular sieves or activated silica gel. Film initially conditioned to 21°C, 50% RH prior to addition of adsorbents. Film's initial acidity: 0.4.

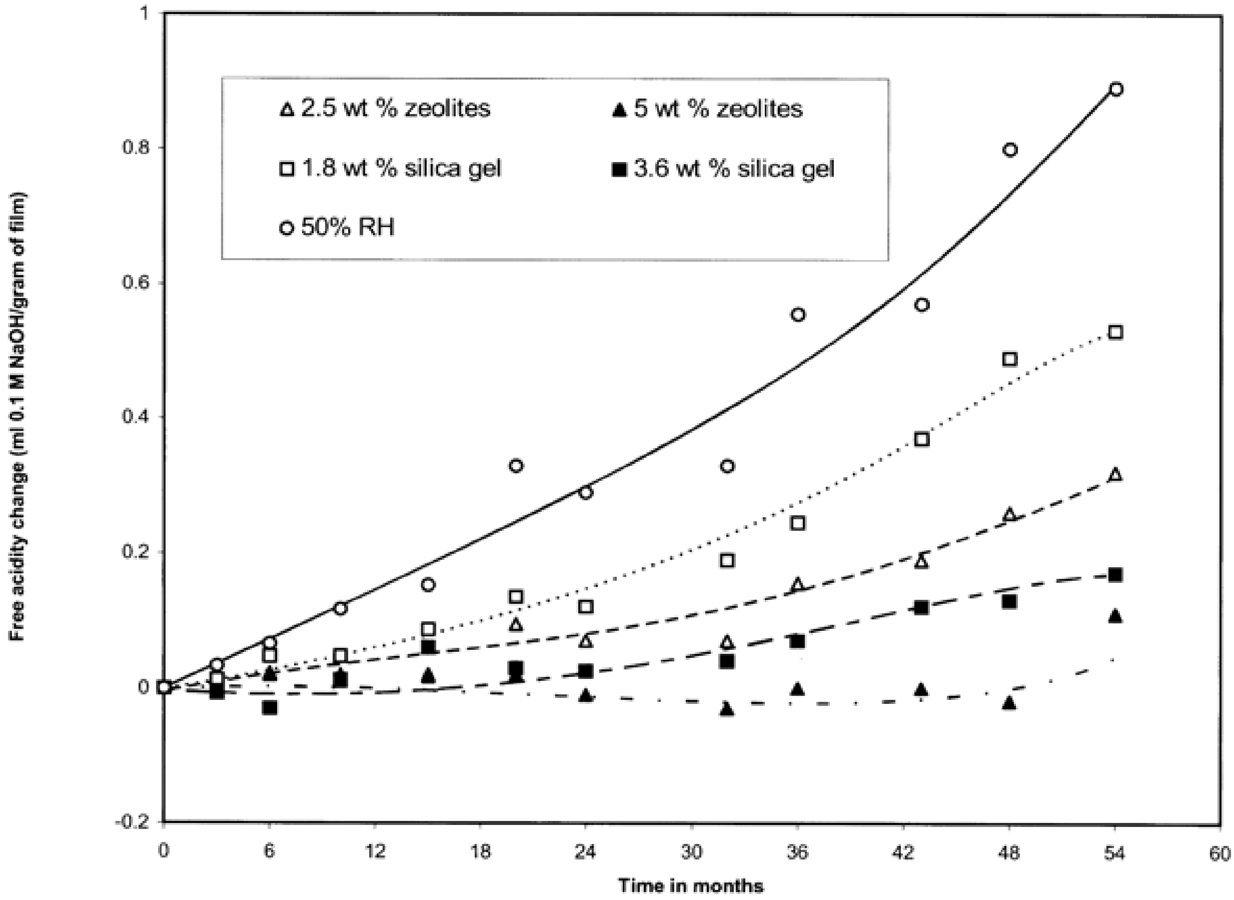


Figure 8: Effect of moisture pre-conditioning at 21°C. Acidity change for 100-foot rolls of pre-degraded CTA film stored at room temperature in sealed cans. Film initially conditioned to 50%, 35%, and 20% RH at 21°C.

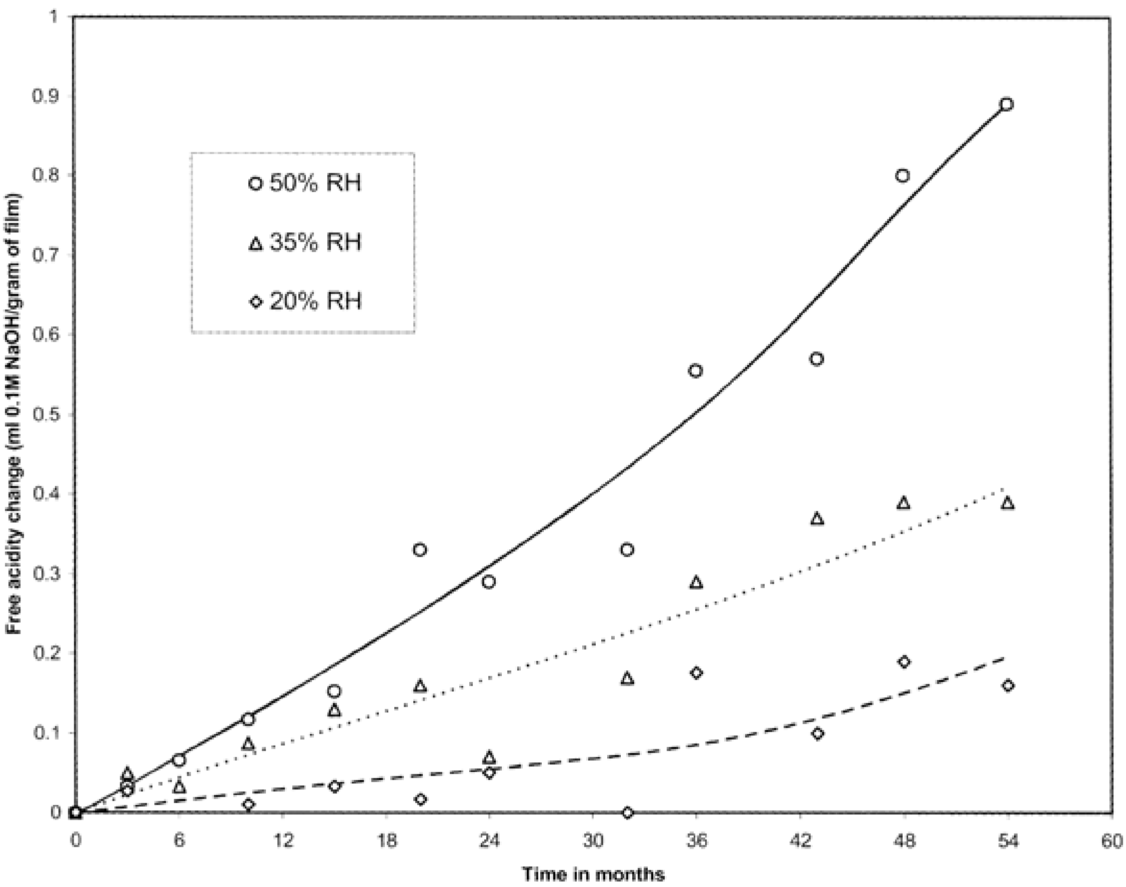


Figure 9: Effect of buffered cardboard disks at 21°C. Acidity change of 100-foot CTA film rolls stored inside sealed metal cans with and without two buffered cardboard disks. Film initially conditioned to 21°C, 50% RH. Initial film acidity: 0.4 to 0.6.

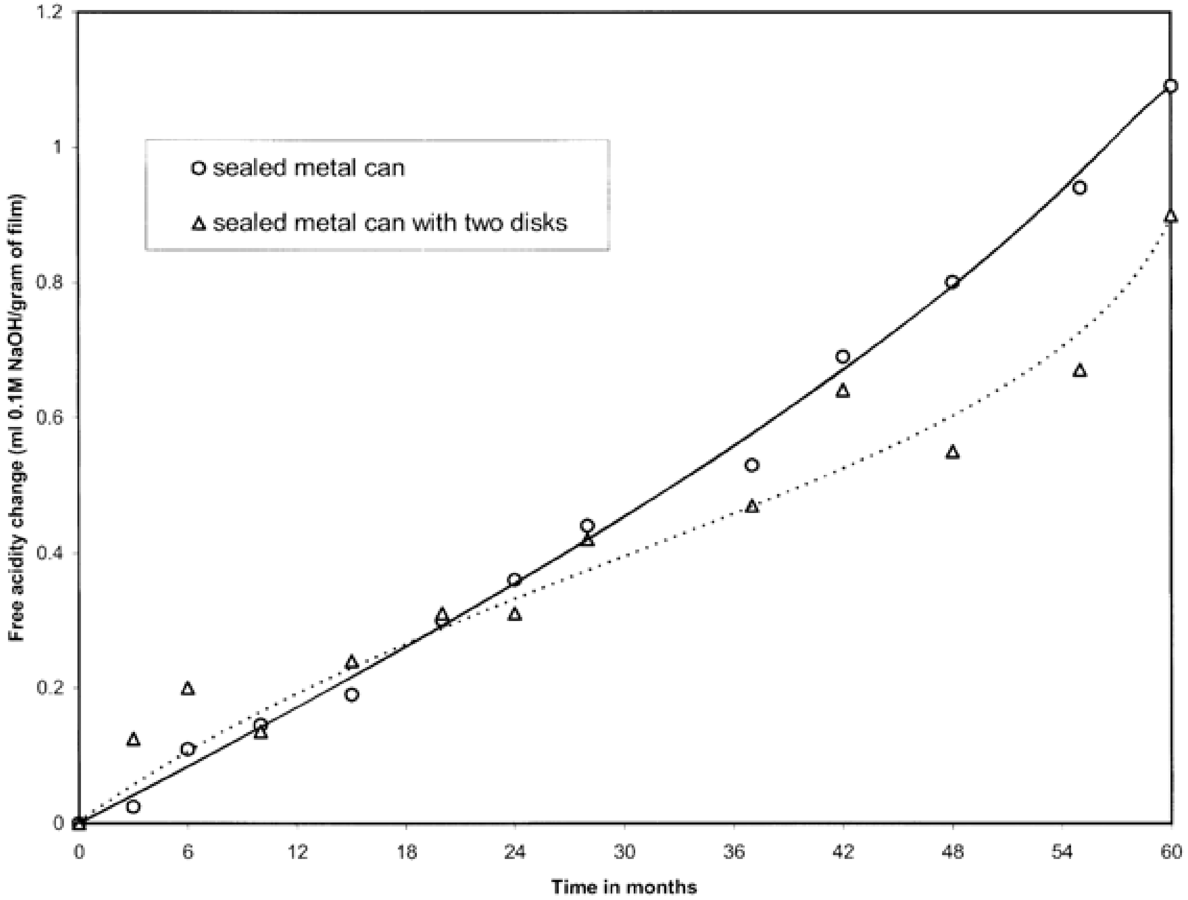
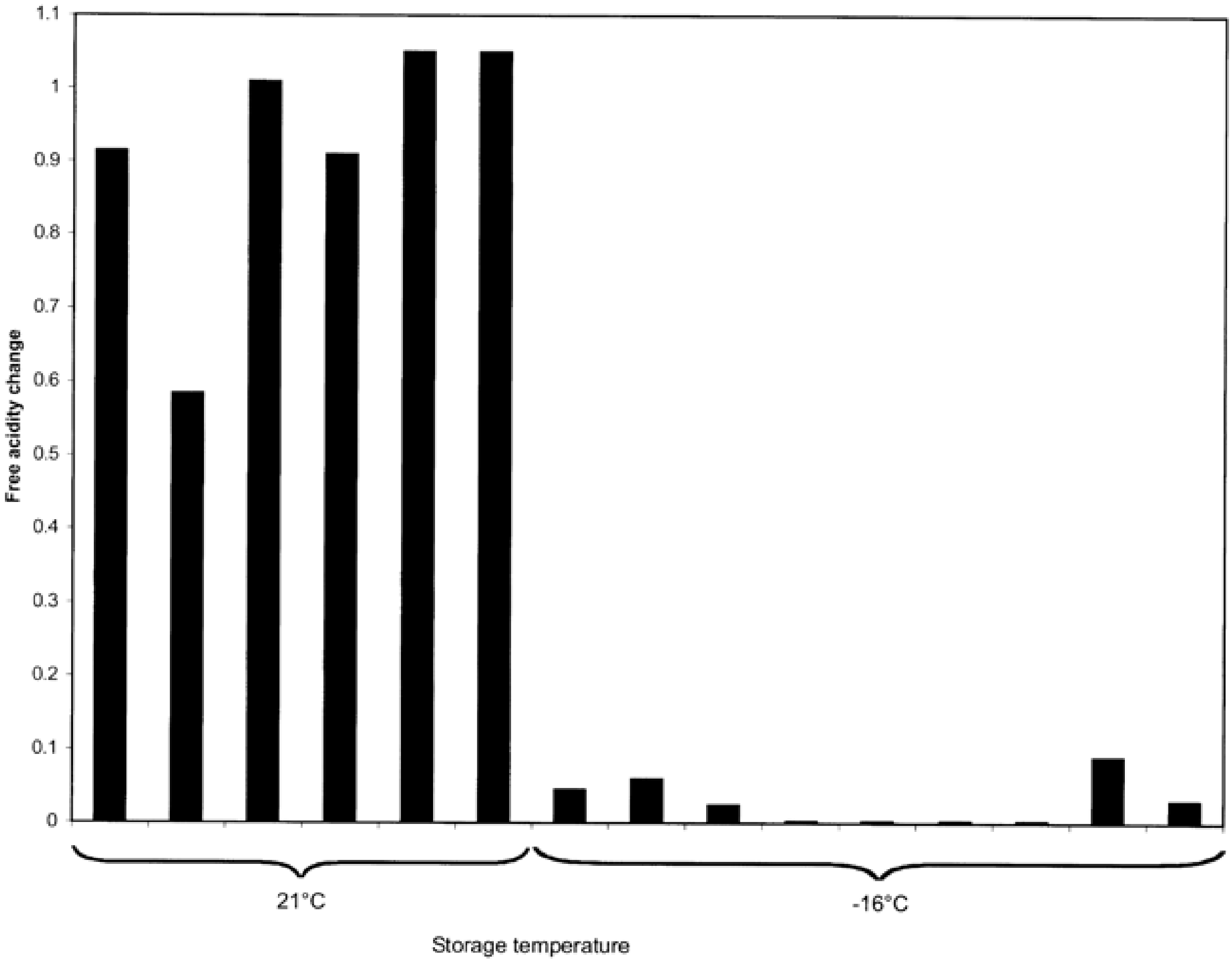


Figure 10: Acidity change of 400-foot rolls of pre-degraded CTA film after five years of storage at 21°C, 50% or at -16°C, 50% to 55% RH. Initial acidity levels were from 0.4 to 0.7.



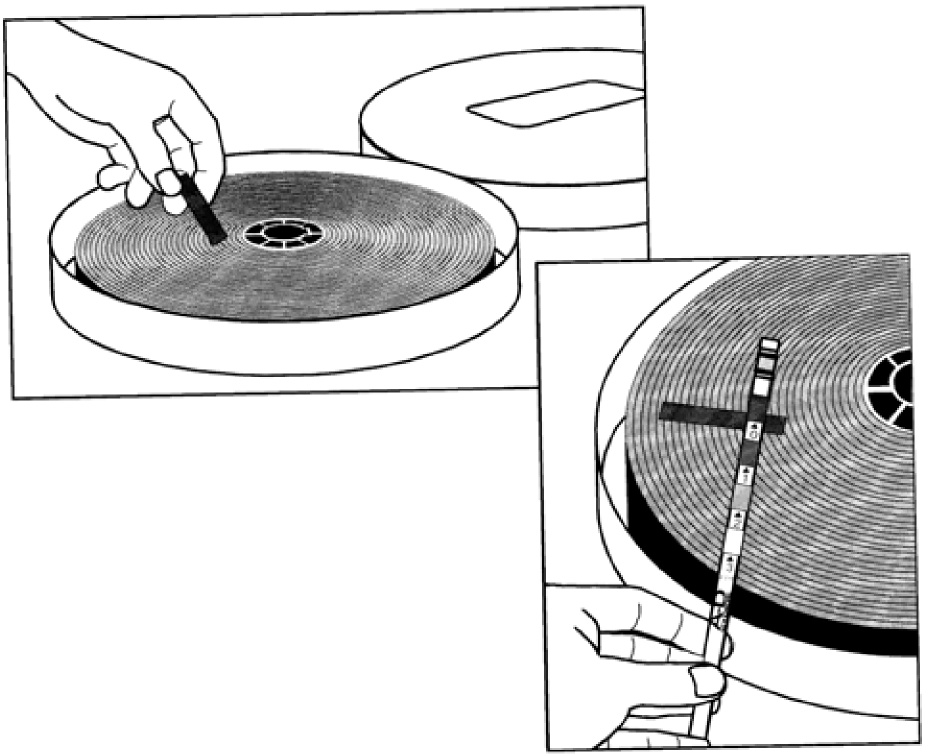


Figure caption:

Using A-D Strips: Place strip in can, wait 24 hours (or more, depending on testing conditions), then compare strip color to reference colors on pencil.

Discussion

George BROCK-NANNESTAD

My question relates to the film you obtained from Kodak. Was this film processed? Did you use the acetate strip alone? What material was used?

Jean-Louis BIGOURDAN

We used cellulose tri-acetate Fuji film. It was positive motion picture processed film.

Franz -LECHLEITNER

It is not easy to find colour after the change. Do you have any other method by which this critical point of 1.5 can be reached?

Jean-Louis BIGOURDAN

No. I have no other methods. However, we performed several field tests using 10 different evaluators. Some people were seeing the strips for the first time while others were specialists. I took them all together and made a statistical interpretation. The ratings have never been separated by more than one-half a level. When all of the results are put together, the solution does not appear to change. I do not find it worrisome if one person reaches a level of 1.5 while another reaches a level of 2. The main point is that this film is in an advanced state of decay. Three years later, the rating will have doubled. We can also estimate the state of decay according to whether the film is kept at 5°C or 10°C. This information should not be considered "crude" simply because we are using an empirical method.

Bruno DESPAS

L'intervention suivante sur les techniques de contrôle de la décomposition des polymères utilisés pour les pellicules cinématographiques et les bandes sonores est présentée par Michele Edge. Michele Edge fait partie du Center for material science research de la Manchester Metropolitan University. Elle est l'une des spécialistes scientifiques mondiales de la décomposition des polymères qui rentrent dans la composition des films. Elle est titulaire d'un PhD de la Manchester Metropolitan University sur la stabilité des films. Elle est professeur en sciences des polymères et a publié plus de 150 articles dans le domaine de la stabilité des polymères.

Approaches to the conservation of film and sound materials

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Introduction

The impermanence of images has been known from the very point of their inception. In 1858 M.C. Sinclair stated: "*Durability may be termed the keystone of photography; on this depends whether it will ultimately stand or fall. Permanence only is wanting to make this wonderful art, in many respects, a boon to society.*" In fact the driving force behind the majority of early developments in photography by Niepce, Daguerre, Talbot, Herschel, Poitevin, Swan, Willis and many others, was the need to overcome the problem of image instability. The survival of the photographic image to the end of the 20th century is testament to the combined efforts of photographers, manufacturers and conservators to circumvent this problem. It is only with knowledge of how material composition relates to permanence that we are able to make informed decisions regarding preservation. The challenge to those involved in conservation of film and sound material lies in the complex nature of its composition.

Conservation of materials may be broadly classified into two areas, preservation and restoration. The purpose of this presentation is to review approaches to preservation, i.e. preventive conservation. It is beyond the scope of this short review to cover all film and sound materials and so it will be restricted to the susceptibility of plastics, since plastic is by far the most common audio-visual support material.

The plastic usually consists of a polymer with other chemical additives incorporated. The polymer itself consists of small structural units (monomers), linked together and continuously repeated to form chains. Energetically the polymer is less stable than the monomer, and as a consequence it has a tendency to lower its free energy by fragmenting to smaller units. This is the process of degradation.

Polymer Degradation and Stability

Degradation may be manifested by both chemical and physical changes. Physical properties are discernible as: distortion (dimensional changes), crazing, cracking, surface deposits, changes in flexibility. Chemical changes are shown as: embrittlement, loss of strength, softening, tackiness, evolved odours, crazing, chalkiness, surface bloom, colour changes. Often the two appear to be alternative routes to decay rather than interrelated processes: This is one reason why elucidating the mechanism of degradation can be problematic.

Polymers may be degraded as the result of exposure to the following agencies: heat, light, atmosphere, hydrolysis and biodegradation. The principle mechanisms of interest in the absence of light (i.e. during archival storage) are oxidation and hydrolysis.
Oxygen usually participates in degradation as a free-radical species and results in polymer chain-scission, cross-linking and secondary oxidation reactions leading to the formation of new functional groups. The mechanism involves a chain reaction comprising: initiation (Step 1), propagation (Steps 2-5) and termination (Step 6).

(1)	polymer	→ **polymer radical**
(2)	polymer radical + oxygen	→ **polymer peroxy radical**
(3)	polymer peroxy radical + polymer	→ **polymer peroxide + polymer radical**
(4)	polymer peroxide	→ **polymer oxy radical + hydroxy radical**
(5)	hydroxy radical + polymer	→ **polymer radical + water**
(6)	radical combination	→ **cross-linked polymer**

It is steps 4 and 5, which cause the greatest damage to the polymer structure, since they lead to chain fragmentation by inter and intra molecular processes. The decomposition of polymer peroxide, or for that matter any peroxide, is highly temperature sensitive. This is why thermal-oxidation poses the greatest problems during the processing of a polymer during fabrication. At high temperatures a greater proportion of the total peroxides present in the material have the necessary energy to fragment. As a consequence of this, between 300°C and 160°C the polymer peroxides decompose in a matter of seconds, between 160°C and 80°C decomposition occurs in minutes, while between 80°C and room temperature decomposition may take hours to years. The faster the decomposition of peroxides, the faster is the degradation of the polymer. The rate of decomposition is also influenced by the specific structure of the polymer. Polymers with tertiary hydrogen atoms on the backbone, or with methylene or methine groups activated by unsaturation are particularly sensitive to oxidative degradation.

It is well known from the literature that the decomposition of peroxides is catalysed by (transition) metal ions, especially iron, copper and chromium. Only very small amounts of metal ions (a few parts per million) can cause considerable damage to a polymer structure. The decomposition takes place according to:

$Fe^{3+} + ROOH = (Fe^{3+}\text{---}ROOH) = Fe^{2+} + ROO\cdot + H^{+}$
$Fe^{2+} + ROOH = (Fe^{2+}\text{---}ROOH) = Fe^{3+} + RO\cdot + {}^{-}OH$

It is important to realise that when the metal ion is coordinated (attached) to other species it may not be free to participate in such reactions. For example, iron present in Prussian Blue is not free to take part in peroxide decomposition reactions. In fact plastics manufacturers often deliberately add metal deactivators, which are compounds able to sequester (coordinate) the metal ion. The 'incorporation' of metal ions in a photographic film is most likely to arise during manufacture and photographic processing.

Atmospheric pollutants such as nitrogen oxides, sulphur oxides and ozone may contribute to oxidation and in moist conditions the acids formed from these species can accelerate hydrolytic degradation.

Hydrolytic degradation is possible in synthetic polymers containing ester (e.g. cellulose nitrate, cellulose acetate, polyester), amide, urethane (e.g. magnetic tape binder) and carbonate (e.g. optical disk) links and in natural polymers containing polysaccharides and proteins (e.g. gelatine, albumen). Hydrolysis leads to a rapid loss in physical properties as the result of chain cleavage, except in esters where side group reactions may complicate matters. Because of the hydrophobic character of most polymers hydrolysis, even when feasible, proceeds slowly under normal ambient conditions. Humid conditions and pH less than 7 (acidic conditions) favour this type of degradation reaction. In the case of photographic film moisture present in the emulsion has a tendency to equilibrate with the base.

Two physical properties of polymers, namely morphology and glass transition temperature (Tg), are important when determining the rate of oxidation and hydrolysis. Most polymers are amorphous solids, i.e. they have a very disordered structure in which the chains are randomly coiled. It is easier for atmospheric gases and moisture to diffuse into the surface layers of amorphous polymers than crystalline polymers. In addition the physical form of the polymer is important. Whether an audio-visual material is fabricated as an individual sheet (stills), disk (CD-R) or tightly wound reel (roll film, magnetic tape) determines not only the rate of uptake of oxygen and moisture, but also the egress of degradation products. This is why unwinding a film reel to release trapped 'vinegar' can be beneficial to longevity. The Tg is the temperature at which the polymer chains have just enough thermal energy from the surroundings for the chains to begin to move. Some types of degradation cannot proceed below the Tg because the chains are 'frozen' in their random coils and the movements necessary for bonds to break cannot take place. The glass transition temperature of cellulose nitrate is *ca.* 50 °C, cellulose triacetate *ca.*120 °C and polyester *ca.* 80 °C.

Current Knowledge
Support Materials

The Polymer: Cellulose Esters

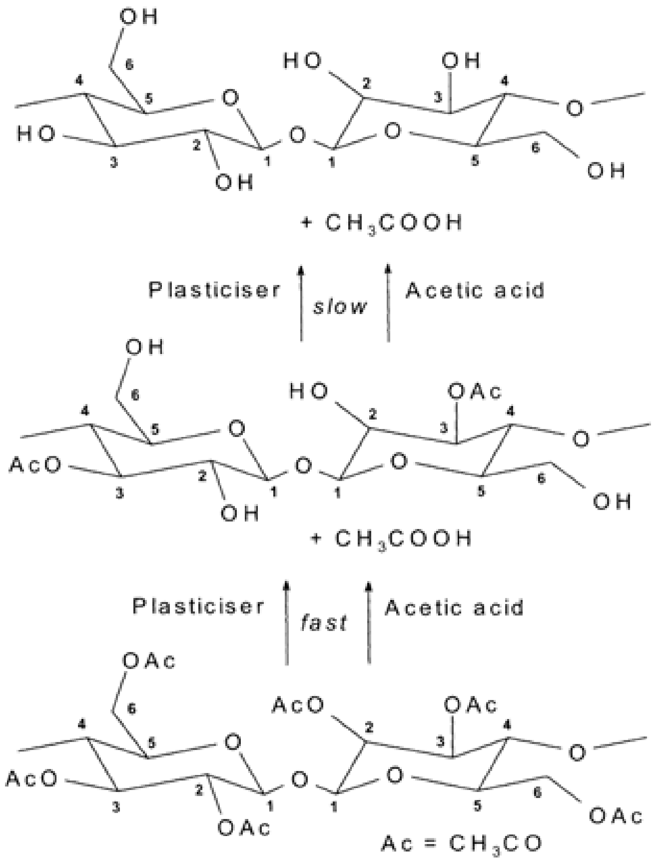
These include: cellulose nitrate, cellulose diacetate, cellulose triacetate, mixed-esters (cellulose acetate butyrate, cellulose acetate propionate). They are based on cellulose (Figure *)

Cellulose nitrate

Unlike the other cellulose esters, cellulose nitrate is particularly sensitive to thermal oxidation. Nitrogen oxides are readily cleaved from the pendant nitrate groups substituted on the chain. In the presence of moisture nitrous and nitric acids are formed, which catalyse the hydrolysis of further nitrate groups. The nitrogen oxides are sufficiently oxidising to convert image silver, to silver nitrate so fading the image via the characteristic sepia tones. The acids may also hydrolyse the gelatin, causing it to become sticky. In sufficient quantity the acids may induce chain-scission. As the chains fragment nitrogen oxides may re-substitute onto the rings. At this stage the film congeals to a honeycomb like mass and large volumes of brown powder may be produced on the surface of the film reel.

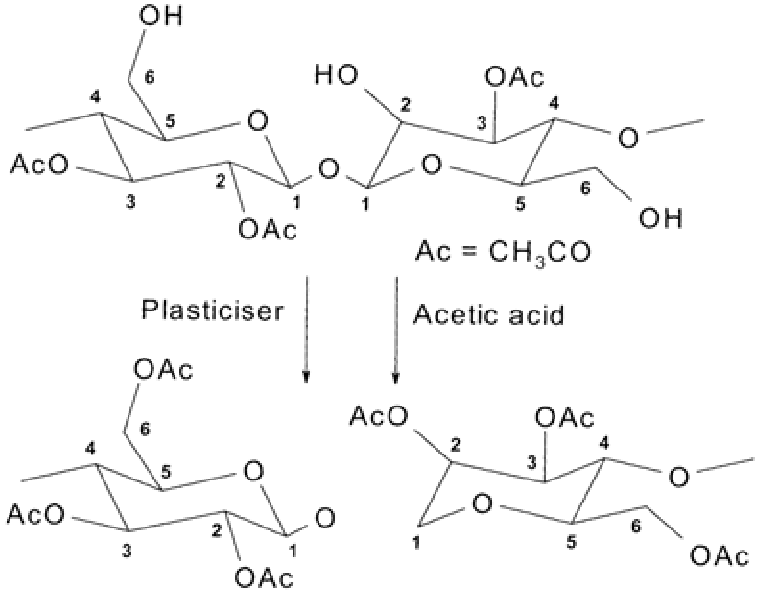
Cellulose acetate

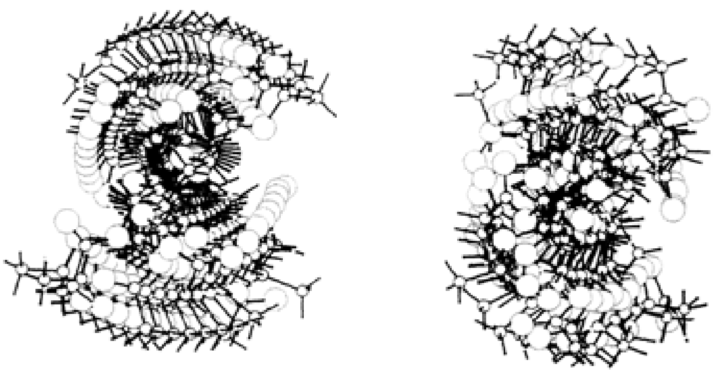
When the cellulose chain is substituted with, on average, two acetate groups per ring the cellulose acetate is referred to as diacetate and when substituted with an average of three acetate groups per ring as triacetate (CTA). Here hydrolysis of acetate groups results in the formation of acetic acid ('vinegar'). This causes the chains 'open-up' allowing easier access to moisture. The acetic acid increases the rate of hydrolysis and so the hydrolytic degradation assumes an autocatalytic nature.



Deacetylation

Chain-scission





Two distinct patterns of degradation are seen in acetate roll films, in some cases the reel becomes flaccid and in others there is embrittlement of the reel.

The relationship between peroxides and metal ions in CTA motion-picture film support is given in Table * (from Edge et al. 1990). Six films in various conditions were analysed for both ferric/ferrous ion and hydroperoxide contents. The most obvious feature of the data is that the films that are severely degraded (Films 5 and 6) have relatively high levels of iron and low levels of peroxides. This is consistent with the ability of iron to decompose peroxides.

Film	Appearance	[Fe](mg/g)	[ROOH] (mg/g)
1	good	<1	<5
2	good	5.3	7
3	good	7.8	23
4	acetic acid odour	12.2	17
5	plasticiser deposits	16.8	<5
6	image loss	31.2	<5

The Polymer: Polyester

Unlike cellulose esters, polyester has no pendant ester groups. Here the ester groups are part of the main polymer chain.

Binders

Magnetic Binders

The binders used for magnetic particles are typically copolymers of polyurethanes: polyester-urethanes, epoxy-urethanes, or PVC-urethane elastomers. A key characteristic of the binder matrix is the presence of minute pores at up to 20% of the total volume. The pores, whose function is to prevent adhesion of the tape surface to playback equipment, permit the rapid diffusion of oxygen and moisture into the binder matrix. In addition, urethanes accelerate the decomposition of peroxides, changing both order of reaction and activation energy. The urethanes used are typically based on 4,4'-methylene bis(phenyldiisocyanate), which on degradation undergoes peroxidation at the central methylene group followed by the formation of quinone-imide structures. These processes lead to extensive crosslinking of the binder layer, seen as embrittlement and eventual shedding of the oxide (Figure *). Depending on the precise copolymer composition of the binder, the peroxides present may have different stabilities. This relates to the specific site where the peroxide is situated within the structure. Table * shows that for three different tape manufacturers that the relative rates of peroxide decomposition do not correlate with the initial peroxide present within the tapes after manufacture.

In contrast to photographic film base where the dominant degradation process is hydrolysis, in magnetic binders there is a complex interplay between oxidation and hydrolysis. Although high humidity levels may instigate hydrolysis, when oxidation is dominant moisture merely serves as a plasticiser.

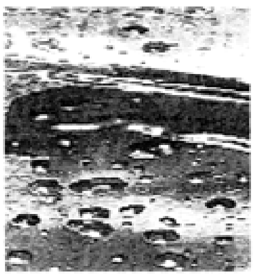
Gelatin Binders

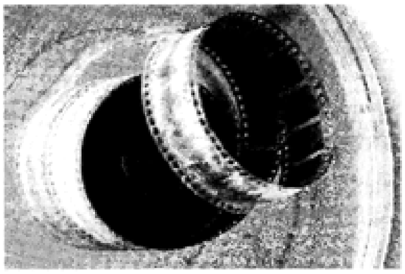
Gelatin is manufactured from the fibrous protein collagen

PLASTICS ADDITIVES

Plasticisers in Photographic Film Base

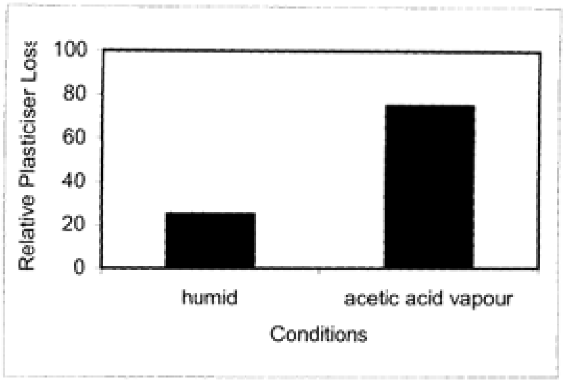
Plasticisers used in plastic film base include camphor, naphthalene, phthalates, glycolates, and phosphates. The plasticisers may be liquids or crystalline solids prior to incorporation in the film base. Calhoun (1944) and Padfield, Hopwood and Organ (1980) claim permanent shrinkage of motion-picture film may be attributed partly to the appearance of exuded plasticiser on the surface of the film. Both liquid and crystalline deposits are observed on the surface of degraded films (Figures * and * respectively).



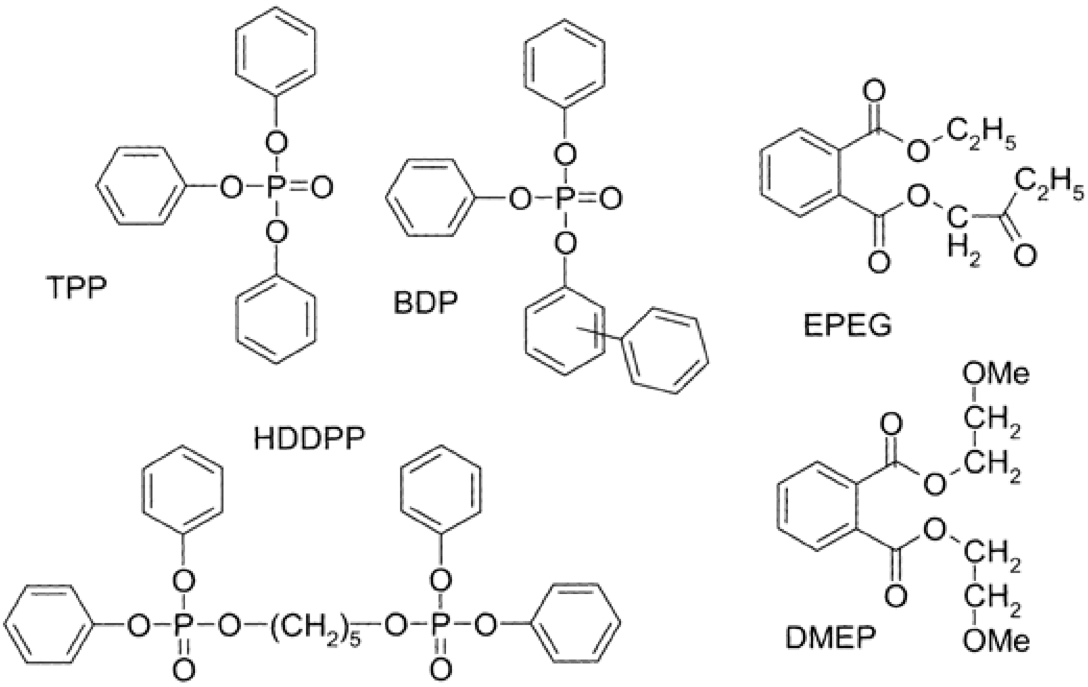


Early studies realised that phthalate plasticisers may produce peroxides.

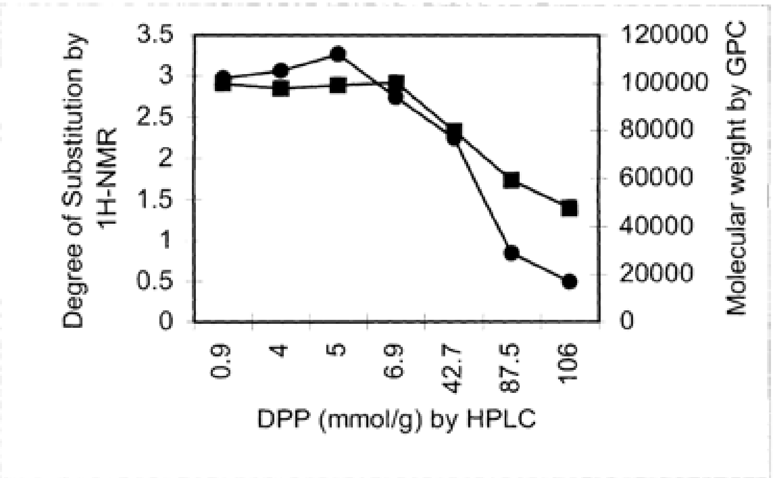
Edge (19**) has shown that for CTA motion-picture film the plasticiser triphenyl phosphate is exuded more readily in the presence of evolved acetic acid than in humid conditions (Figure *).



Shinagawa, Murayama and Sakaino (1992) have reported that unplasticised cellulose triacetate film is very stable when compared to its plasticised counterpart. These authors examined a range of structures used commercially as plasticisers for CTA support (Figure *). They demonstrated that the plasticiser triphenyl phosphate was susceptible to hydrolysis (Table *, Figure *) giving diphenyl phosphate (DPP) and phenol. DPP is a strong acid, and in its presence the pH of CTA support can fall as low as 2.0. Glastrup (19??) has shown that residual fixer results in higher levels of DPP, phenol and acetic acid.



Duration of storage (years)	DPP (mmol/g)	DS by 1H-NMR	MW by GPC
33	32.8	1.78	73000
33	31.1	1.90	78000
31	29.9	2.06	90000
31	22.9	1.62	61000
26	13.4	2.52	118000



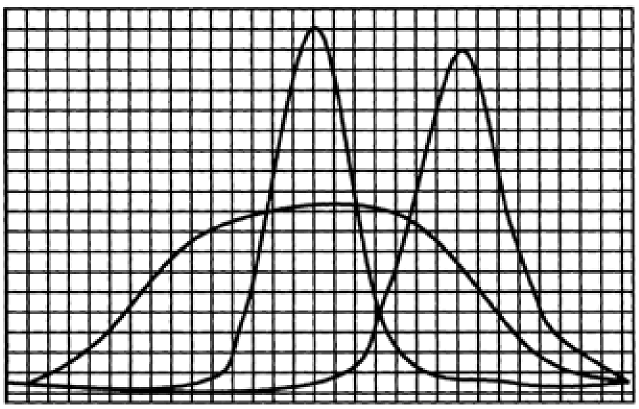
In the case of cellulose nitrate film, nitrogen oxides can react with the plasticiser, and this has been shown to be the case for camphor and triphenyl phosphate.

Details about manufacture remain largely proprietary information

Lubricants in Magnetic Binders.
In addition to the pores present in the binder layer, lubricants (fatty acid esters) are also needed to prevent adhesion of the tape to playback equipment. As with

Future Needs (Unanswered Questions) Foresight Planning

Why is it so difficult to predict the lifetime of an audio-visual material?
The rate of degradation may depend on the film brand, type, production date, processing, storage history. We know that films do not deteriorate in chronological order. If for a particular film brand we quantify incidences of degradation as a function of the life expectancy, the distribution of this data should reveal the vulnerability of the material to deterioration (Figure *).



Optimum storage conditions have been defined by application of a modified form of the Arrhenius relationship. This shows how the rate constant and hence rate of a reaction is influenced by temperature.
Problems:
Moisture content isolines reveal that the T_g of gelatin shifts to lower values with increasing moisture content
Thermogravimetric analysis shows that the weight loss corresponding to de-esterification moves to lower temperature.i.e. the E_A for de-esterification changes with degree of substitution!

An AUTOCATALYTIC reaction!

Due to the sheer volume of work to be undertaken many of the Arrhenius plots quoted in the literature contain no more than five data points and correlation coefficients are not quoted.

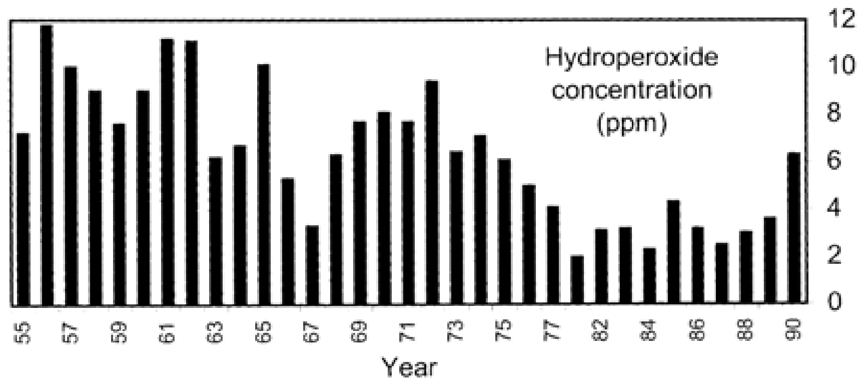
Despite these concerns the Arrhenius relationship has been surprisingly useful in many cases
More sophisticated methods of data analysis do exist. While to some extent we have put 'the cart before the horse', perhaps some of the data compiled could be fed into experimental design packages, which use a

factorial approach and surface response methods, to identify the relative importance of a number of factors when present in combination.
Padfield has questioned the economic sense of stringent standards that still allow deterioration of badly manufactured or processed film, and yet still require expensive equipment that may not be necessary for film in good condition. He suggests that we should question the emphasis on importance of room climate, when observation implies that microenvironment may be more important.

SURVEY OF AUDIO-VISUAL COLLECTIONS.

Having amassed a substantial amount of information regarding the mechanisms of deterioration, it is timely to apply this to a technical survey of collections.

Despite the fact that early surveys of collections relied upon visual inspection of the condition of materials, they demonstrated the value of such an approach. One of the first of these, the Horvath Negative Survey, examined collections of nitrate-support filmstock. Based purely on visual inspection this review was able to show that pockets of degradation occurred for film produced in certain years. Such information is invaluable to the archivist when carrying out a risk assessment of a collection.
Edge et al. In 1988 with the NFTA (UK) we randomly sampled 925 films from their collection. Only 92 showed evidence of 'vinegar syndrome' and 90 of these were magnetic track materials! The average age of these films being 30 years.



Discussion

Ed Zwaneveld from The National Film Board of Canada

I appreciate the work you perform and the information you shared with us. Based on our own evaluation of our archives (40 000 samples), I confirm that magnetic sound film degrades in about half the time of motion picture film. I would be very interested in hearing more about the effect of processing. You referred to fixing and washing. Obviously, motion picture laboratories have made attempts to reduce the amount of time during which film is washed. Is the time of washing an issue?

Michele EDGE

Your question is not an easy one. Over the last 20 years, severity and temperature have risen while washing times have decreased. Processors have made this choice for purely economic reasons. I do not see any problem with modern processing methods. I would like to highlight the fact that film collected in the 1940s and 1950s were not subject to such stringent methods and are more likely to present signs of residual fixer materials. These break down to produce peroxides.

Bruno DESPAS

Le prochain intervenant est Bertrand Lavédrine, qui dirige le centre de recherche sur la conservation des documents graphiques. L'exposé de Bertrand Lavédrine portera sur l'analyse statistique de l'état de conservation des collections de films sur support en triacétate de cellulose. Bertrand Lavédrine est l'auteur de nombreuses publications sur l'analyse et la conservation des documents photographiques, et en particulier des autochromes, premier procédé industriel de photographie couleur.

Analyse statistique de l'etat de conservation d'une collection de films sur support en triacetate de cellulose

— —

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(Centre de recherches sur la conservation des documents graphiques) - France

Michelle Aubert , Jean-Louis Cot
(Service des archives du film, Centre national de la cinématographie) - France

Benoît Riandey
(Institut national des études démographiques) - France

Introduction

Pendant une quarantaine d'années, le triacétate de cellulose a été considéré comme un support de film stable. C'est seulement vers la fin des années quatre-vingt que se généralise la prise de conscience des problèmes liés à sa conservation. On constate en effet qu'après une trentaine d'années de stockage, de nombreux films cinématographiques sur support en triacétate exhalent une odeur de vinaigre, phénomène rapporté sous le nom de « syndrome du vinaigre » Cet incident s'était déjà produit en 1954 dans des archives cinématographiques en Inde et n'avait guère attiré l'attention à l'époque. On se préoccupait alors essentiellement de la conservation des films en nitrate de cellulose, particulièrement instables et inflammables, et de celle des films en couleurs chromogènes, dont les colorants avaient tendance à s'affadir. Pour éviter les accidents, on recopiait les premiers sur des supports en acétate de cellulose. Quant aux seconds, on tentait, dans le meilleur des cas, d'en ralentir la dégradation en les conservant au froid. Or en l'espace d'une vingtaine d'années, le syndrome du vinaigre est devenu la principale menace des collections cinématographiques. La découverte des risques engendrés par l'acétate de cellulose est quelque peu décourageante : aucune collection n'est épargnée. En France, le service des Archives du film possède environ un million de bobines de films cinématographiques dont les trois quarts sont sur support en triacétate de cellulose, et leur exploitation a révélé que l'on en trouvait régulièrement atteintes par le syndrome du vinaigre. La nécessité s'est donc fait sentir de réaliser une étude épidémiologique pour déterminer l'ampleur du mal et décider des mesures à prendre pour le circonscrire.

Évaluation statistique de l'état de conservation d'une collection

Pour connaître l'état d'un fonds, il suffit de passer en revue tous les éléments qui le constituent. Dans le cas du service des Archives du film, en considérant que l'analyse d'une bobine réclame 10 minutes, l'étude totale du fonds demanderait plus de 60 ans à une personne. Même en se limitant aux longs métrages déposés au SAF entre 1969 et 1985, on a affaire à environ 150 000 bobines de films, dont l'analyse exhaustive demanderait une bonne dizaine d'années. L'intérêt de l'approche statistique réside dans cette économie de temps et donc de moyens.
Plusieurs études statistiques ont déjà été effectuées dans les institutions patrimoniales sur des collections de livres[1] [2], de films, de microfilms[3] ou de photographies[4] [5]. L'étude statistique peut se révéler complexe si l'on veut analyser avec rigueur un fonds patrimonial de

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[1] Drott C.M. « Random sampling : a tool for library research », *College and Research Libraries*, 30, May 1969, p.119-125.
[2] Goldstein M., Sedransk J., « Using a sample technique to describe characteristics of a collection », *Colleges and Research Libraries*, March 1977 , p.195-202.
[3] Nishimura D.W., « Surveying a microfilm collection », rapport IPI 1994, non publié.
[4] Erlandsen R., « The national plan for conservation of photographs in Norway », *Research Techniques in Photographic Conservation*, proceedings of the conference in Copenhagen, 14-19 May 1995.
[5] Johnsen J.S., « Conservation management and archival survival of photographic collections », *Göteborg Studies in Conservation*, 5, Copenhagen : Acta Universitatis Gothoburgensis, 1997.

nature et d'origine très diverses. La difficulté est de suivre une méthodologie simple et correcte qui aboutisse à des résultats fiables.

ORGANISATION ET STRATIFICATION DE LA COLLECTION

Pour mener à bien une étude statistique, une collection de films peut sembler un modèle idéal. Les éléments étant semblables les uns aux autres, il convient simplement de prélever un lot de films formant un échantillon représentatif de la collection. Mais une collection de films cinématographiques offre une réalité beaucoup plus complexe qu'un ensemble de bobines rangées soigneusement. Les grandes collections patrimoniales sont constituées par l'assemblage de fonds d'origine ou de nature différente et donc rarement uniformes, et les archives cinématographiques n'y font pas exception. Une œuvre cinématographique est formée de toute une variété d'éléments qui font partie de sa genèse. Lors du tournage, on réalise un film négatif, qui peut être en noir et blanc ou en couleurs, ainsi qu'un enregistrement magnétique pour la bande son et un négatif son. À partir des négatifs on tire des interpositifs. Tous ces éléments n'ont pas la même importance numérique, historique et patrimoniale. Les négatifs, quand ils sont présents, constituent un ensemble particulièrement précieux. D'autre part les conditions de stockage ou la fragilité des éléments peuvent être différentes d'un groupe d'éléments à l'autre. Pour éviter que des fonds spécifiques soient surestimés ou sous-représentés par un prélèvement aléatoire, il convient de donner à chacun un poids différent et une approche différenciée : on a alors recours à une analyse dite stratifiée. Chaque fonds est traité distinctement en veillant à avoir des effectifs suffisants.

Nous avons réparti les films en 8 groupes : négatifs noir et blanc, négatifs couleurs, interpositifs noir et blanc, interpositifs couleurs, copies d'exploitation noir et blanc, copies d'exploitation couleurs, négatifs son, bandes son magnétiques. Nous avons trouvé un certain nombre de films dont le fichier n'indique pas s'ils sont en couleurs ou en noir et blanc. Ceux-ci ont été rassemblés dans deux catégories supplémentaires : les négatifs non renseignés et les copies d'exploitation non renseignées. Ils ont fait l'objet d'une analyse distincte, qui a permis de déterminer s'ils étaient en couleurs ou en noir et blanc et de les replacer dans leur famille respective. Les films sont stockés à Bois d'Arcy dans des bâtiments climatisés à 16 °C, 60 % d'humidité relative, sauf sur un site (le bâtiment A) où la climatisation ne fonctionne pas encore. Cette différence dans les conditions de conservation pouvant générer des états de conservation différents, nous avons décidé d'inclure ce paramètre dans l'étude. Pour chaque type de film, il a été précisé s'il provenait, ou non, d'un bâtiment climatisé.

Cette simple organisation intellectuelle de la collection pour les besoins de l'étude statistique, réclame une bonne connaissance et une description exacte du fonds. Bien que le Service des archives du film soit informatisé, il a fallu consacrer un travail important au tri de la collection selon ces requêtes, et au relevé du nombre de films dans chacune des catégories. Après réorganisation, la population de chacune des strates allait de mille à plusieurs dizaines de milliers de bobines de films, comme on peut le voir dans le tableau 1.

Figure 1 : nombre de bobines dans les strates analysées

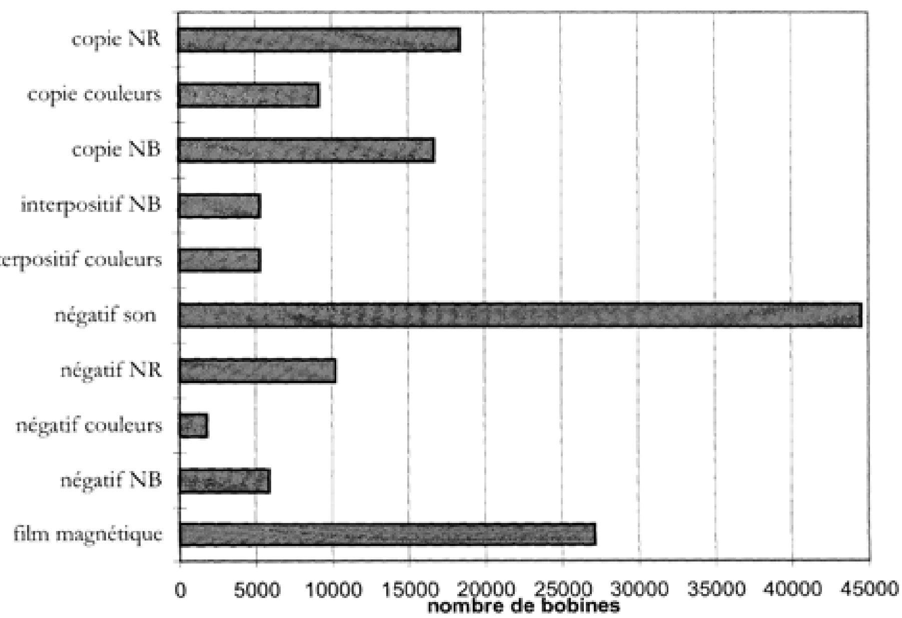


Tableau 1 : recensement des films déposés au SAF entre 1969 et 1985 comportant plus de trois bobines

abréviation	type	films	bobines
MAG	film magnétique	3 627	27 131
MIMNB	négatif noir et blanc	871	5 878
NINC	négatif couleurs	259	1 822
NIMNR	négatif non renseigné	1 414	10 237
NSN	négatifs son	6 233	44 545
ITP	interpositif couleur	821	5 281
PIM	interpositif noir et blanc	2 133	5 281
CEXNB	copie d'exploitation noir et blanc	2 659	16 711
CEXC	copie d'exploitation couleurs	1 583	9 191
CEXNR	copie d'exploitation non renseignée	3 198	18 414

L'ECHANTILLONNAGE

Il nous est apparu d'abord nécessaire de clarifier notre terminologie. Venant de domaines différents, les mots employés n'avaient pas toujours le même sens. Ainsi selon certains le mot « film » désignait une bobine, pour d'autres, il s'agissait de l'œuvre formée de plusieurs bobines. Nous avons donc dénommé :

« article » une bobine de film ou une bande magnétique

« élément » le film (soit un ensemble de bobines)

« œuvre » l'ensemble constitué de la source son, le négatif, l'interpositif et les copies.

Nous avons sélectionné les films à analyser à l'aide d'un tirage systématique. Les éléments ont été classés par ordre chronologique d'arrivée dans les collections et on a effectué un prélèvement à intervalles réguliers. Toutefois, pour connaître l'état d'un film, qui peut comporter de 4 à 10 bobines, il serait nécessaire d'analyser tous les articles qui le constituent. Nous n'avions en effet, aucune idée *a priori* sur l'homogénéité de la détérioration : toutes les bobines d'un même film seraient-elles ou non dans le même état de dégradation ? Une analyse exhaustive permettrait de définir correctement l'état du film, mais elle réduirait nos possibilités d'analyse sur l'ensemble de la collection. Aussi avons-nous décidé de tirer deux bobines au hasard pour chaque film sélectionné. Le tirage de deux bobines n'a été poursuivi que lorsque l'on notait une hétérogénéité fréquente des articles dans une strate. Il est certain que le modèle statistique pour décrire une telle démarche est complexe : le nombre de bobines étant différent d'un film à l'autre, la probabilité n'est plus la même. Cette approche nous donne simplement une estimation sur le caractère homogène ou hétérogène de l'état de conservation des différentes bobines de chaque film.

Pour l'étude globale de la collection nous ne garderons que l'analyse d'une seule bobine : en cas d'hétérogénéité dans les résultats, c'est la bobine la plus dégradée qui primera. Il faut cependant bien garder à l'esprit que postuler que l'état d'un film est donné par un seul article nous conduit à sous-estimer l'état de dégradation de la collection, en cas d'hétérogénéité. En effet il est possible que l'on ait tiré une ou deux bobines en bon état alors qu'il en existe au moins une plus dégradée dans celles restantes.

Le deuxième problème qui se pose est celui du nombre de films à analyser, c'est-à-dire la taille du prélèvement à effectuer dans chacune de ces strates : combien d'éléments analyser ? Ce choix a été dicté non pas par le calcul statistique mais par des contraintes purement matérielles, c'est-à-dire le temps dont nous disposions pour analyser chacune des strates. L'utilisation des tables permet de déterminer la précision à partir du nombre de prélèvements et des résultats que nous avons obtenus.

LES CRITERES

Chaque bobine prélevée a fait l'objet d'observations dont certaines pourront servir lors d'une exploitation ultérieure des résultats :

- La date de dépôt : c'est-à-dire la date d'arrivée du film aux Archives (variable de 2 à 15 ans après fabrication). Toujours postérieure à la création de l'élément, c'est le seul repère historique fiable.
- L'emplacement du film dans les réserves.
- La taille de la boîte des films de 120, 300 ou 600 (en mètres).
- Le matériau de la boîte : plastique ou métal.
- Le format du noyau en matière plastique autour duquel est enroulée la bobine.
- Le diamètre de la bobine en cm.
- Le format du film : 16 mm, 35 mm...
- La compacité du film autour du noyau : la bobine se déforme par pression des doigts ou le film est compact.
- Le type de film (négatif, positif...).
- La marque de la pellicule quand elle est identifiable : Agfa, Kodak, Pyral...
- La date la plus récente figurant sur la marge du film. Elle peut correspondre à la date de réalisation de la copie, mais cette donnée est sujette à de nombreuses erreurs.

- La présence ou non d'une odeur de vinaigre.
- Et enfin le niveau d'altération.

Cet état d'altération du support en acétate est déterminé en mesurant l'acidité ambiante au contact de la bobine par les indicateurs de pH, ou AD-strips, mis au point par l'Image Permanence Institute. Les films sélectionnés pour l'analyse sont déposés dans une salle réservée à cet usage. Dans chaque boîte on place l'AD-strip au contact du film ; la boîte est fermée et laissée 24 heures à 19 degrés. Selon la couleur de l'indicateur après 24 heures, on déduit le niveau d'altération du film : 0, 1, 2 ou 3. La couleur
bleue correspond à l'état 0, le film est considéré en bon état. La couleur verte correspond au niveau 1, elle indique un film qu'il faut surveiller. La couleur vert clair correspond au niveau 2, le film réclame un traitement. Si
l'indicateur vire au jaune, on atteint le niveau 3, la dégradation est extrême, il faut traiter le film immédiatement. Il a été parfois possible de distinguer des nuances et ainsi de créer des niveaux intermédiaires : 0,5, 1,5 et 2,5 qui n'ont pas été conservés pour le bilan de l'étude.

LES RESULTATS

Sur les huit strates étudiées, aucune n'est épargnée par le syndrome du vinaigre. Les résultats sont résumés dans le tableau 2. Ils ont été calculés pour un intervalle de confiance de 95%, signifiant que si l'on renouvelle 20 fois l'analyse, 19 fois on aboutira aux mêmes résultats. On peut distinguer plusieurs groupes (figures 2 et 3). Les négatifs couleurs sont dans le meilleur état avec simplement 20% d'éléments en voie de dégradation. Les copies, les interpositifs et les négatifs en noir et blanc ainsi que les interpositifs couleurs sont statistiquement dans un état à peu près équivalent avec environ 35% d'éléments en cours de dégradation. Les négatifs son et les copies couleurs présentent environ 50% d'éléments ayant amorcé un processus de dégradation.

Nous n'avons trouvé, pour l'instant, aucune raison à avancer pour justifier une plus grande fragilité des copies couleurs ou des négatifs son. L'analyse de la date de dépôt des éléments, de la marque, de la nature des boîtes n'a pas permis de trouver d'explications satisfaisantes.

Tableau 2 : pourcentage des films dégradés dans chacune des strates

strate	nombre de films analysés	% de films analysés	% de films dégradés (intervalle de confiance de 95%)
négatif couleurs	102	39%	21% ±8%
copie NB	127	5%	31% ±8%
interpositif NB	90	4%	34% ±10%
interpositif couleurs	97	12%	35% ±10%
négatif NB	96	11%	39% ±10%
négatif son	103	2%	51% ±10%
copie couleurs	77	5%	59% ±11%
film magnétique	179	5%	87% ±6%

Figure 2 : pourcentage de films en voie de dégradation dans chacune des strates

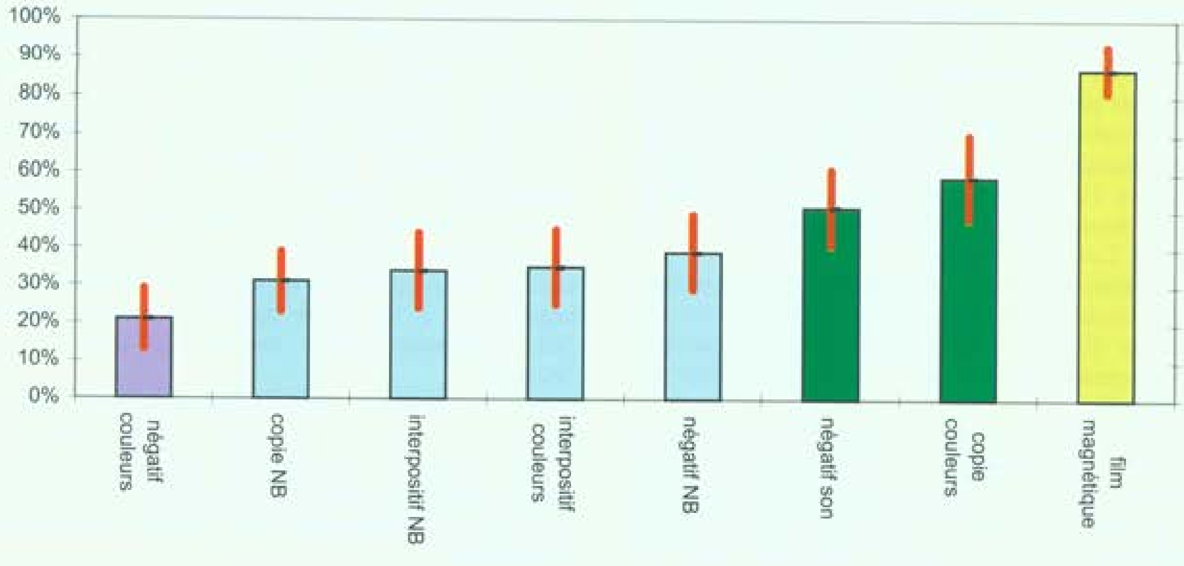
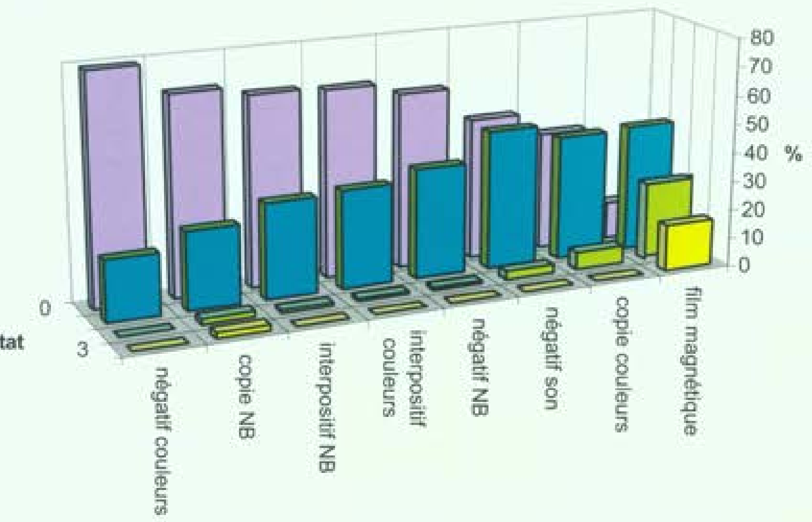


Figure 3 : répartition de la détérioration dans chacune des strates

(les histogrammes du fond représentent le % d'éléments au niveau 0, à l'avant au niveau 3, et entre, les niveaux intermédiaires)



Les films magnétiques révèlent l'état le plus critique. Ces films, sur support en acétate de cellulose, ne sont pas à proprement parler des films, mais ils représentent un intermédiaire important lors de la réalisation d'une œuvre cinématographique. On a analysé 5 % de cette collection, qui comporte 3627 éléments soit plus de 27 000 articles. Deux articles ont été analysés pour chaque élément. Dans seulement 13 % des cas les deux bobines analysées étaient en bon état. 77% de la collection sont entrés dans une phase de dégradation notable, et 10% atteignent le niveau 3, c'est-à-dire un état extrême de dégradation.

Pour un même élément, il existe une hétérogénéité dans l'état des bandes magnétiques d'une boîte à l'autre.

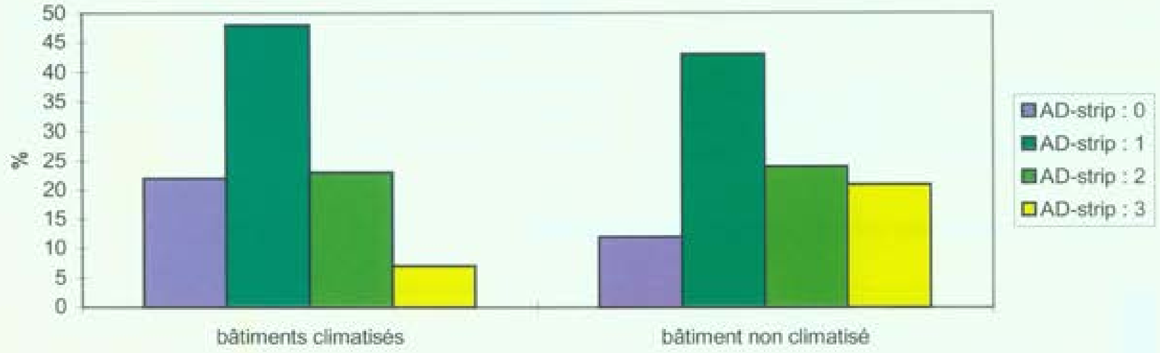
Quand on établit un tableau croisé, on remarque que si dans 65 % des cas, l'état de la première bobine est égal à celui de la seconde, dans 35 % des cas ils sont différents ; cette différence est d'une unité de dégradation dans 28 % des cas, de deux unités dans 6 % des cas ; dans moins d'1 % des cas, cet écart atteint 3 unités.

65 %	: état bobine 1 = état de la 2ème bobine
28 %	: état bobine 1 = état de la 2ème bobine +1
6 %	: état bobine 1 = état de la 2ème bobine +2
1 %	: état bobine 1 = état de la 2ème bobine +3

Influence du lieu de stockage

Nous avons comparé les résultats obtenus statistiquement sur l'état des films conservés d'une part dans des magasins climatisés, et d'autre part dans un magasin qui ne l'est pas (figure 4). En moyenne, on observe « un glissement » vers une dégradation plus importante dans le magasin qui n'est pas climatisé. Ainsi pour les films magnétiques, il y a seulement 12 % d'éléments en bon état contre 22 % dans les réserves climatisées.

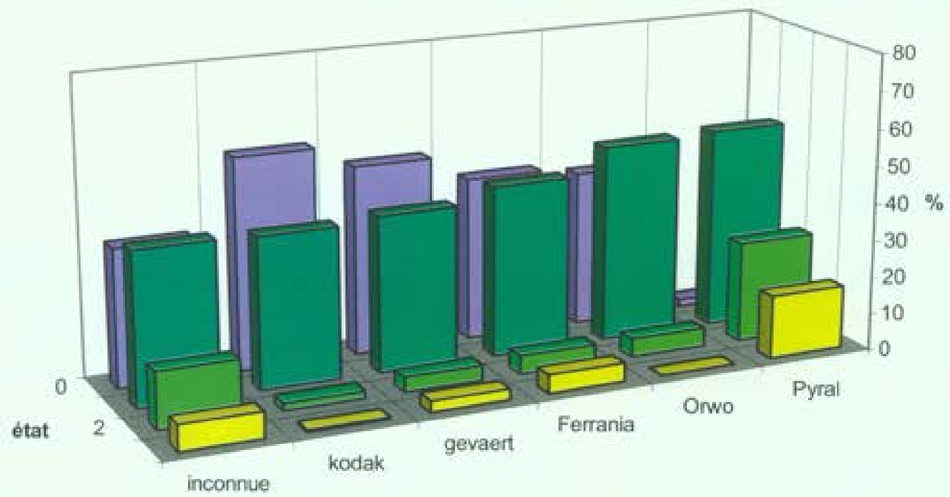
Figure 4 : état de conservation des films magnétiques : influence du lieu de stockage



Influence des marques

On observe de légères différences selon les marques tous supports confondus (films+bandes magnétiques). Seule la marque Pyral (films magnétiques) accuse un niveau d'altération très prononcé puisqu'il n'existe plus que 2 % d'éléments intacts (figure 5).

Figure 5 : répartition de la détérioration selon les marques
(les histogrammes du fond représentent le % d'éléments au niveau 0, à l'avant au niveau 3, et entre, les niveaux intermédiaires)



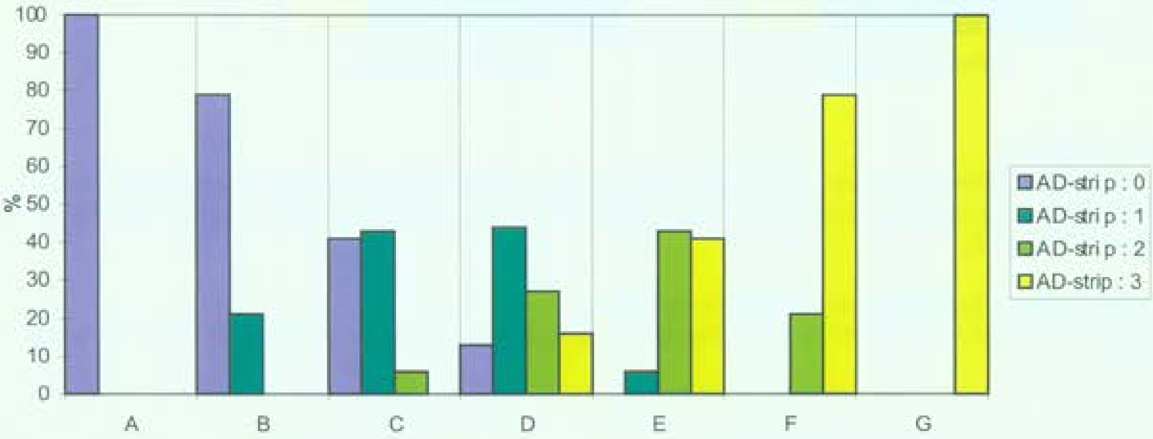
Influence du contenant

Nous n'avons pas noté de différence significative entre les films conservés dans des boîtes en plastique et ceux conservés dans des boîtes métalliques : le pourcentage de films en cours de dégradation est du même ordre (50 %) tous supports confondus.

Répartition de la détérioration dans chacune des strates

Lorsque l'état d'altération d'une collection augmente, il se traduit également par une plus grande hétérogénéité dans l'état de dégradation des divers articles. L'étude de ces différents strates nous donne ainsi une idée de l'évolution d'une collection (figure 6). À l'origine (A) tous les éléments sont en bon état (100 % au niveau 0), puis avec le temps des films commencent à se dégrader, des articles au niveau 1 de dégradation sont décelés (B), ensuite apparaissent des articles au niveau 2 (C) puis 3 comme c'est le cas pour les collection de bandes magnétiques représentées dans la partie centrale du graphique (D). On peut supposer que la collection évolue symétriquement, les films au niveau 0 disparaissent quasiment (E), puis c'est le tour des niveaux 1 et 2 (F) pour ne laisser dans le cas extrême que des films au niveau 3 (G).

Figure 6 : évolution du syndrome du vinaigre dans une collection



Analyse thermogravimétrique

Un deuxième aspect de ce travail a été de développer d'autres techniques pour évaluer l'état d'altération d'un support en acétate de cellulose. En effet la mesure de l'acidité à l'aide d'indicateurs comme les AD-strips se base sur la présence de vapeur acide dans l'environnement du film. Si le film a été ventilé par une exploitation récente, cette mesure peut être faussée. Quant à la mesure du pH par titrimétrie en solubilisant une bande de film et en neutralisant l'acidité par une solution d'hydroxyde de sodium à 0,1 N (d'après la norme ISO 10602), elle est longue et oblige à détruire 1 à 2 grammes de film. Nous avons donc étudié la possibilité d'appliquer l'analyse thermogravimétrique ou ATG.

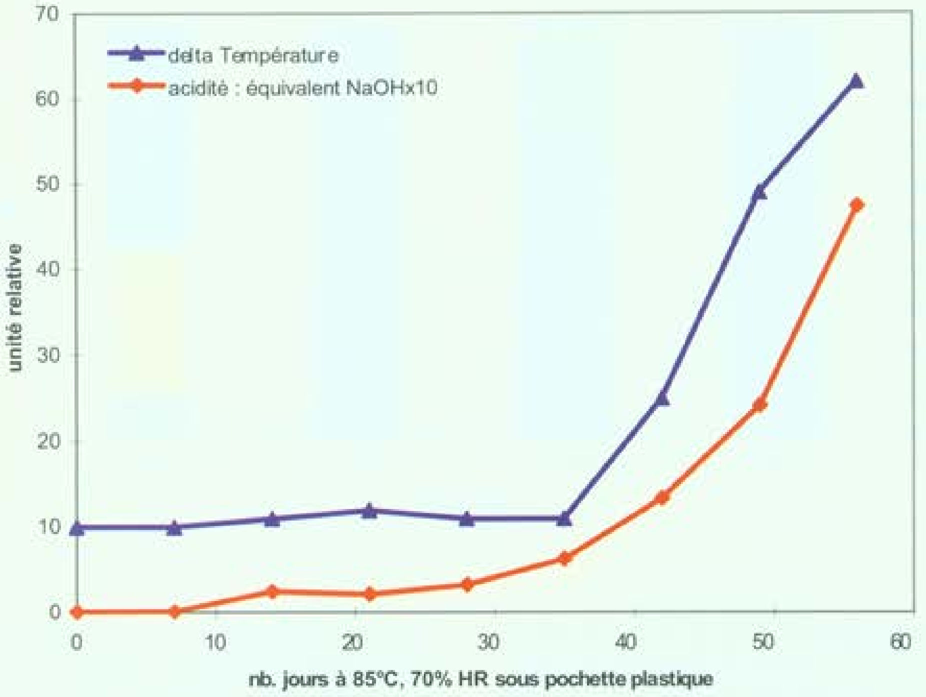
L'ATG consiste à suivre la variation de la masse d'un matériau en fonction de la température et du temps. Le changement de masse que subit l'échantillon lorsqu'on le chauffe correspond à un ensemble de processus chimiques et physiques qui peut permettre de caractériser les différents constituants par l'étude du profil des courbes. Cette analyse est micro-destructive, elle requiert 1 milligramme de triacétate que l'on met dans la nacelle de la balance suspendue à un ressort en quartz, l'ensemble étant placé dans un four. Un gaz composé de 20 % d'oxygène et de 80 % d'azote à une pression de 2,7 bars, balaie l'échantillon pendant l'analyse. Nous avons utilisé un appareil de Perkin Elmer TGA7 série 1020, le gradient de température est de 10 °C/min, en commençant à 150 °C jusqu'à 600 °C. La présence ou l'absence d'émulsion sur le micro-prélèvement ainsi que sa position - sur le bord ou au centre du film - ne semble pas jouer de façon déterminante sur les résultats de l'analyse.

Les courbes de perte de masse accusent une lente diminution de la masse et aux alentours de 370 °C à 380 °C une perte significative. Cette température est calculée précisément en traçant la dérivée première. Il semble que plus le triacétate soit dégradé, plus cette valeur tend à diminuer. La valeur la plus élevée que nous ayons trouvée au cours de cette étude est de 380 °C, alors que pour un support dégradé, elle peut descendre jusqu'à 340 °C. Pour la suite de cette étude, nous nous attacherons à suivre cette variation, que nous appellerons ΔT, entre la température de décomposition supposée initiale que nous avons fixée à 380 °C et celle mesurée après vieillissement.

ANALYSE THERMOGRAVIMETRIQUE DE FILMS VIEILLIS ARTIFICIELLEMENT

Afin d'établir une corrélation entre l'analyse thermogravimétrique et l'acidité du film, nous avons soumis des morceaux d'un film en acétate datant de 1973, à des vieillissements de plusieurs semaines à 85 °C, 70 % HR. dans des pochettes en plastique (PA/EVOH/PE, réf. Sudpack 90 microns). Nous avons également fait vieillir les films à l'air libre, mais le vieillissement était plus rapide lorsque ils étaient conditionnés dans des pochettes en plastique. Ces films ont été périodiquement analysés en thermogravimétrie et l'acidité libre évaluée par titrimétrie.

Figure 7 : comparaison ATG et pH



Les résultats sont reportés sur la figure 7. La courbe rouge correspond à l'acidité du film, et la courbe bleue à l'évolution du ΔT. On constate une étroite corrélation entre les deux courbes. Toutefois, il est indéniable que l'acidité est un paramètre plus sensible : entre 0 et 35 jours, alors que l'acidité croît de 0,007 à 0,63 (équivalent NaOH), la thermogravimétrie n'indique aucune évolution. Que signifie, en termes de dégradation, une acidité de 0,63 ? L'Image Permanence Institute a établi une relation entre la mesure de l'acidité par titrimétrie et la mesure réalisée par les indicateurs AD-strips : on voit dans le tableau 3 que 0,63 correspond au niveau 2.

Tableau 3 : correspondance entre AD-strips et acidité

Acidité évaluée par titrimétrie	Niveau donné par les AD-strips
<0,1	0
0,2	1
0,7	2
>2,0	3

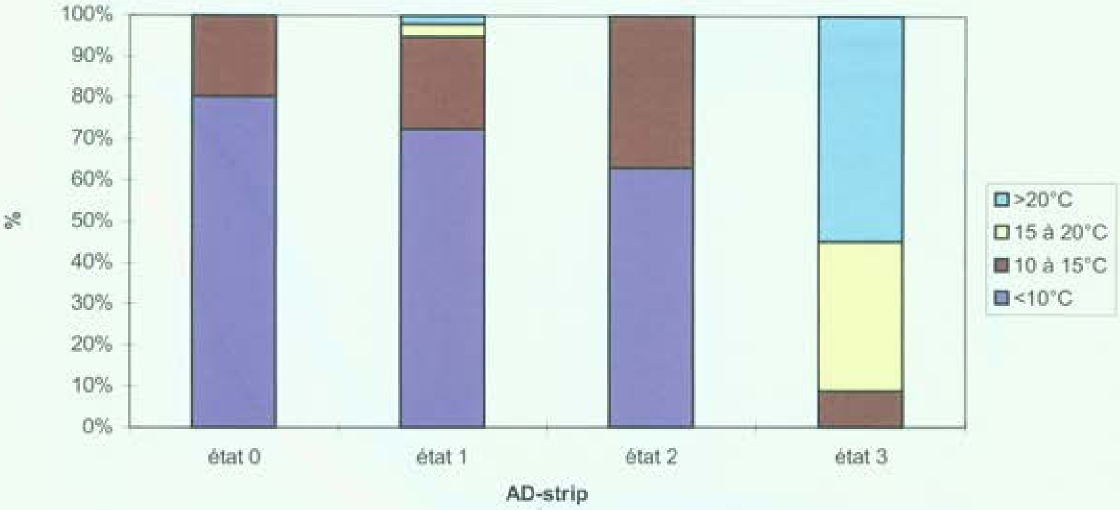
Ainsi l'utilisation de la thermogravimétrie devrait au mieux permettre de différencier entre deux classes de films, ceux dont la dégradation est inférieure au niveau 2 et ceux pour lesquels elle est supérieure. L'analyse des films cinématographiques stockés à Bois d'Arcy devra nous permettre de vérifier cette hypothèse.

ANALYSE EN ATG DE FILMS VIEILLIS NATURELLEMENT

Au cours de l'étude au service des Archives du film nous avons effectué sur les bords d'une centaine de films, un microprélèvement que nous avons analysé en ATG. Pour la centaine de films étudiés nous avons mis

en relation le niveau d'altération mesuré par les AD-strips et le ΔT obtenu par ATG..
Les histogrammes (figure 8) montrent que lorsque les AD-strips indiquent le niveau 0, 1, 2, les films présentent des variations dans leur température de décomposition qui vont de 0 à 15 °C. Lorsque l'on atteint le niveau 3 des AD-strips, les films présentent des variations de température supérieures à 15 °C. Ces résultats confirment les précédents : l'analyse thermogravimétrique ne permet pas de différencier les premiers stades de dégradation qui correspondent aux niveaux 1 et 2. Par contre, si le ΔT dépasse 15 °C, le film est au niveau 3.

Figure 8 : comparaison entre AD-strip et ATG



On note sur les histogrammes (figure 8) qu'il existe des cas particuliers, où les AD-strips indiquent un état 1 alors que les thermogrammes semblent indiquer une dégradation importante. Deux de ces cas se sont révélés dus à la nature du support, on était en présence de nitrate de cellulose et non pas d'acétate. Une erreur avait été faite dans l'identification des supports que la thermogravimétrie a permis de découvrir fortuitement. Dans les autres cas on peut supposer que les films ont été ventilés ou exploités récemment, et que le niveau d'acidité ambiant est faible et n'est pas représentatif de la détérioration du support.

Conclusion

Cette étude statistique nous a permis d'évaluer globalement l'état de la collection et de noter des disparités dans l'état de conservation des diverses strates. Cette approche s'avère une démarche intéressante : elle établit dans un délai relativement bref, un diagnostic qui permet de décider des priorités d'action en fonction de l'importance patrimoniale des divers éléments. Tous les éléments étudiés (films couleurs, noir et blanc, son, négatifs, interpositifs) ont entamé un processus d'altération mais les bandes magnétiques sont dans l'état le plus critique et réclament soit un stockage à température plus basse et à plus faible humidité soit un transfert sur un nouveau support. Le reste de la collection doit être suivi avec attention. L'indicateur AD-strip est un outil particulièrement performant qui permet de mettre en évidence la progression du syndrome du vinaigre dans une collection de films. L'analyse thermogravimétrique n'est pas aussi sensible. Elle permet toutefois de confirmer des stades d'altération, en particulier si le film a été ventilé et que l'acidité ambiante ne permet plus d'évaluer son niveau de dégradation. Cette analyse pourra s'appliquer, par exemple, à l'évaluation de la dégradation de plans-films.

Remerciements
Ce travail a été réalisé avec l'aide financière du CNC et les précieuses contributions de Martine Gillet et de Cécile Guérin (CRCDG), de Nicolas Ricordey et de Olivier Brech (CNC)

Discussion

Dietrich SCHÜLLER

I would like to clarify something. What is the format of the examples used?

Bertrand LAVÉDRINE

Ce sont les supports magnétiques qui ont servi pour l'enregistrement des films. Je n'ai pas ici l'information sur le format mais je pourrai vous la donner tout à l'heure. Y a-t-il quelqu'un des Archives du film qui pourrait répondre ?

Michelle AUBERT

C'est un format 35 millimètres.

George BROCK-NANNESTAD

Il s'agit donc de films perforés magnétiques pour la production de film et non de bandes magnétiques pour la production de l'audio.

Bertrand LAVÉDRINE

Tout à fait. Il s'agit d'une bande perforée qui sert à la production du son des films de cinéma. C'est un intermédiaire des productions des films cinématographiques.

Bruno DESPAS

La dernière intervention de la matinée nous est présentée par Mark-Paul Meyer et Paul Read. Elle a pour thème la conservation et la restauration des films atteints par le syndrome du vinaigre. Mark-Paul Meyer est diplômé de philosophie de l'université d'Amsterdam. Il a été critique cinématographique. Il est maintenant responsable des collections et de la restauration au Nederland Filmmuseum. Paul Read a passé une partie de sa carrière chez Kodak. Il a d'abord été chercheur puis directeur de la Kodak photography school où il a enseigné en particulier la post-production et la technologie film. Il a été ensuite responsable d'exploitation au laboratoire Kay de Londres. Il est aujourd'hui consultant indépendant, spécialiste de la post-production, de la restauration des films d'archives et plus généralement des technologies numériques appliquées aux films.

Restoration and preservation of vinegar syndrome decayed acetate film

Mark-Paul Meyer
Nederland Filmmuseum - Pays-Bas

Paul Read
Soho Images - UK

DESCRIPTION OF AN AFFECTED COLLECTION

While in India recently I (PR) looked at a typical laboratory collection of film with vinegar syndrome decay. In the tropics this problem is very serious in quite recent film. The collection commenced in 1974. Vinegar decay was common, with about 12% of film over 20 years old effected, and about 3% in film up to 12 years old. The collection was almost entirely of 35mm colour negatives of feature films and a few prints. The temperature varied from 20-38C, humidity 40-80%RH, ambient conditions for the area.

The films most likely to decay were considered, by the staff, to be the following:

- Varnished, "coated" and 3M Photoguard treated negatives (often quite recently)
- Colour Print films made on ORWO print film
- Films stored in polythene bags
- Perforated Magnetic Sound track film stocks.
- Film that have been "polished" to remove base scratches.
- The worst period is considered to be the mid 1960's to early 1970's, and earlier film less effected.

These are all groups that many of us believe are particularly vulnerable.

As with other collections of decaying film, I was struck by the range of symptoms of decay. Films were:

- sticky, the coils stuck together in the worst cases
- limp, having lost all stiffness
- crusted with crystals of plasticizer,
- damp, even dripping with plasticizer,
- blackened, almost appearing to be charred by fire,
- emulsion becoming detached from the base
- emulsion decaying and images lost before the base decays
- the film edges curled and creased, often with severe cockling
- Shrinkage, sometimes with no other apparent symptoms
- the film crisp and brittle, curling into a tube and finally shattering

Some of these symptoms were in combination, but apparently not part of an easily recognized sequence of decay. Not all films smelled strongly of acetic acid, and some did not smell at all. Some of the most "charred" and dried film did not smell. Some technicians think that some decay may not be vinegar syndrome decay but other problems of storage, and that some decaying film suffers from several problems at once. Certainly it was well documented, prior to the recognition of vinegar syndrome, that some acetate film (and diacetate and butyrate) becomes crisp, very shrunken, brittle and dry, and can shatter into fragments, with no apparent vinegar smell and no classic symptoms of vinegar decay.

THE GAMMA PROJECT

That these problems in particular occur in the tropics has been common knowledge for many years, but only quite recently film archives in Europe realised that vinegar decay isn't just a problem of countries with a warm and humid climate. In August 1998 the Association of European Film Archives (ACE) sent out a questionnaire to 31 archives in Europe. As a result of this questionnaire it became evident that some archives already have a serious vinegar problem. Even more significant was that, although extensive research on vinegar syndrome has been carried out and numerous papers published, there is no clear set of universally accepted recommendations for the handling of already decaying film to limit further decay. A link between certain types of film and the risk of decay is known by inference or observation. Known examples are coated and varnished prints, and magnetic striped film. However no recommendations exist for the treatment of such film. Nor is it known if it is possible to decrease the risk of decay by treatment. Nor is it known what particular problems occur or how they can be overcome during restoration.

It was after the evaluation of the results of the 1998 questionnaire that the ACE asked the GAMMA Group, a research group of European Film Archives and Film Laboratories, to bring together the results of academic research on the one hand, with empirical data, daily experience, and needs of archives on the other. With the help of several archives the GAMMA Group created a list of the questions to which answers were still needed, covering storage, handling, preservation and restoration. It was the GAMMA Group's idea to list all the possible questions relevant to archival practice, and eventually to provide the answers. This process of formulating questions and answers is still going on and the final results will be presented during the Archival Film Festival – Cinema Ritrovato – in Bologna, next July.

In the mean time, some Gamma Group members and a number of other archives that have technical departments with a deep interest in acetate decay were asked to provide answers to the questions. The questions were also sent to a group of film laboratories in India. Although the questionnaire covers all aspects of storage and conservation the Gamma Group realized that a wide range of methods are or were in use to facilitate printing of partially decayed film, but no documented evaluation of effectiveness has ever been done. It was decided to list these restoration techniques in preparation for a series of tests to see which could be recommended, and to provide data for other researchers.

The following are the results of a trial using 7 laboratories (all of which have some vinegar syndrome experience), 4 archives, and 4 commercial collections (all in London); 15 questionnaires in all. All the laboratories provided replies to most of the questions. The archives did not have their own laboratories and were principally small size local or specialist collections. The questionnaire was followed up by telephone or direct contact in every case as filling in a questionnaire seems to be a difficult process for archivists, and even more difficult for laboratory technicians!

The results of this extensive request for information are still coming in, and so this is a preliminary report (which may help to modify the questionnaire to extract more data) which deals only with restoration aspects.

ISSUES ARISING FROM QUESTIONNAIRE RESPONSES SO FAR

1 Confusions over the identification of vinegar decay and other time-related effects

It seems that a number of time-related effects of safety films are frequently considered to be vinegar syndrome, when they are may be another effect. The following effects are often recorded as vinegar decay:

1.1 Shrinkage, shrivelling, loss of flexibility of cellulose diacetate and butyrate films. These film bases were used for many 16mm films prior to the introduction of cellulose triacetate. Almost all early 16mm black and white film was described as cellulose diacetate and Kodachrome film was introduced in 1936 on a "cellulose butyrate" base. Diacetate is recorded very rarely as suffering from vinegar decay, butyrate does not appear decay in this way. In India extensive 1930's 16mm film collections are shrunken and often shrivelled to crisp and brittle fragments but are not generally suffering from vinegar decay, whereas 1970's 35mm films are badly decayed. Two extensive collections of early Kodachrome, one in Chicago, the other in the UK, all on "butyrate base", are in generally excellent condition. *(Note: although manufacturer's have often described their film bases as if they are single cellulose esters, it has been brought to our attention by Jean-Louis Bigourdan of IPI that bases described as, specifically, "cellulose butyrate" and "cellulose propionate", were mixed cellulose esters, and included acetate as well. Clearly this is another area where more documentation, and base analysis of collection's would be helpful, to establish where risk of decay is increased.)*

1.2 Loss of plasticizer by acetate films. The plasticizer can leave the film as a sticky semi-liquid

1.3 deposit which may also crystallise on the film surface. This may be at the same time as vinegar decay but may occur without any vinegar decay as exemplified by the smell or presence of acetic acid.

1.4 Film that is losing it's plasticizer becomes first limp and without the characteristic stiffness of fresh film, and then as the plasticizer evaporates or crystallizes, becomes brittle and dry.

1.5 Evaporation of water from the emulsion, and also the film base. The brittle crazed emulsion, which sometimes cracks off film, is often due to high temperatures and water loss. It seems that the film base too can loose water to the extent that it becomes brittle. Several laboratories know this to be the case and re-humidify the film while still in its roll by standing for some days over a water bath. This is well known to be effective.

2 Special risk films

In a paper published some years ago Michelle Edge recorded the risk of decay to film coated with ferric oxide magnetic sound-tracks. For example, the enhanced incident of decay in these films is well documented in the Scottish and North West Film Archives in the UK, which have collections of 1965-1980 16mm Ektachrome EF news-film, which was striped prior to exposure and processing. Sound was recorded on the film during exposure.

The Royal Belgian Film Archive has documented a significant increase in decay in print films that have some form of coating, used to protect release prints from damage due to handling.

The 3M Photoguard system of UV hardened polymer coating which is more recent than the use of varnish and lacquers, is considered to increase the risk of decay by Indian laboratory technicians. This is important since the technique is used to protect original negatives, rather than prints.

These and other archives are unsure of the best approach to the conservation of their collection and pose important related questions, of which the following are the most significant:

2.1 Is the decaying film "infectious"? The increased acetic acid given off the decaying film might effect other film, either similar film not so far down the decay process, or unstriped film nearby.

2.2 Can film decay be influenced by treatments that reduce the local acetic acid? The most obvious technique is to wash film. Acetic acid is very soluble and after washing the level of acid is substantially

2.3 reduced, to virtually zero concentration immediately following the wash. This is a reasonably low cost option and if the life of a film could be extended this would be a valuable technique.

2.4 Is there any benefit in removing the varnish coatings on print films? Where this is possible (and sometimes it is not) the internal acetic acid content can be expected to fall, and this is presumed to extend the films life. This is a complex question as most film coatings can only be removed by organic solvents such as are used for film cleaning. Some or all of these solvents appear to remove plasticizers from the base as well.

3 Special treatments for vinegar syndrome film

It seems that almost every laboratory, whether set up as part of an archive, or commercial lab with a service to archives, has techniques they use to deal with vinegar syndrome film. In every case the purpose seems to be to ensure the film will pass through a printer and a print made. So far quite a number of techniques have been listed. It is clear that the fact that "decaying" film may be suffering from a range of time-related defects confuses the situation. Some techniques are quite clearly ineffective, others are reported to be effective, and some are better for other effects but are used as a general approach.

3.1 1.1.1.trichloroethane, used for many years, is now being replaced by perchlorethylene, isopropyl alcohol, and hydrofluoroeythylene is also being tested. All film in a film laboratory is solvent cleaned prior to printing, and during the laboratory post production a negative may be cleaned many times. It is clear that these solvents do remove the plasticizers from the surface of decaying film, and do reduce or remove the stickiness of film, and in that respect help to make printing possible. However, they presumably may remove plasticizer from the film base as well, and therefore increase the problems. Solvent cleaning is reported by one commercial laboratory as being "essential" for limp film, but "disastrous" for already brittle film. Research in this area is vital - not simply to establish whether solvent cleaning is wise, but also to establish whether repeated solvent cleaning effects the life of a film.

3.2 Re-washing. Re-washing is often used to treat scratches in the emulsion of a film. The emulsion of the film is immersed in water, allowing the gelatin to soften and swell. The edges of the scratch will anneal and as the film dries they will stay together. The wetting time is usually kept as short as possible, and special solutions can be used to swell the top emulsion layer. Several laboratories said that re-washing slightly decayed acetate film appears to make the film less limp and assists printing.

Some laboratories have equipment that re-washes and cleans the films in one single operation, others re-lace modern processing machines. Kodak recommends a re-washing process called RW1 for removing emulsion scratches and for cleaning which uses a temporary re-lace of an ECN2 processor.

Kodak Rewash RW1

Prebath PB-6 and it's buffers (normally part of the ECN-2 Process). 21C for 2mins with a recirculation rate of 20-40L/min. Swells the emulsion, causing the scratches to be filled and embedded dirt particles to be released and buffed off.

Wash. 31-38C. 3 min with a wash rate of 300ml/min.

Final Rinse. 21-38C. 10 secs with a recirculation rate of 20-40L/min; the last solution in the modern ECN-2 process FR-1 is generally used for this.

3.3 Some laboratories simply re-process film through the same process used to develop the film.

3.4 Some laboratories re-process the film through a Black and White Print process whatever the film type.

3.5 (Note: Another solution formula has been used recommended many years to re-wash black and white film by Kodak and others:

Re-wash Solution:

50gms per litre of sodium sulphite,
50gms per litre of borax.
A high pH is essential.
Concentration and temperature is not very critical.
1 minute at 20C
Water wash for 10minutes at 20C
Final rinse stage
1 500:1 Photoflo solution to help uniform drying.

So far we have not found any laboratory using this formula.)

4 De-shrinking treatments.

Since the introduction of printers that can handle severely shrunken films as a routine (like the Debrie TAI and the BHP Modular) there is less need for de-shrinking processes. However, two of laboratories contacted mentioned that they had used de-shrinking treatments on vinegar syndrome film to enable the film to be printed, and this is successful. All are based on the use of acetone. De-shrinking with acetone is reversible - in time the film shrinks again. Some film re-shrinks so quickly, in just a few minutes, that the process is not practical.

4.1 Two formulae are worth mentioning:

A 1:1:3 mix of acetone, glycerol and water. The film, in its original roll, is placed in a closed metal container, a metal grill above the liquid surface.

Months at 10C or weeks at 30C may be needed to re-extend the film back to near its original dimensions. The process can be accelerated, especially for large rolls, by placing the roll in a reduced pressure [down to 30mm Hg], preferably at 25C and held at this pressure for several hours or days.

Sometimes the acetone is supplemented with Camphor [a plasticizer for nitrate film] or a methyl phthalate [plasticizer for acetate film] and the rate of de-shrinking is then slightly reduced.

4.2 The **Redimension** Process.

This is a Canadian franchised mixture of various solvents and plasticizers in acetone, and is also effective. The formula is not published but seems to be similar or the same as to the mixture above plus plasticizer, and works more slowly. It is done in a metal container or in a reduced pressure vessel to speed the process up.

5. Re-humidifying.

Emulsions become brittle due to loss of water and may also shrink more than the film base producing a cracked image. Occasionally the emulsion flakes off. A widely practised technique is to stand the film roll on a support over water. This is very effective although it may take weeks in low temperatures before the cracking flakes appear to link up. It has been reported that the film base may be similarly re-humidified as the film does seem to de-shrink under these conditions, and certainly becomes more flexible and less brittle. Two laboratories reported that they had used simple re-humidification on vinegar syndrome film to good effect. One company reported trying the **Rehumid Process,** another franchised Canadian procedure, designed "to replace the loss of a film's water content with a less volatile agent". It seems to be another cocktail of acetone, water and oils. It is effective in making cracked, brittle and shrinking emulsion more pliable, and is also used in a vacuum chamber.

6. Vacuumate

Several commercial laboratories have said they believed the Vacuumate process to be the best treatment for decaying film, although only one has used it. Restoration House Inc of Canada introduced the Vacuumate process more than 30 years ago as a franchised treatment to improve the suppleness and lubrication of films and to give some protection from fungi. It has been used especially for cinema prints prior to being sent to the tropics and to treat films that have already been effected by fungi or bacteria. The original literature from the 1960's describes all the symptoms of decaying acetate film we are familiar with today, and describes Vacuumate as the sure fire protection from decay and a cure for it!

Again the process takes place without unwinding the roll and without passing the film through any liquid. The reels are placed in a vacuum chamber and the pressure is reduced to 30mm Hg. The temperature is controlled to 25C. In a sequence that takes about 21/2 hours five separate chemical mixtures are releases into the chamber. These vaporise and are taken up by the film emulsion and/or the film base. Vaccuumate does have some de-shrinking effect since one solution contained Acetone.

With comments, in parenthesis, from Restoration House literature, the process is as follows:

Solution 1 Acetaldehyde ("reduces the excess moisture from processing").

Solution 2 Turpentine, various natural oils, acetone and 1,1,1 Trichloroethane ("conditions the base and emulsion, providing protection against drying and brittleness")

Solution 3 Acetaldehyde, Isopropyl Alcohol, water and oils ("hardens and toughens the film's emulsion").

Solution 4 1,1,1 Trichloroethane, Paraffin Wax and oils ("provides a permanent lubrication, ensuring that the film remains supple").

Solution 5 The same as solution 4 plus a mineral oil ("provides an additional external lubrication for release prints to be projected").

Some components probably have no, or virtually no, effect. Some like acetone have base de-shrinking properties. Others like acetaldehyde are very effective emulsion hardeners and fungicides (but are extremely unpleasant to handle and subject to strict safety requirements). Film is effectively lubricated by these oils. Whether the film life is really improved seems to be unproven, although films destined for the tropics were certainly made more resistant to fungal and bacteria attack.

Soho Images in London ceased to use this process for archive film when it did not seem to benefit decaying film, and on new film when there seemed to be no evidence to support the claim of an increased film life. The reputation of this process as a rejuvenator does not seem to be warranted by the results.

7. Water based "hardening" solutions.

The nature and chemistry of decaying structure of cellulose acetate film base is clearly important in the design of a method for restoring dimensional stability of film. Two laboratories admitted to testing a water based hardening process aiming to, either delay the onset of vinegar syndrome decay, and/or enable some already decaying film to be printed. An effective process is likely to have some commercial value. Consequently the methods being tested are well protected. It seems likely they are a multistage approach, using water based processes first, to provide base "hardening", followed by a solvent clean, to remove plasticizers and perhaps excess treatment chemistry.

One other laboratories uses a simpler sequence of treatment that they have found give a benefit to decaying film in order to improve the printing. This is re-washing, using either a black and white print process or RW1, followed by

Solvent cleaning using Isopropyl alcohol.

COMMENT

Recent changes in film handling equipment have made some of these chemical processes virtually redundant for their original purpose. Specialist printing equipment for archive film no longer needs film of exactly the standard pitch between the perforations. Also quite badly decayed film can be scanned on a continuous motion capstan drive telecine-type scanner without the necessity for the film to be in the same condition as for a film printer, so digital restoration, if affordable, is a new option.

These old techniques are therefore being reinstated as no other technique allows the film to be printed or even unwound, but their efficiency on vinegar syndrome film seems a little in doubt

Film archives also need to be sure that any process their film is being put through will not impair the film or the image, unless they are sure that there is no other way. In 1997 NFTVA decided not to permit the use of any of these treatments as a routine by the laboratories that restored or preserved their collection. This was simply because there was no evidence that the long term effect on the film had no effect on the onset of decay, or any other deleterious effect. It was also clear that modern printers and telecine scanners, plus the judicial use of aquarium-type total immersion wet gates made these treatments unnecessary.

The test survey so far has not revealed any revolutionary new treatment procedures, and has actually shown that no effective procedures for restoring vinegar syndrome film exist.

INTERIM LIST OF AREAS FOR INVESTIGATION.

1 Most acetate film probably suffers from several related or unrelated decay syndromes as it ages. These need to be disentangled and identified before suitable techniques can be planned.

2 There may be several different physical symptoms of vinegar syndrome decay. The literature does not catalogue these or explain why. These physical symptoms, all or most of which influence the problems in printing, may need different solutions as different conditions result in different problems during printing.

3 Since the acetic acid from decaying film is "infectious" can decay be slowed by washing out acetic acid? This is widely believed to be the case and some laboratories sell a washing service. It is relatively cheap to do but not evaluated.

4 Does solvent cleaning increase or decrease the risk or likelihood of decay? All, or almost all film is solvent cleaned prior to printing as a routine, and solvent cleaning decayed film removes the sticky plasticizer crystals.

5 Film in early stages of decay suffer from dimensional instability and some techniques try to deal with this by chemically "hardening" the film base, probably not very successfully. Is this a sensible or feasible possibility?

6 Some archives avoid chemical and physical treatments, on the grounds that the effects in the future are unknown. Some film laboratories are still using complex chemical treatments. What is the effect of these treatments on the future "life" of a film? Does this matter if the treatment is effective, and printing achieved?

Synthèse des 4 conférences portant sur le syndrome du vinaigre

Bruno DESPAS

Jean-Louis Bigourdan nous a parlé de l'efficacité des différents types de stockage, de l'influence des macro et des micro-environnements sur la dégradation des films. Il est revenu sur l'utilisation d'une méthode simple de contrôle de l'acidité, qui est le principal indicateur d'évolution du syndrome du vinaigre, mise au point par l'IPI. Au vu de ces différentes données, Jean-Louis Bigourdan nous a proposé une stratégie de gestion des éléments qui composent les collections.
Michele Edge nous a permis de rentrer dans la structure moléculaire des supports. Elle a insisté sur le fait que, s'il ne peut exister de matériaux audiovisuels permanents, il faut pouvoir en identifier les risques par l'utilisation, entre autres, d'indicateurs non destructifs. Elle a souligné l'influence de la présence d'ions métalliques dans la dégradation, constatée par l'ensemble de la communauté, qui affecte de manière plus importante les supports magnétiques perforés.
Bertrand Lavédrine nous a fait part d'une très intéressante analyse statistique de la décomposition des éléments dans une grande archive, qui met en évidence, encore une fois, l'état alarmant des films magnétiques perforés.
Enfin, Mark-Paul Meyer et Paul Read nous ont présenté les résultats des travaux du groupe Gamma sur l'influence des procédures de restauration et de traitement des films dans les laboratoires sur l'évolution du syndrome du vinaigre. Ils ont mis en évidence les films à risque (traitement photoguard) et l'influence des techniques de laboratoire conventionnelles.
Avez-vous des questions pour les différents intervenants ?

Ed ZWANEVELD, National Film Board of Canada

My question is addressed to Paul READ. In the 1960s, experiments were carried out on the chemical hardening of film. At that time, alum was used. I could look into my notes to find the exact date.

Paul READ

Without being absolutely certain, I believe that one of the hardening materials in use is chrome alum.

Bob CURTIS-JOHNSON, Alaska Moving Image, US

My question is addressed to Michele. She listed 925 film collection tests, 90 of which had magnetic striping. How many other mag-stripes were used? What percentage of those showed decay?

Michele EDGE

I cannot remember exactly, since the experiments took place in 1988. I believe approximately 20% of the magnetic tape samples showed Vinegar Syndrome. A very large collection of acetate film was sampled. Yet, Vinegar Syndrome was present far more frequently in the samples with the magnetic track.

Sean DAVIS, England

I am more involved in sound archives. In general, we have large holdings of recording tape as opposed to perforated film. Acetate-based tape dries out, leading to dimensional problems and making it more difficult to handle. However, the Vinegar Syndrome is quite rare. I have a collection a still photographs from 1911 onwards. Those negatives show no deterioration whatsoever.

Michele EDGE

It is very difficult to say; everything depends on the storage conditions and the specific past history. The collection from the film archives contains samples from a variety of different regions. Without knowledge of the past history, it is difficult to make correlations of that kind. This is why it is very important that there be some kind of statistical evaluation similar to that described by Bertrand this morning. That would allow us to assess and make those correlations. The first real attempt at a statistical overview was a survey by Horvath, who examined nitrate film. He found interesting patterns between certain manufacturers and could pinpoint the changeover from nitrate to acetate. Unless one knows the pre-history and the storage conditions, it is very difficult to make ultimate conclusions.

Peter ADELSTEIN, Image Permanence Institute

The film from 1911 is obviously cellulose nitrate, considered to be a very unstable material. That is not necessarily true. At the time when it was manufactured, some of it was quite good, while some was very poor. That which has survived tends to be very good. The material that could have stirred up some concern disappeared long ago.
I would also like to comment on cellulose acetate butyrate. Laboratory tests have shown that this material behaves in a manner similar to that of cellulose tri-

acetate. I have no idea why Kodachrome looks good. Another concern relates to aqueous treatment. When film is highly degraded the emulsion can become soluble in aqueous solution. Thus, while it is possible to treat the film and save the film base, the image might be lost. That is the dubious advantage.
Lastly, I would like to bring a bit of historical perspective to the discussion, being older than anyone else in this room! The first time we ever experienced Vinegar Syndrome was when working with Indian film. In the 1950s, the Nehru government sent some film to Kodak. No one understood the problem at the time. When we realised that the film base had become deacetylised, we attributed it to the very high, humid conditions that existed in India. We did not realise the magnitude of the problem.

Paul READ

Your point about using water-based material for some of this decayed film is very interesting. The laboratory that provides us with the information for this knew that, if it had gone too far, the emulsion would be removed. They certainly felt that washing had a beneficial effect.

Dietrich SCHÜLLER

Quarter-inch acetate-based audio tapes were used well into the mid-1960s. We first learned about the Vinegar Syndrome at the Second Joint Technical Symposium in Berlin and we immediately looked into the matter at the Austrian Academy of Sciences. We discovered that a critical mass of acetate is required to trigger the process when using magnetic perforated films. This is not true when using small quarter-inch tapes. The mass of acetate present in the stocks is not the same. I should also specify that all of the tapes that presented a smell were ventilated. After that time, they did not show any further signs of deterioration.

Paul READ

I would like to add some other information about the presence of iron in photographic emulsions as well. If one looks back to the silent period, Prussian blue is widely used as a toner on nitrate film. Then, starting in the mid-1920s, that blue (ferric cyanide) was used for two-colour systems. It was, in fact, the two-colour primary. Many of these films were acetate films, especially in the 1930s. The first tri-acetate films later appeared, in the 1940s. Despite the huge amounts of iron present, many of these films do not exhibit any more Vinegar Syndrome decay than we might have expected.

George BROCK-NANNESTAD

It is my distinct impression that we are dealing with the surface area for weight ratio. Of course, in magnetic tape for consumer use or professional use, the area is much larger in relation to the thickness, amounting to one-seventh the thickness of the 35 millimeter film. The volume is reduced by as much, while the distance from the centre is much smaller. This should probably be modelled and compared with reality.

In film stock used for photographs, diacetate predominates. Neither nitrate nor triacetate are used. Thus, for film from 1911, I would suggest diacetate.

Michael FRIEND

Paul, I would like to make a comment and ask a question. Firstly, I can provide quite a bit of evidence of the acetate deterioration in Kodachrome. There is no doubt that Kodachrome does deteriorate in that way, despite the fact that the colour holds up fabulously well. Have you uncovered any evidence or performed any research on the incompatibility of these various treatments (i.e., 3M's processes with vacuum dimensioning, the move from soft processes to harder processes, cleaning)?

Paul READ

No, we have not performed such research. It is only the last few months that we have realised the prevalence of these techniques. They are not necessarily well-advertised. It is now very essential that we begin to look at these and elaborate some recommendations for or against this method, specifying in which situations it could be useful.

John REED

My question is primarily directed to Paul, but could also apply to others. I was interested in the comment on the acetate base-to-coating ratio. What are your most recent results? We received a relatively recent collection including 16-millimeter and 35-millimeter film, some of which includes black and white zones for the subtitles. We have experienced considerable difficulties as a result of the Vinegar Syndrome on those black and white zones. The film dates back to 1986 and the problems have now reached 2.5. It is interesting to see that the film is so recent, yet the level so high.

Paul READ

I am sure the archives will have far more information on that. The youngest film on which I have observed the Vinegar Syndrome is from India. It is seven years old and is a EC02 Kodak color negative. I wrote down the emulsion level, but no longer remember it. It had leapt out of the polyurethane bag and was falling off the wall of acetic acid. The edges of the film were already growing brown. This is the youngest film I have ever witnessed with such problems. The extremely poor storage conditions are without a doubt responsible for this.

Bruno DESPAS

Je remercie l'ensemble des intervenants pour la grande qualité de leur prestation. Merci également au public pour son attention et sa participation.

Cold storage using the fica apparatus (Poster)

—— ——

David Walsh
Film and Video Archive, Imperial War Museum, London

What is it?

The FICA (Film Conditioning Apparatus) was developed by the Swedish Film Institute to solve the problem of long-term storage of colour film. The equipment provides a means of pre-conditioning and vacuum sealing film prior to cold storage.

The Theory

Current recommendations for storing colour film vary, but typically a temperature around -20°C and a humidity in the region of 25%RH are quoted.

The Swedish Film Institute considered two possible approaches to cold storage:

a) conditioning at a constant relative humidity (25-30%RH) with the temperature reduced in stages allowing the films to become acclimatised at each stage, followed by storage at controlled humidity and temperature.
b) conditioning at 25-30%RH at 20°C, followed by vacuum packing in sealed bags and storage in a conventional freezer.

The research, supported by film manufacturers such as Kodak, established that there is no significant difference in effectiveness between the two methods, with a suggested lifetime based on accelerated ageing tests of at least 500 years for Kodak 5243 colour intermediate stock kept at -25°C.

Disadvantages of method (a)

- Conditions of -5 to -20°C and 20 to 30%RH represent an extremely low moisture content: a cold store held at such stringent conditions is expensive to install and costly to run.

- A breakdown or fault in the air conditioning machinery could result in moisture settling on films and the possibility of water damage.

Advantages of method (b)

- Pre-conditioning allows storage in any type of commercially available freezer of any size since the film is sealed in its own dry micro-climate.

- Films do not suffer in the event of power failures or freezer breakdowns.

- Films can easily be moved out of store for stock-taking, freezer maintenance etc.

- Running costs are low.

Disadvantages of method (b)

- Pre-conditioning is labour-intensive since each film must be individually conditioned and sealed.

- Pre-conditioning requires the purchase and maintenance of conditioning apparatus

The Apparatus

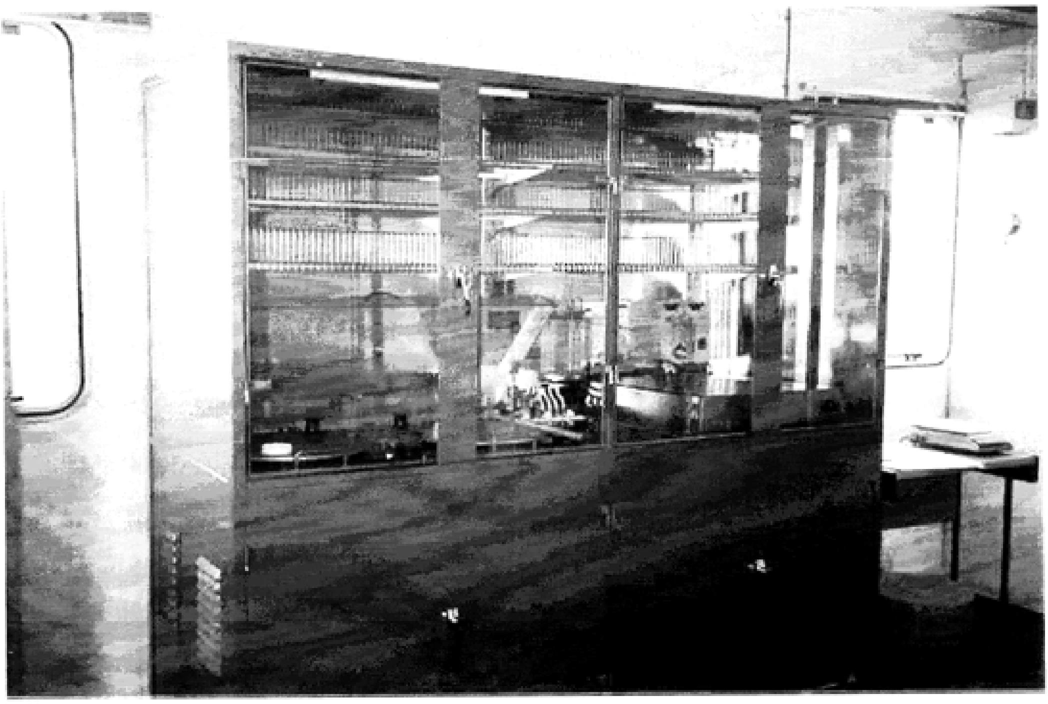
The FICA equipment consists a film winder, shelves and a vacuum sealing device contained in a cabinet in which the conditions are controlled at 20-25%RH and approximately 20°C.

Metal foil bags are provided for packing the films.

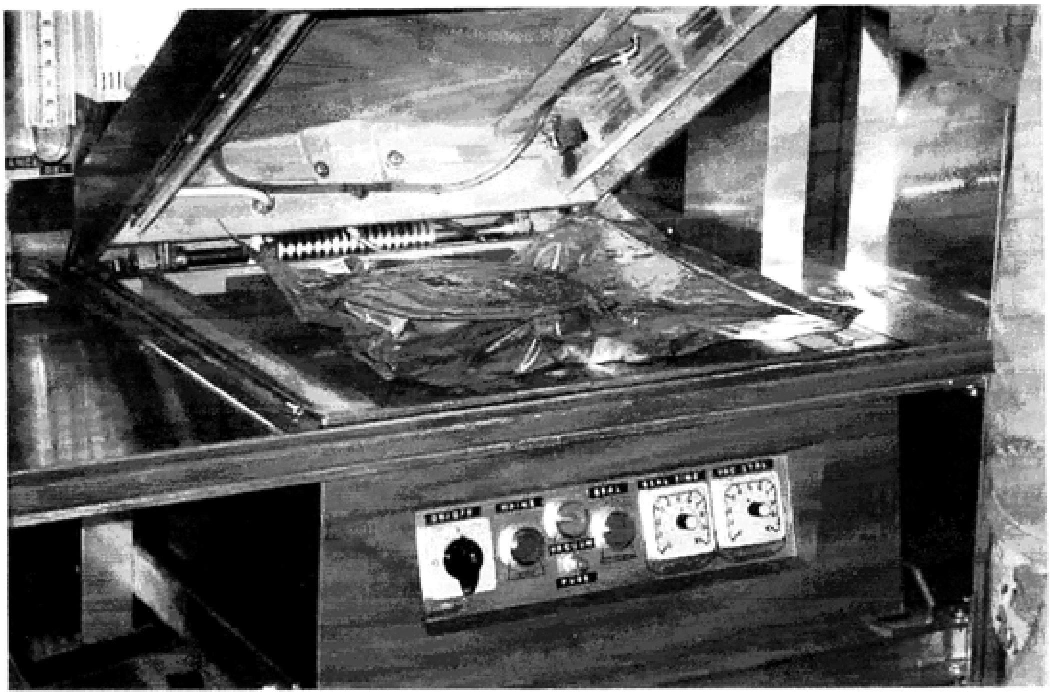
The Technique in Practice

Once the conditions inside the cabinet have stabilised at the recommended temperature and humidity, the film is wound through at low tension. The resulting loose winding facilitates the release of moisture from the film and allows for shrinkage during the process.

The film is placed on one of the shelves in the cabinet and allowed to reach equilibrium with the cabinet conditions.
The process generally takes 1 to 2 weeks. The film can be weighed at the start and during the process to monitor its progress. It is taken to be completely conditioned when there is no more weight loss - total weight loss is typically a little over 1.5%.



The film is placed inside a foil bag, which is placed in the vacuum sealing device. This device automatically evacuates most of the air from the bag and then seals it by welding. The sealed bag is placed inside a second bag and the process repeated.



The film can now be removed from the FICA cabinet and placed in any suitable cold store. The Imperial War Museum stores the conditioned packages in plastic filmcans in coldrooms approximately 20 cubic metres in size at -20°C.

For access, the film must be removed from the cold store and allowed to warm up in normal room conditions before opening the bags (at least 24 hours is recommended). The opened film should be allowed to reach equilibrium with normal humidity over a period of at least another 24 hours before use.

An alternative approach to storing films at low temperature

Instead of pre-conditioning the film before sealing it, the film can be sealed in a bag containing a buffer (such as silica gel). Provided the buffer is itself conditioned at the desired relative humidity, the buffer will absorb moisture, and the film desorb moisture, until equilibrium is reached at approximately the right level. Because the buffer has a greater capacity for moisture than the film, it is able to absorb the necessary moisture without any marked change of its equilibrium moisture content. (A system of this sort is commercially available for storing photographs, incorporating packaging, buffers and indicator patches to warn when moisture levels become too high).

Advantages of a "buffer" system.

- There is no need to have a film conditioning cabinet.
- The system is self-correcting in the event of migration of water vapour through the packaging. A certain amount of water can be absorbed by the buffer without significantly affecting the moisture level of the film.
- The system is effective with simpler packaging (eg bags taped closed)
- Indicator patches give a clear warning of packaging problems.

Disadvantages of a "buffer" system.

- The buffer still needs to be pre-conditioned to the correct moisture content.

- The film still needs to be wound loosely to guard against damage from dimensional changes.

- Simpler packaging which allows water vapour through means closer monitoring is needed.

- There may be concerns about introducing additional material (ie the buffer) in close proximity to the film.

Some questions answered

Surely when air in the bag is cooled, the relative humidity will rise and the film will end up in a humid environment?

No. Because the amount of air in the bag is small, the amount of moisture in the air is tiny compared with that contained in the film. The film will act as its own "buffer" by absorbing a small amount of moisture from the air until equilibrium is reached at roughly the same RH as that set during pre-conditioning. The change in moisture content of the film will be negligible.

Is there a danger of ice forming within the emulsion of the film?

No. Water within the base and the emulsion of film is not present in the same form as free water. There is no danger of it forming ice crystals in these conditions.

Is there a difference from the film's point of view between cold storage in a fully air-conditioned, humidity-controlled vault and cold storage using the FICA system?

The moisture content of a film in conditions of constant relative humidity remains roughly the same at any temperature. A film conditioned at 25%RH at room temperature will therefore contain about the same amount of moisture as a film stored at 25%RH and -20ºC, so there is no significant difference between the two methods.

How effective are the bags as a vapour barrier?

The Imperial War Museum makes spot checks on the weight of the packages for any sign of moisture ingress. So far (after 15 years) there has been no sign of any problems.

Some questions asked

The FICA system allows the packaged film to be placed immediately in the cold store after conditioning at 20ºC. What is the effect of such a sudden -40ºC drop in temperature?

What is the effect of sealing up films prone to decomposition, such as nitrate and vinegar syndrome acetate? Is the decomposition arrested sufficiently for the autocatalytic effect to be insignificant?

Does any organisation actually operate humidity and temperature controlled stores at these levels (25%RH and -20ºC)? Are the engineering and operating problems soluble?

Is the relative humidity level actually important at low temperatures? We know of the case of the films found in the Yukon permafrost which were untroubled by their ordeal. Is there any research on the effect of moisture content on longevity at low temperature (-20ºC)?

The author would be interested in any feedback on the above.

Traitement des films cinématographiques contaminés par les moisissures
(Présentation par affiches)

Malalanirina RAKOTONIRAINY, Fabien FOHRER, Bertrand LAVÉDRINE

Centre de recherches sur la conservation des documents graphiques - France

La gélatine, constituant essentiel des films cinématographiques, est susceptible d'être attaquée par les micro-organismes. Ces altérations peuvent être très localisées et superficielles, mais dans certains cas on observe une destruction partielle, voire totale, de l'image (Stickley F.L., 1986). Pour éviter une dégradation irréversible, plusieurs traitements fongicides ont été proposés, dont certains sont préconisés par les fabricants de matériel audiovisuel et photographique (Beach W.M., 1976 ; Eastman Kodak Compagny, 1985 ; Bard C., Kopperl F., 1986 ; Opela V., 1987).

Notre étude a pour objectif d'une part de choisir le produit qui soit le mieux adapté à la désinfection de ces films, en offrant le spectre d'activité le plus large possible, tout en étant inoffensif pour l'homme et pour les matériaux, d'autre part d'en définir le protocole d'utilisation.

Dans un premier temps, nous avons analysé en laboratoire l'activité antifongique des produits sélectionnés sur des échantillons de films contaminés. Les produits les plus efficaces ont été ensuite testés en conditions réelles sur des bobines entières

RECHERCHE D'UN FONGICIDE EFFICACE : Tests *in vitro*

SOUCHES UTILISÉES

Les analyses microbiologiques sur des films contaminés nous ont permis d'isoler et d'identifier les souches suivantes : *Aspergillus versicolor, Eurotium chevalieri, Aspergillus glaucus, Penicillium variabile, Penicillium expansum.*

Pour travailler sur une gamme d'espèces plus large, nous avons pu, grâce à une étude bibliographique, compléter la liste par les souches suivantes : *Aspergillus flavus, Aspergillus niger, Eurotium amstelodami, Alternaria alternata, Aureobasidium pullulans, Cladosporium cladosporoïdes, Chaetomium globosum, Fusarium solani, Penicillium chrysogenum, Penicillium frequentans, Trichoderma viride, Stachybotrys atra.* Ces souches sont entretenues sur un milieu de culture gélosé MGA contenant 2 % de malt, 1 % de glucose et 2 % d'agar. Elles ont été utilisées pour inoculer des films sains. Pour ce faire, des morceaux de films sont directement posés sur un milieu MGA préalablement ensemencé par une suspension de spores. Suivant la souche, on obtient des films moisis au bout de 2 à 3 semaines d'incubation à 26 °C.

CHOIX DES FONGICIDES

Un certain nombre de produits ont été retenus selon différents critères : soit ils sont cités dans la littérature spécialisée, soit ils sont utilisés par certains centres d'archives, soit encore ils sont recommandés par des fabricants de matériel photographique. Enfin nous avons ajouté à la liste des produits expérimentés par le CRCDG depuis quelques années.

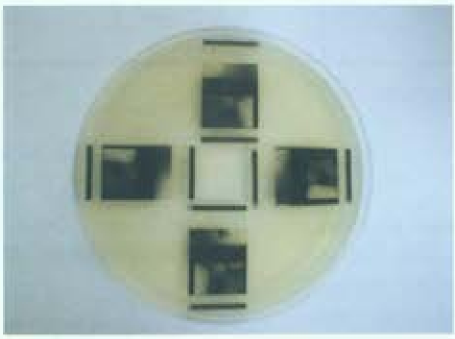
nom commun et matière active	état
Formaldéhyde *aldéhyde formique*	solution à 36 % stabilisée avec 10 % de méthanol
Vitalub QC 50® *chlorure d'alkyldiméthylbenzylammonium*	solution à 50 %
Thiabendazole *(thiazolyl-4)-2-benzimidazole*	poudre
Xédazole® *(thiazolyl-4)-2-benzimidazole*	solution à 30 %
Chlorispray® *chlorohexine, glutaraldéhyde, formaldéhyde, ammonium quaternaire et éthanol*	solution prête à l'emploi
Orthophénylphénol	pastille
Fluosilicate de zinc *Hexafluorosilicate de zinc, hexahydraté*	poudre
Chlorure de benzalkonium	poudre
Imazalil *1- [2-(2,4-diclorophényl)-2-(2-propényloxyl)éthyl]-1H-imidazole*	solution à 20 %
Kathon *isothiazolone (2-méthyl-4-isothiazoline 3 et 5-chloro-2-methyl-4-isothiazoline 3-1)*	liquide
Aquasan MX® *chlorure d'ammonium quaternaire*	liquide
Proxel GXL® *1,2-benzisothiazoline-3-1*	liquide

Tableau 1. Liste des produits testés *in vitro*

MODE OPÉRATOIRE

L'évaluation de l'activité antifongique des différents produits a été réalisée à température ambiante, suivant les protocoles donnés en annexe. Pour chaque produit, afin de rechercher les conditions les plus efficaces, nous avons fait varier les paramètres suivants : la concentration (donnée ici en pourcentage par rapport au poids ou au volume, selon que le produit est solide ou liquide), le solvant (eau ou éthanol), le temps d'application, la nature et la durée du prétraitement.

Après chaque essai, l'efficacité du traitement est contrôlée par la mise en culture d'une trentaine d'échantillons de films sur un milieu MGA (photo). Après 21 jours d'incubation à 26 °C, on note la présence ou non d'un développement mycélien. Des témoins non traités sont également mis en culture dans les mêmes conditions.



Mise en culture des échantillons de films traités (Photo CRCDG)

Le traitement est considéré comme efficace quand aucune croissance n'apparaît sur les échantillons de films traités. Les résultats sont exprimés en pourcentage moyen de colonies développées, calculé à partir des 30 morceaux de films analysés.

Résultats des essais *in vitro*

L'efficacité des différents traitements testés est donnée dans le tableau 2.

Fongicide	Protocole	Concentration (%)	Temps de contact (min)	Colonies développées (%)
Formaldéhyde liquide	1 2 3	1 1 3	1, 3, 7 7 7	90 35 0
Formaldéhyde gazeux	4	-	20 (heures)	0
Vitalub QC50®	5	10, 20,100	7	0
Vitalub QC50® puis Formaldéhyde 1%	5	20, 100	7	0
Thiabendazole	6	0,5, 1,2 15, 100	6	80 0
Thiabendazole puis Formaldéhyde 1%	6	15, 100	6	0
Xédazole®	7	5 10 15	6 6 6	75 30 15
Chlorispray	8	100	7 15	80 0
Orthophénylphénol	9	3	6	15
Fluosilicate de zinc	10	1 3	2, 4, 6 2, 4, 6	40 15
Fluosilicate de zinc - Vitalub QC50®	11	1, 5	6	15
Chlorure de benzalkonium	12	1 3, 5	6 6	70 20
Fluosilicate de zinc - Chlorure de benzalkonium	13	1, 3	6	5
Imazalil	14	5, 10, 15	6	40
Kathon	15	1, 5, 10	6	90
Aquasan MX®	16	0,1, 0,2 1 5	6 6 6	90 50 0
Proxel GXL®	17	0,5, 1 3, 5	6 6	75 80

Tableau 2. Efficacité *in vitro* des différents produits

Formaldéhyde liquide

Protocole 1. Le formaldéhyde est en solution aqueuse avec du bicarbonate de soude. Quel que soit le temps de contact (1, 3 ou 7 min),tous les films traités présentent un développement mycélien à peu près équivalent à celui des témoins.

Protocole 2. Les films subissent un prétraitement de 30 min avec un tensioactif, suivi d'un bain de 3 min dans une solution de bicarbonate de soude. Dans ces conditions, aucune croissance fongique ne réapparaît au bout de 21 jours d'incubation.

Protocole 3. Les films sont traités directement pendant 7 min dans un bain de formaldéhyde à 3%. Aucun redéveloppement mycélien n'est observé.

Vapeurs de formaldéhyde

Protocole 4. Les films traités aux vapeurs de formaldéhyde à 28 °C pendant 20 h ne présentent pas de développement mycélien après une remise en culture.

Vitalub QC 50®

Protocole 5. Quels que soient la concentration testée (10, 20 ou 100 %) et le protocole utilisé (avec ou sans prétraitement au tensioactif, directement ou complété par un bain au formaldéhyde, en solution dans l'eau ou l'alcool), le Vitalub QC 50 inhibe totalement la croissance de toutes les souches contaminantes mais laisse un léger dépôt gras sur les films traités.

Thiabendazole et Xédazole®

Protocoles 6 et 7. À 0,5, 1 et 2 %, le thiabendazole a très peu d'effet sur les souches contaminantes. À 15 % et quel que soit le protocole utilisé (avec ou sans prétraitement au tensioactif, directement ou complété par un bain au formaldéhyde), le thiabendazole inhibe la croissance de toutes les souches. Il faut noter que le thiabendazole en poudre se dilue très difficilement dans l'eau. C'est pour cette raison que nous avons pris du Xédazole, préparation soluble dans l'eau, à base de thiabendazole. À une concentration de 5 % en thiabendazole, le Xédazole a très peu d'effet sur les souches. En revanche, à une concentration finale de 15 % en thiabendazole, il est relativement efficace mais quelques spores éparses résistent au traitement.

Chlorispray®

Protocole 8. Un temps de contact de 7 min dans un bain de Chlorispray n'est pas suffisant pour empêcher la croissance fongique de certaines espèces. En revanche, un temps de contact de 15 min inhibe la totalité des souches testées. Malheureusement ce temps de contact, trop long, n'est pas applicable *in situ*.

Orthophénylphénol

Protocole 9. À 3 %, l'orthophénylphénol est relativement efficace mais quelques spores de *A. versicolor* et de *A. niger* résistent au traitement. Des concentrations plus élevées n'ont pas été testées car ce produit risque d'endommager les supports.

Fluosilicate de zinc

Protocole 10. Le fluosilicate de zinc à 1 % (concentration considérée comme fongicide en agro-alimentaire), n'est pas efficace pour inhiber la totalité des souches traitées quelle que soit la durée d'exposition (2, 4, 6 min). À 3 %, son efficacité est meilleure mais encore insuffisante pour inhiber complètement toutes les souches.

Association du fluosilicate de zinc et du VitalubQC 50

Protocole 11. L'association fluosilicate de zinc-Vitalub (1 %-5 % P/V) dans une solution alcoolique arrête le développement de toutes les souches, excepté *P. variotii*.

Chlorure de benzalkonium

Protocole 12. À la concentration de 1 %, préconisée par plusieurs auteurs, le chlorure de benzalkonium n'est pas totalement efficace ; *A. versicolor*, *P. variotii*, ainsi qu'une souche de *Penicillium expansum*, résistent au traitement. À 3 et 5 %, quelques spores éparses de *A. versicolor* et de *P. variotii* restent viables.

Association du fluosilicate de zinc et du chlorure de benzalkonium

Protocole 13. L'association des deux produits dans une solution semi-alcoolique donne de très bons résultats, les souches testées sont presque totalement inhibées.

Imazalil

Protocole 14. À 1, 5, 10 ou 15 %, l'imazalil est très peu actif sur les souches testées.

Kathon

Protocole 15. Préconisé à la concentration de 1 % comme fongicide, cette solution est très peu active sur les souches testées, même si on augmente la concentration à 5 %.

Aquasan MX®

Protocole 16. À des concentrations inférieures ou égales à 1 %, l'Aquasan est très peu actif sur les souches testées. En revanche, à 5 %, la croissance de toutes les souches est inhibée.

Proxel GXL®

Protocole 17. À 0,5, 1, 3 ou 5 % le Proxel GXL est très peu actif sur les souches testées.

EN RÉSUMÉ

- Deux produits se sont révélés totalement inefficaces : le Kathon et le Proxel GXL.
- Tous les autres ont une action antifongique plus ou moins marquée, en fonction de la concentration et du temps de contact. C'est le cas par exemple du thiabendazole, dont l'efficacité varie de 20 % à 100 %, selon la concentration, ou du Chlorispray®, dont l'efficacité varie elle aussi de 20 % à 100 %, mais selon le temps de contact.
- Certains produits très efficaces ont été rejetés :
  - ⇒ le VitalubQC 50®, qui laisse un dépôt gras sur les films ;
  - ⇒ le Chlorispray®, qui demande un temps de contact trop long ;
  - ⇒ le thiabendazole, difficile à mettre en solution, d'un coût relativement élevé, et dont l'action varie en fonction de l'état de contamination des films ;
  - ⇒ les vapeurs de formaldéhyde, qui nécessitent un appareillage particulier.

TRAITEMENT EN CONDITIONS RÉELLES DE BOBINES DE FILMS MOISIS

Pour les essais *in situ*, on a retenu trois produits, en choisissant pour chacun d'eux le protocole d'application le plus court et le plus simple à mettre en œuvre:

- ⇒ le formaldéhyde en solution à 3 % et 4 %
- ⇒ l'Aquasan MX ® à 5 %
- ⇒ le mélange fluosilicate de zinc-chlorure de benzalkonium-éthanol, respectivement à 1% - 3%-25% et 1% - 5 % - 25%.

Nous avons profité de ces essais pour évaluer l'efficacité du perchloroéthylène, auquel certains auteurs prêtent des propriétés antifongiques, et de l'oxyde d'éthylène, couramment utilisé en France pour désinfecter les documents graphiques, mais dont la toxicité nécessite une désorption rigoureuse.

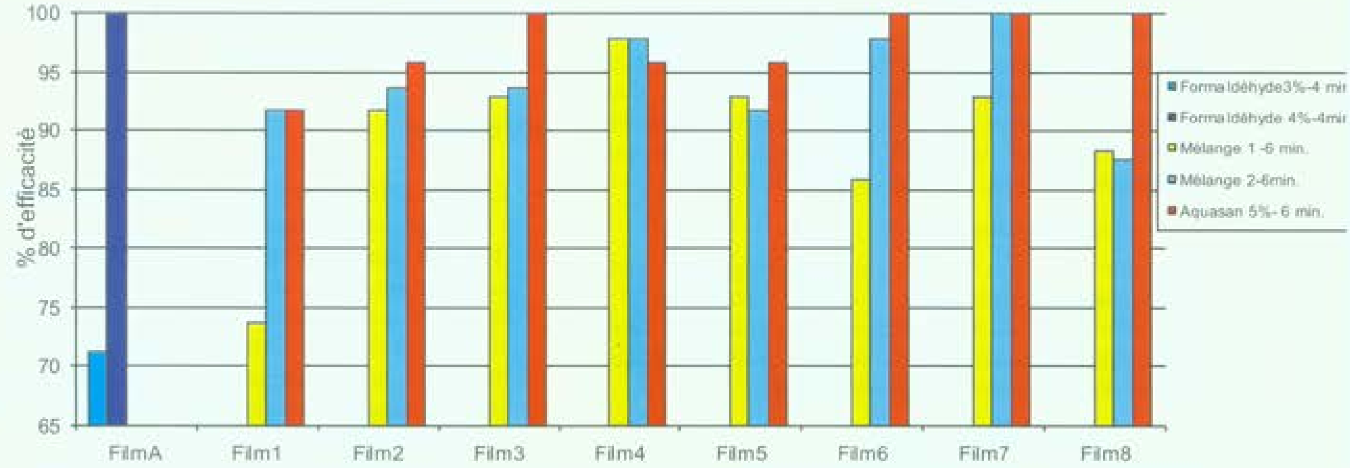
Formaldéhyde, Aquasan MX ®, mélange fluosilicate de zinc-chlorure de benzalkonium

Les traitements ont été réalisés dans une développeuse avec des bains de fongicides à 20 °C. Le film déroulé passe d'abord dans le bain de fongicide suivant le temps défini par le protocole choisi, puis il est rincé dans un bain d'eau avant d'être séché et réenroulé. Excepté pour les traitements au formaldéhyde, tous les essais ont été effectués sur 8 films (noir et blanc et couleurs) ayant des degrés de contamination différents. Chaque traitement a été réalisé deux fois.

Après chaque traitement, une trentaine d'échantillons de chaque film sont mis sur des milieux de culture MGA en boîte de Pétri. Après 21 jours d'incubation à 26 °C, on note la présence ou non d'un développement fongique et on compare le nombre de colonies développées avec celui des témoins non traités.

Les résultats (Figure 1) montrent que :

- un traitement au formaldéhyde à 4 % pendant 4 minutes est très efficace.
- un traitement avec de l'Aquasan à 5% dans l'eau pendant 6 minutes suivi d'un rinçage à l'eau donne également des résultats tout à fait satisfaisants.



Mélange 1 : fluosilicate de zinc 1% + chlorure de benzalkonium 3% + éthanol 25%
Mélange 2 : fluosilicate de zinc 1% + chlorure de benzalkonium 5% + éthanol 25%

Figure 1. Efficacité moyenne des traitements *in situ*

Perchloroéthylène

Nous avons testé ce solvant, utilisé dans les centres d'archives pour le nettoyage des films, dans une essuyeuse. Le film déroulé passe dans un bain de perchloroéthylène durant un temps plus ou moins long suivant la vitesse de défilement choisi. Il est ensuite rincé par un jet d'eau puis séché avant d'être réenroulé. Cinq vitesses de défilement ont été testées : 1140, 1620, 2520, 2740, 3480 tours/min. Les résultats montrent que le perchloroéthylène a une action sur les films : quelle que soit la durée de contact, on a une nette diminution de la contamination mais malheureusement encore insuffisante pour détruire toutes les souches. Testé *in vitro*, le perchloroéthylène n'a pas d'effet sur les souches utilisées. La baisse de contamination observée est donc uniquement due à une action mécanique qui élimine une partie des contaminations fongiques de la surface des films.

Oxyde d'éthylène

Les films très dégradés, qui ne supportent pas de traitement aqueux, doivent être traités de manière différente. Nous avons donc vérifié l'efficacité du traitement à l'oxyde d'éthylène (Oxyfume 2002) sur une bobine entière de film, la boîte à demi ouverte, en respectant les conditions de traitement suivantes : température 25 °C, humidité relative (HR) 50 %, durée d'exposition 20 h, 5 rinçages à l'air suivis de 10 cycles de prédésorption d'une heure. À la sortie de l'autoclave, la vitesse de désorption de l'oxyde d'éthylène résiduel dans les boîtes, mesurée avec des tubes Dragger est inférieure à 350 ppm/h (Figure 2). La bobine est ensuite mise à désorber dans une armoire ventilée à 30 °C, la boîte légèrement ouverte. Il faut 24 jours pour avoir des taux inférieurs à 1 ppm/h.

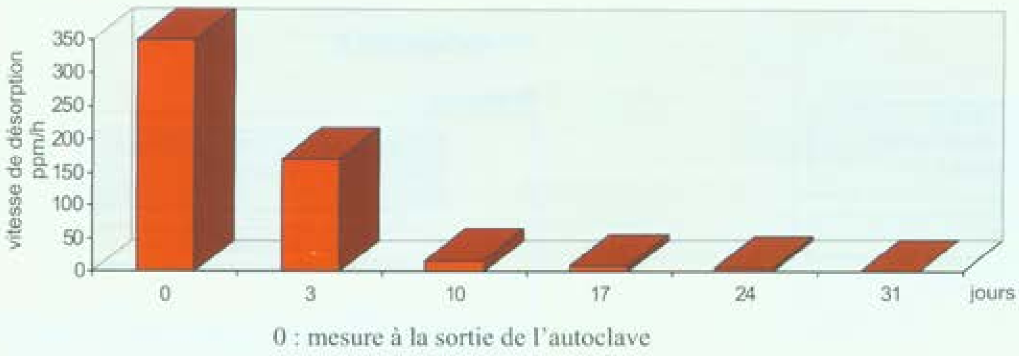


Figure 2. Désinfection d'une bobine de film à l'Oxyfume 2002 : désorption de l'oxyde d'éthylène résiduel

Au bout de 31 jours, les échantillons de papiers moisis qui avaient été insérés dans les spires de la bobine sont mis en culture pour contrôler l'efficacité biologique du traitement. Aucune souche ne s'est redéveloppée après 21 jours d'incubation à 26°C.

CONCLUSIONS

- Un traitement au formaldéhyde à 4 % avec une durée d'exposition de 4 minutes environ est très efficace. Cependant, étant donné la forte toxicité de ce produit, son emploi dans une développeuse requiert des cuves étanches et une aspiration efficace au dessus de l'appareil. Si ces conditions ne peuvent être satisfaites, nous en déconseillons fortement l'utilisation.
- Le perchloroéthylène permet certes de diminuer le taux de contamination des films, mais il n'a qu'une action mécanique de surface et n'a aucune réelle activité antifongique.
- Un traitement avec de l'Aquasan à 5 %, suivi d'un rinçage à l'eau, donne des résultats tout à fait satisfaisants qui doivent être confirmés par d'autres essais sur plusieurs films.
- Le traitement à l'oxyde d'éthylène est très efficace mais il suppose une immobilisation assez longue de ces films, puisque la désorption pour une bobine dure plus de 30 jours. On le réservera donc aux films très dégradés qui ne peuvent supporter un traitement aqueux.

Par ailleurs, cette étude sera complétée par des tests physico-chimiques pour analyser l'effet des fongicides sélectionnés sur les composants du film.

Bibliographie

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4. Opela V. 1987. The danger from fungi and bacteria encountered during permanent storage of film material. in Archiving the audio-visual heritage : Joint Technical Symposium papers. Berlin. s.l.ed., p.25-28.
5. Stickley F. L. 1986. The biodegradation of gelatin and its problems in the photographic industry. *The Journal of Photographic Science*. vol. 34, p. 111-112.

Protocoles utilisés

FORMALDÉHYDE

Protocole 1

Solution aqueuse
Bicarbonate de soude 0,6 % +
Formaldéhyde 1 %

Temps de contact 1, 3, 7 min

Rinçage à l'eau + Séchage

Protocole 2

Tensioactif 0,5% 30 min

Bicarbonate de soude 0,2 % 3 min

Rinçage à l'eau

Formaldéhyde 1% 7 min

Séchage

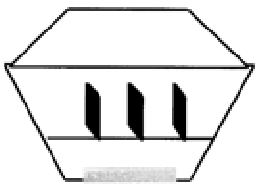
Protocole 3

Formaldéhyde 3 % 7 min

Rinçage à l'eau + Séchage

VAPEURS DE FORMALDÉHYDE

Protocole 4



Temps de contact 20 heures
Température 28 °C
Humidité relative 63%

VITALUB QC 50

Protocole 5

10%, 20% (dans l'eau ou l'alcool 70%), 100 %

Temps de contact 7 min

Rinçage à l'eau + Séchage | Bicarbonate de soude 0,2 % 3 min

Rinçage à l'eau

Formaldéhyde 1 % 7 min

Séchage

prétraitement ou non avec un tension actif 5 min

THIABENDAZOLE

Protocole 6

0,5%, 1%, 2%, 15% (dans l'eau)
ou 100 %

Temps de contact 6 min

Rinçage à l'eau + Séchage | Bicarbonate de soude 0,2 3 min

Rinçage à l'eau

Formaldéhyde 1 % 7 min

Séchage

avec ou non prétraitement avec un tensioactif 5 min

XÉDAZOLE

Protocole 7

5%, 10 %, 15 % (dans l'eau)

Temps de contact 6 min

Rinçage à l'eau + Séchage

CHLORISPRAY

Protocole 8

Chlorohexine, Glutaraldéhyde
Formaldéhyde, Éthanol
sel d'ammonium quaternaire

Temps de contact 7, 15 min

Rinçage à l'eau + Séchage

ORTHOPHÉNYLPHÉNOL

Protocole 9

3 % (dans l'éthanol 70 %)

Temps de contact 6 min

Rinçage à l'eau + Séchage

FLUOSILICATE DE ZINC

Protocole 10

1% , 3 % (dans l'eau)

Temps de contact 2, 4, 6 min

Rinçage à l'eau + Séchage

FLUOSILICATE DE ZINC + VITALUB QC 50

Protocole 11

Fluosilicate de zinc 1%
Vitalub 5 %, éthanol 25%

Temps de contact 6 min

Rinçage à l'eau + Séchage

CHLORURE DE BENZALKONIUM

Protocole 12

1%, 5 % (dans l'eau)

Temps de contact 6 min

Rinçage à l'eau + Séchage

FLUOSILICATE DE ZINC + CHLORURE DE BENZALKONIUM

Protocole 13

Fluosilicate de zinc 1%
Chlorure de benzalkonium 3 %,
éthanol 25%

Temps de contact 6 min

Rinçage à l'eau + Séchage

IMAZALIL

Protocole 14

1 %, 5 %, 10 %, 15 % (dans l'eau)

Temps de contact 6 min

Rinçage à l'eau + Séchage

KATHON

Protocole 15

1%, 5%, 10 % (dans l'eau ou l'éthanol 25%)

Temps de contact 6 min

Rinçage à l'eau + Séchage

AQUASAN MX

Protocole 16

0,1 %, 0,2 %, 1 %, 5 % (dans l'eau)

Temps de contact 6 min

Rinçage à l'eau + Séchage

PROXEL GXL

Protocole 17

0,5 %, 1 %, 3 %, 5 % (dans l'eau)

Temps de contact 6 min

Rinçage à l'eau + Séchage

Effet des polluants atmosphériques sur les disques compacts
(Présentation par affiches)

Léon-Bavi VILMONT

C.R.C.D.G - (France)

Les disques compacts ou CD existent principalement sous 2 formes :

- enregistrée : l'information est inscrite par moulage au cours de la fabrication en usine. Ainsi les CD-ROM ou les CD audio sont des CD pressés
- enregistrable : le disque compact CD-R est vierge en sortie d'usine. Il est prêt à être gravé par l'utilisateur.

CD PRESSES

ils sont constitués d'un substrat de polycarbonate portant l'information sous forme de microcuvettes, sur lequel sont déposés successivement une couche réfléchissante (aluminium), une couche de vernis, et éventuellement un dépôt d'encres.

ECHANTILLONS TESTÉS

CD-rom publicitaires, CD audio, CD sans couche de vernis.

TRAITEMENT

les CD pressés sont exposés à 2 niveaux de pollution :
(1) => SO_2/NO_2 20/40 ppm
(2) => SO_2/NO_2 10/20 ppm
à 23°C, 50 % HR

et prélevés au fur et à mesure suivant l'état de la couche d'aluminium

EVALUATION

observation visuelle de l'état de la couche réfléchissante en aluminium qui devient transparente

RÉSULTATS

- la corrosion se manifeste par la disparition de la couche réfléchissante en aluminium
- grande sensibilité de cette couche au traitement
- attaque par le bord extérieur du CD, puis par la zone de fixation et les faces
- mise en évidence du rôle protecteur de la couche de vernis mais aussi des encres

CD-R ou ENREGISTRABLES

- ils sont constitués d'un substrat de polycarbonate sur lequel sont déposés successivement une couche sensible, une couche réfléchissante (en or ou argent), une couche de vernis, et éventuellement un dépôt d'encres.
- ils diffèrent principalement par leurs couches sensible et réfléchissante.

ECHANTILLONS TESTÉS

	couche sensible	couche réfléchissante
cdr-1	***phtalocyanine***	***or (Au)***
cdr-2	***cyanine***	***or (Au)***
cdr-3	***azo***	***argent (Ag)***
cdr-4	***inconnue***	***or (Au)***
cdr-4	***inconnue***	***argent (Ag)***

TRAITEMENT

les CD-R sont exposés à un mélange de SO_2 /NO_2 20/40 ppm à 23°C, 50 % HR

- 12+13 semaines : cdr-1, cdr-2 et cdr-3 (essai en double)
- 13 semaines : pour les cdr-4

EVALUATION

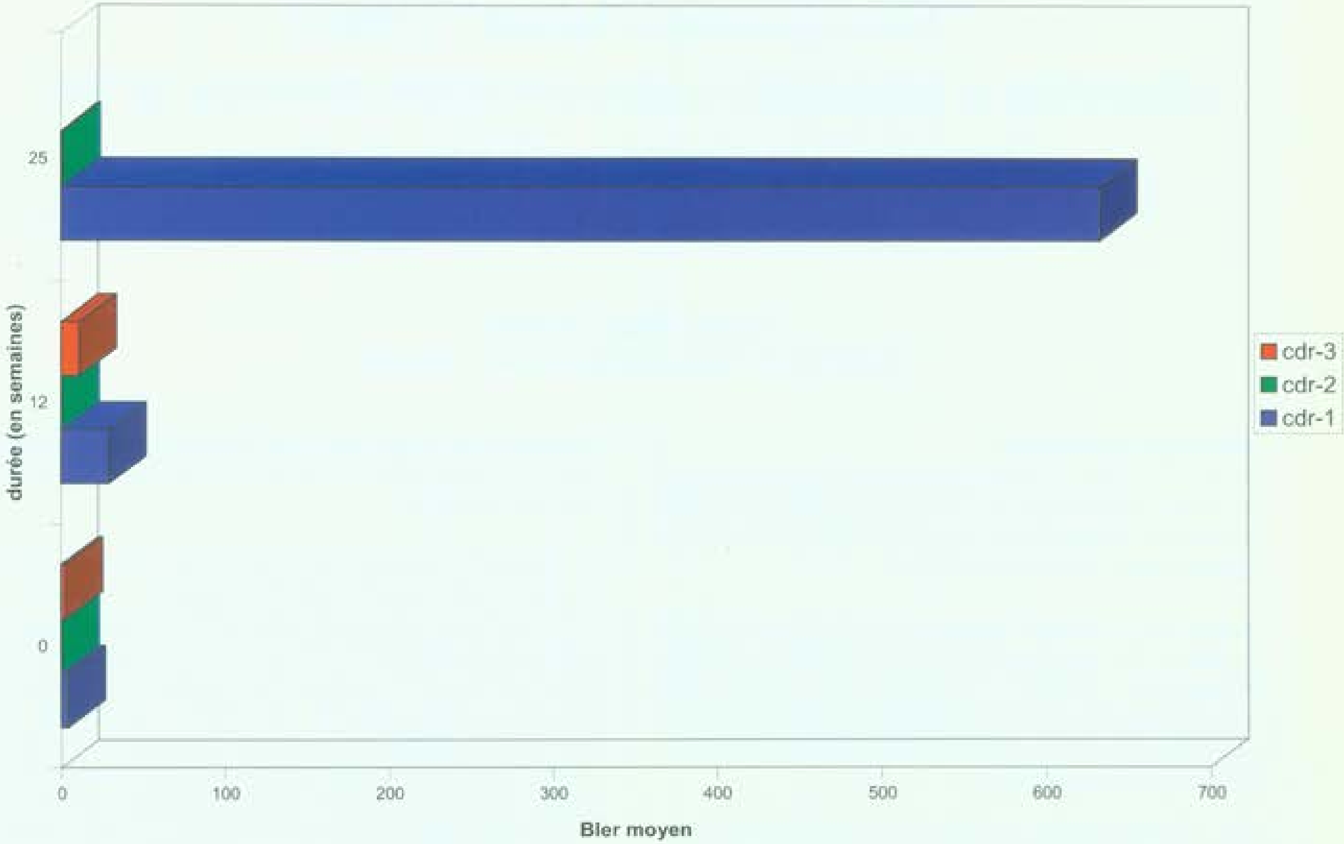
- mesure du BLER (taux d'erreurs global), reflet de la qualité des CD-R
- comparaison visuelle de la sensibilité des couches en argent par rapport à celle en or pour cdr-4

RÉSULTATS

- après 25 semaines d'exposition, importante élévation du BLER pour cdr-1, lecture impossible pour cdr-3. Seul cdr-2 se maintient bien :
=> comportement inégal des CD-R à la pollution

- pour une même fabrication (cdr-4),
=> comme on s'y attendait, l'or résiste mieux à la corrosion que l'argent

Evolution du BLER en fonction de la durée d'exposition à SO2+ NO2



The vinegar syndrome attacks "The Haunted Palace" (1963) choosing a preventive conservation strategy at the Danish Film Institute/Film Archive (Poster)

Jesper Stub Johnsen
Danish Film Institute/Film Archive - Denmark

We have a problem

In June last year a routine check before presentation of the colour motion picture "The Haunted Palace" (1963) revealed a characteristic smell of acetic acid and a colour change forming red images.

A test with A-D strips[6] showed an acid level of 2. That is above the autocatalytic point according to Image Permanence Institute.[7] However, the physical and technical quality of the reels did not prevent projection. The edge codes show that the film is an Eastman Color produced in USA in 1963.

Since "The Haunted Palace" is too degraded for showing in the future we have decided to use the film for a research project to help us choose a new preservation strategy for the Film Archive.

We need your help!

In order to indicate if the deterioration of our copy of "The Haunted Palace" is caused by bad storage conditions or an inherent vice in the film base, we need your help!

If you have a print of this title in your archive we would very much appreciate a report including the following information about your print: the origin and year for the film base and the condition of the film (acidity measured with e.g. A-D strips, fading of images etc).

Storage history of the Danish Film Institute's Archive:

The Archive contains around 28.000 titles, which cover the period from the very early film production in Denmark until the most recent titles. All types of materials from black-and-white silent movies on nitrate base to colour films on acetate and polyester base are kept in the archive.

In the last 40 years the majority of the films have been stored in cold vaults designed to produce a climate at 12°C and 50% relative humidity (RH) corresponding to a dewpoint around 2°C. However, the temperature has been set to 5-7°C which has resulted in changing humidity from 60-100 % RH.[8] Translated to Preservation Index[9] the expected lifetime of the film collection can be estimated from 25-100 years. This relates however, to the chemical decay shown as dissolving acetate bases and bleaching of the colour images. These signs are already found regularly during routine check of films in order.

This storage climate is very far away from the climates recommended in the international standards (See Figure 1).[10] The films are also at very high risk from other humidity-related decay. Signs of deterioration caused by growth of mould, insects and ferrotyping are frequently found.

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[6] A-D Strips: Film Base Deterioration Monitors from Image Permanence Institute, Rochester Institute of Technology, 70 Lomb Memorial Drive, Rochester, NY 14623-5604 USA, www.rit.edu/ipi.

[7] Reilly, J.M. (1993) *IPI Storage Guide for Acetate Film*, Image Permanence Institute, Rochester Institute of Technology, New York, 24 p.

[8] The chosen storage temperature corresponds to a dewpoint below zero at 50% RH. This is outside the capability of the air conditioning equipment. However, at 5-7°C a dewpoint at 2°C corresponds exactly to 70-80% RH. This might explain the high and varying RH. that has been measured during the last many years.

[9] Reilly et al. (1995) *New Tools for Preservation. Assessing Long-Term Environmental Effects on Library and Archives Collections*, The Commission on Preservation and Access, Washington, D.C., 35 p.

[10] ISO 18911-1999 *Photography - Processed safety photographic films - Storage Practice*.

FICA Packing

In the middle of the 1990's the Film Archive acquired a FICA packing system[11] to overcome the problem of controlling the very high humidity in the storage vaults. In the FICA system the films are pre-conditioned to a low humidity before heat-sealing in a high moisture barrier packaging material. Instead of improving the macroenvironment the FICA system is designed to improve the microenvironment around each film making the permanence of the film independent of the outside relative humidity.

However, when research on deterioration of acetate film is based on accelerated aging studies the test material is often packed in air-tight packaging which corresponds to the FICA packing system with as much air as possible squeezed out. This creates a microenvironment with a very low volume of air compared to material. When there is little air in an isolated package the autocatalytic behaviour of the deterioration process very quickly results in faster deterioration since the released acid can not escape. When mat board is included in a vapour-tight package the rate of decay is reduced dramatically because the acid is trapped in the mat board.[12]

As a conclusion on these findings it has been demonstrated that ventilation around the film is very important to remove the released acid vapour. To avoid detrimental results of using the FICA-system the use of molecular sieves or activated silicagel has been researched.[13] These compounds are placed together with the film inside the packaging and are designed to trap the released acids. However, new research has demonstrated that the benefit of these solutions depends on the procedure followed and at best has the same influence as lowering the RH from 50 to 20% in an open macroenvironment.[14]

From 1999 the Danish Film Institute has started improving the quality of the film storage and has been encouraged by the Ministry of Culture to begin the process of developing a concept for a new archive. In December 1999 a new 600m^2 climate controlled storage room designed to hold 5°C and 40% RH were opened (See Figure 1: new archive: Naverland). However, we still need to find a preservation strategy for the major part of the collection that still is in the old storage.

[11] Gooes, R. and Bloman, H.E. (1983) An Inexpensive Method for Preservation and Long-Term Storage of Colour Film, *SMPTE Journal* 92, pp. 1314-1316.

[12] Adelstein, P.Z. et al. (1992) Stability of Cellulose Ester Base Photographic Film: Part I - Laboratory Testing Procedures, *SMPTE Journal* 101, pp. 339-346.

[13] Ram, A.T. et al. (1994) The Effect and Prevention of the Vinegar Syndrome, *Journal of IS&T* 38, pp. 249-261.

[14] Bigourdan, J-L. et al. (1998) Preservation strategy for acetate film collections based on environmental assessment and condition survey, Care of Photographic Moving Images & Sound Collections, 20th -24th July, Conference Papers, York, England, pp. 28-37.

The Project:

We need to know if it at all is beneficial to include the FICA-packing system as a part of the future preservation strategy at the film archive or if we should focus on an optimised open macroenvironment.

For this purpose naturally degraded films such as "The Haunted Palace" can be of practical value.

The acidity of the acetate base of "The Haunted Palace" and other naturally degraded acetate base films form the Film Archive will together with fresh films be measured using the water-leach titration method.[15]

Each film will be cut into lengths of 100 m and divided into 4 groups.

One group of each film is taken apart as controls.

A group of each film is FICA-packed and stored at low (5°C), medium (20°C) and high (40°C) temperatures. The acidity of the films is measured frequently. This simulates aging during storage in the FICA-system as originally recommended.

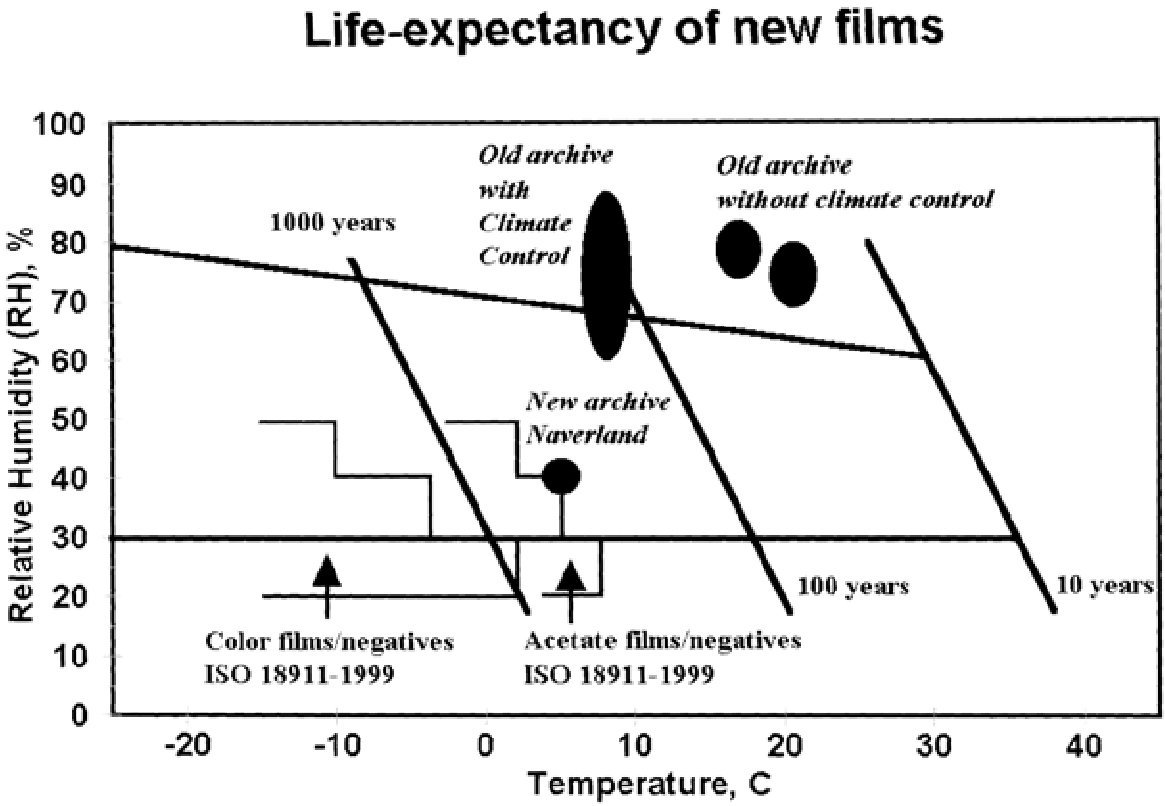
Another group of each film is FICA-packed with molecular sieve and stored at low (5°C), medium (20°C) and high (40°C) temperatures. The acidity of the films is measured frequently. This simulates aging during storage in the FICA-system as recommended with respect to prevent the vinegar syndrome form develop.

The two groups above also simulate (except at 40°C the situation at the old storage facilities of the Film Archive).

Another group of each film is packed in polypropylene film cans with holes for ventilation and stored at low (5°C), medium (20°C) and high (40°C) temperatures at 40% RH. The acidity of the films is measured frequently. This simulates the actual storage situation at the Film Archive (except at 40°C) with respect to the best storage facilities at the moment.

The results of the above tests will be used as guidance for deciding the preventive conservation strategy for the Film Archive in the 21st century.
We hope to conclude on this project at the next Joint Technical Symposium.

[15] Adelstein, P.Z. et al. (1995) Stability of Cellulose Estar Base Photographic Film: Part III - Measuring of Film Degradation, *SMPTE Journal* 104, pp. 281-291.


Life-expectancy of new films
Relative Humidity (RH), %
100
90
80
70
60
50
40
30
20
10
0
Old archive
with
Climate
Control
Old archive
without climate control
1000 years
New archive
Naverland
100 years
10 years
Color films/negatives
ISO 18911-1999
Acetate films/negatives
ISO 18911-1999
-20
-10
0
10
20
30
40
Temperature, C

Media testing in audiovisual archives

Why is my tape falling to bits?

Ian Gilmour

ScreenSound Australia (formerly the National Film and Sound Archive) - Australia

Introduction

For many years ScreenSound Australia, the National Film and Sound Archive, has investigated the decomposition and failure of magnetic and optical media, and has studied the ways in which they react with their storage and usage environments. In this paper I will explain when and why we test media, what we test for, and how.

Like many other audiovisual archives, our job is to support and promote the use, enjoyment and understanding of a small part of the world's heritage in sound and moving images. One of our main tasks is to preserve media, and to sustain their means of reproduction for the purpose of providing access to content.

1.1 Purposes - Why test recording media and when?

Media testing is an essential part of the chain of quality control necessary for optimising preservation and service delivery systems. ScreenSound has ongoing programs for testing and evaluating new film stocks, tapes and discs, and for monitoring a large collection of audio, video, film and related material on many different formats. There are stages and levels of tests. In the first instance it is important to select the best blank media for recording or copying so that we can maximise the chances of retaining AV content in the best condition for the longest period of time. In the longer term, whether or not our collections are stored on the best media to begin with, we need to monitor their condition in order to determine when to transfer or migrate content, and to prioritise items for preservation and restoration. Testing new stocks or monitoring existing collections for risk management can be based upon either threshold decisions [where an item either meets a minimum standard or it doesn't] or it may involve rating or ranking.

At a more analytical level, we must understand how and why media fail, so that we can optimise storage conditions to minimise deterioration, and to work out the best processes for restoration and recovery of decomposing or disaster-affected items. This deeper level of material testing and analysis must be applied to both new media which may be expendable, and to older items in collections which have aged naturally, and which usually may not be destroyed [although occasionally when older items are deselected, eg. in the case of multiple or inferior duplicates, it can be very valuable to have expendable older material for this purpose]. In any case, archives are often asked to advise creators and producers on the best media, and on optimal storage, handling and preservation methods. Concern for media life expectancy extends beyond the walls of archives.

1.2 Performance Criteria - What are we testing for?

Recording media, whether tape or disc; audio, video or data, must deliver certain performance criteria:

- sound and image quality – resolution, consistency or uniformity
- cost - machinery and media, storage
- capacity/speed – load & seek time, transfer rate
- running properties – low noise, wear etc.
- longevity: durability, stability - they must perform for the duration required

[this may be anywhere from less than a day to over a century]

This last aspect, time, is not just an additional parameter. It is really a dimension of the others. We must distinguish between durability or fragility, which relate to damage or wear in regular usage and handling, and the physical and chemical stability to survive long term storage in a range of environments. Initial performance testing involves very different processes to testing for long-term stability where we investigate the material behaviour and the condition of the signal below the audible or visible surface level.

Obviously all the essential requirements such as cost, size, basic AV quality must be met before long term performance is considered. It doesn't matter how long a tape or disc lasts if it won't record and play back a good signal, or if it costs more than the user can afford. This is where quick pass/fail tests are useful.

All too often, however, the price and the presence of audible/viewable sound and pictures are the only criteria considered. This situation is particularly risky with digital recording and playback systems which may conceal marginal performance of media until the error tolerance of the system is exceeded and major failure occurs. In analogue systems there is usually a direct relationship between the quality of the medium, and the sound or picture quality. In digital systems the subjective quality of audio and images is related to the electronics, such as D/A converters, clock stability or linear circuitry, rather than the media. If a recording fails gradually, the sound or image quality may not deteriorate in an obvious way until an unrecoverable state has been reached - the 'cliff-edge' effect.

The formulation and manufacture of recording media involves a balance or compromise between several, often conflicting parameters. For example, higher storage densities are achieved with thinner tape formats having narrow tracks which are less resistant to contamination or damage. Short term running properties may be enhanced by lubricants and plasticisers which cause deterioration over time, or which mask other symptoms of decomposition. Tapes with lower surface asperities may exhibit better uniformity in the short term, but wear more rapidly due to increased head contact.[16] Similarly, it may be possible to construct a tape or disc system which satisfies all of the criteria for quality, capacity, speed and lifespan, but at a premium cost. Recording or storage media are usually only a small percentage of the **total cost** of recording and dubbing. Recording media vary, and you don't always get what you pay for.

Archives account for only a small part of the total magnetic media market, with about 1% of sales in audio and video products. As a result, the permanence or life-expectancy of media may not be the primary goal of manufacturers. Many recordings ultimately end up in archives, however, following their original intended purpose in the broadcasting, production or recording industries. It is important therefore to ensure that recordings which are likely to have long term cultural or intellectual value are stored upon media and systems which have good performance in both the long and short terms.

As archivists we must be able to select media with the best balance between life expectancy and the other important criteria to meet our needs. In addition to measuring short term performance criteria, we should know well media will last and how they will fail, so that we can select the best formulations for recording and dubbing, and so that we can take steps to reduce their demise. Mainstream users also should know how well performance criteria are met but they often rely upon sales representatives, advertising, or trends in the industry. We should therefore carry out proper tests, or find out from someone who knows. Manufacturers are becoming more conscious of life expectancy and usually welcome our feedback.

2. Types of testing

Several types of testing may be needed in a large organisation. The ideal tests are quick and easy, without requiring highly skilled personnel, complex procedures or elaborate equipment. This is particularly important when we are checking large numbers of existing recordings, films or other material in archives with tens – or hundreds of thousands of physical items. collection for dubbing or treatment. We may use a simple pass/fail test or we may use rating or ranking in which we need to know degrees of condition.

Quick tests may involve visual assessment, indicators, a brief check of running performance, or may focus on the output signal under typical operating conditions. components For a deeper understanding of the processes of failure, we may have to analyse materials or individual components. Often we must avoid altering the medium or its content, however. Virtually any test which is intrusive has a risk of altering or damaging the medium under test.

3. Tape composition and decomposition - Why do tapes fail?

The life expectancy of tapes is governed normally by the magnetic coating rather than by the substrate. The coating may be a continuous metal film, or a magnetic particulate dispersion held within a polymeric binder system. Traditional gamma-ferric oxide and more recent barium ferrite particles may be quite stable on their own, but problems such as losses in remanence, coercivity and corrosion have been reported in Co-Fe, CrO_2 and metal pigments.[17,18,19] Chromium dioxide is a physically and chemically active pigment which adsorbs water, and readily converts to chromium (III) and chromium (IV) compounds.[20]

Failure of lubricants, plasticisers and other additives may cause a loss of running properties. Chemical failure of binders is still one of the most serious problems, causing shedding/debris [soft and hard errors], and poor running properties. The most common types of binders are polyester-polyurethanes. They tend to react with moisture by hydrolysis which can make them sticky and cause head clogs.[21]

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[16] Osaki, H. "Role of Surface Asperities on Durability of Metal-Evaporated Magnetic Tapes" *IEEE Trans on Magnetics* 29/1 Jan 1993: 11

[17] Okazaki, Y. et al "Estimating the Archival Life of Metal Particulate Tape" *IEEE Trans on Magnetics* 28/5 Sep 92: 2365

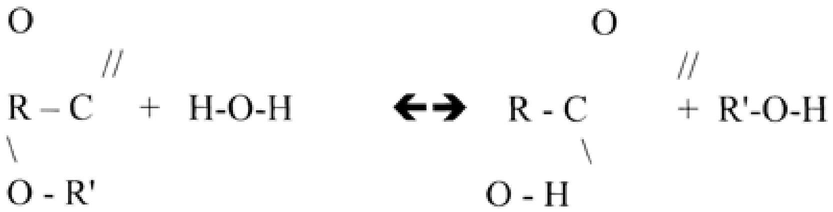
[18] Speliotis, D. & Peter, K "Corrosion Study of Metal Particle, Metal Film and Ba-Ferrite Tape" *IEEE Trans on Magnetics* Vol. 27 No. 6, Nov 1991: 4724-4726

[19] Van Bogart, J 'Media Studies Final Report' *Technical Report RE-0017* National Media Lab, St Paul Mn. July 1994

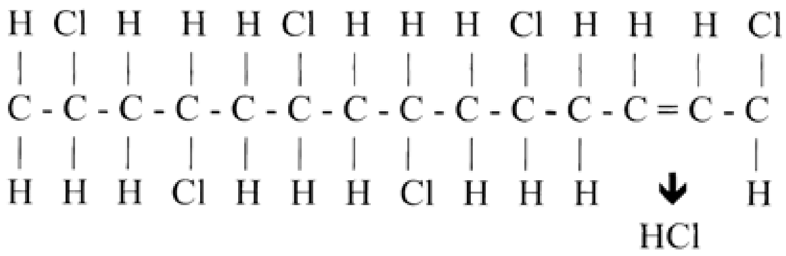
[20] Gähde, J. et al "Polyurethane Cross-Linking by Chromium (III) Compounds" *IEEE Trans on Magnetics* Vol. 29 No 3, July 1993:2101

[21] Bertram, N & Cuddihy, E. "Kinetics of the Humid Aging of Magnetic Recording Tape" *IEEE Trans on Magnetics* 18/5 Sep 82: 993

$$\text{Ester} + H_2O \leftrightarrow \text{carboxylic acid} + \text{alcohol}$$



Another type of binder is PVC which can produce hydrochloric acid as it breaks down.



Particulate coating react adversely with humidity and pollutant gases.[22,23]

The substrate or base film is normally the most stable part of a tape, although modern tapes with extremely thin bases are susceptible to deformation, causing dropouts, non-uniformity and tracking errors. Temperature extremes and stress caused by environmental fluctuations or transports are a particular danger. Manufacturers are increasingly using exotic materials such as PEN or polyamide to overcome these difficulties, although these newer polymers do not have a proven archival performance.[24]

4. How we test media

We can conduct media testing at three levels: magnetic or optical [how well they hold a signal], physical or mechanical, and chemical. Testing magnetic or optical signal level relates most closely to the operational environment. It can be fairly quick and non-intrusive [it doesn't destroy media] but often only highlights symptoms rather than underlying causes. Physical and chemical tests tend to be more analytical and time-consuming, and may require more detailed interpretation.

Accelerated ageing

The problem with new stocks of film, tape or recordable discs is just that - they are new. We often don't know what will go wrong with them in the long term unless we wait for many years or decades. We know that often media will break down when we add energy in the form of heat or light, or that they may react with water, oxygen, acids, pollutant gases or other chemicals around them.

We can try to speed up the natural processes of decomposition by exposing media to stressors such as heat, light, moisture, gases and acid catalysts. At ScreenSound we try to keep the samples in their original state by leaving cassette tapes in their shells but with the housings open, rather than cutting off short lengths of tape which are completely open to the environment. This is for two main reasons: We record and play back test signals which are easily corrupted by handling. We also wish to factor in the interaction between different materials inc. shells, slip sheets, guides, metal parts, and bonds between layers which can occur in normally spooled and packaged tapes.

What does or doesn't occur during accelerated ageing? Although it is commonly understood that many kinetic reactions proceed at roughly double the rate for every 6°C increase in temperature, and for a roughly 20% increase in relative humidity above ambient, there are limits upon how far we can extrapolate or speed up reactions. The rates at which gases and liquids diffuse, the presence of microcondensation or unnatural, local concentrations of materials, and changes in rates of adsorption of different compounds can lead to variance between natural and artificial ageing. Physical and mechanical parameters, such as air flow in stores do not always scale in a linear fashion. Handling damage on samples is a potential hazard. At 35 to 40 °C it is easier to grow mould than to promote hydrolysis. Conditions

[22] Morrison, F. and Corcoran, J. "Accelerated Life Testing of Metal Particle Tape" *SMPTE Journal* 103:13, Jan. 1994

[23] Mather, M.C.A. Hudson, G.F. Hackett L.D. "A Detailed Study of the Environmental Stability of Metal Particle Tapes" *IEEE Trans on Magnetics* 28/5 Sep 92: 2362

[24] Weick, B.L. and Bhushan, B. "Characterization of Magnetic Tapes and Substrates" *IEEE Trans on Magnetics* Vol. 32 No 4, July 1996

should be non-condensing and should include adequate time for ramping up and down from ambient – we don't want to end up assessing flood damage.

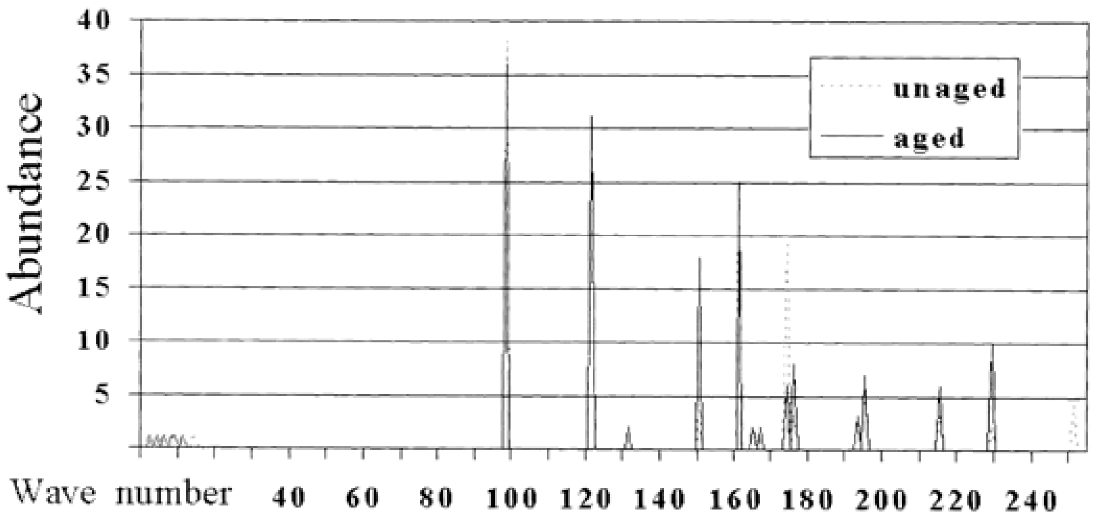
4.1. Chemical testing and analysis

The two most simple chemical tests we can perform are solvent extraction and pH or acid measurement[25]. Solvent extraction involves the measurement of soluble by-products of decomposition by immersing a tape in a suitable solvent such as acetone, and measuring the change in mass due the loss of the extractable components. SE works best on tapes with coatings which are relatively thick compared to the total thickness. Allowance must be made for lubricants and other extractables which aren't related to decomposition. Spectral analysis can be used to determine the composition of extractables.

The other fairly simple test is pH measurement as an indicator of the acid levels due to hydrolysis or similar reactions. We've recently completed a large scale risk assessment survey of around 17,000 magnetic sound reels using IPI strips.

Like many archives we have begun to notice a higher incidence of vinegar syndrome on full-coat magnetic sound film, than on corresponding picture emulsion stocks. The test strip results are entered in our database, MAVIS and are used in reports to prioritise dubbing and restoration. Some of the results were interesting, including a number of recent polyester-based reels which showed no signs of shedding. A more thorough version of acid measurement is to finely chop a sample, immerse it in de-ionised water and measure pH directly with a probe. Although this is a bit more targeted than testing free acid in the air of the storage container using indicator strips, there are still limitations to what it will tell us.

More comprehensive analysis can be performed using GCMS [gas chromatography mass-spectrometry], GPC [gel permeation chromatography], infra-red or Raman spectroscopy, and NMR [nuclear magnetic resonance][26]. In the example below, the changes in height and width of peaks in the aged sample spectrum suggest a loss of molecular weight, and a change in reactant bonding. The ideal systems are those which involve the minimum of sample preparation and sample size.

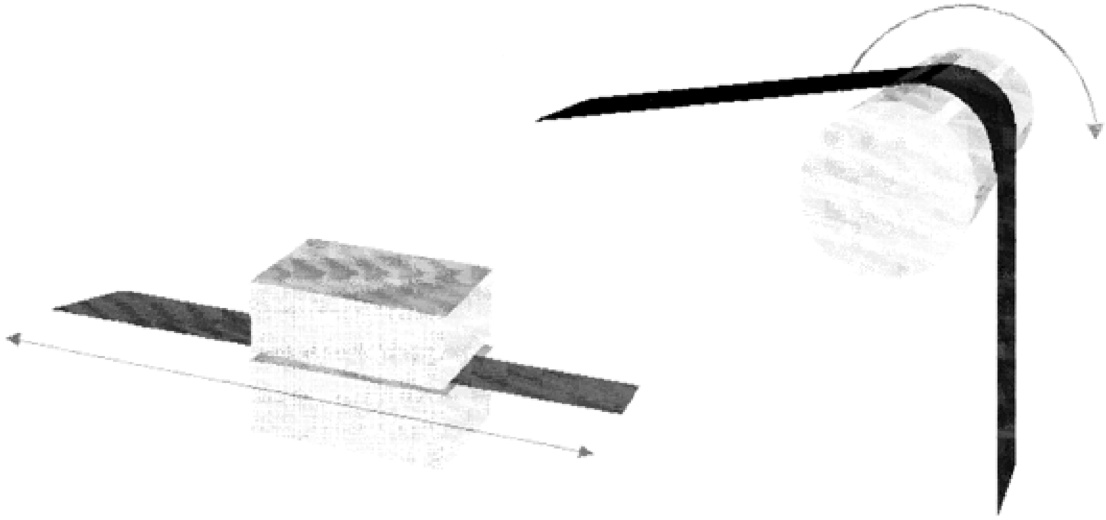


[25] The terms pH and acidity are used here in a simplified context. The author recognises that they are not synonymous.

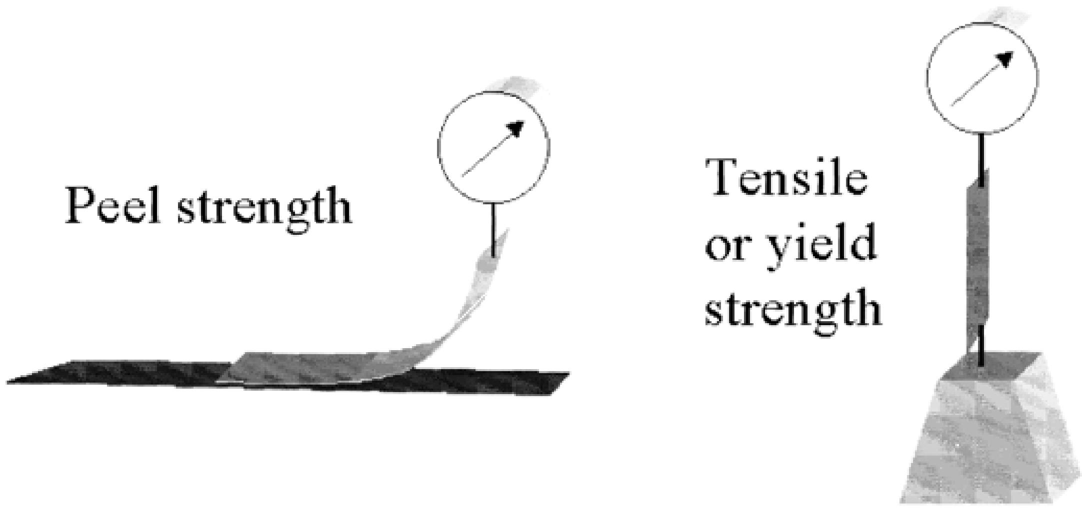
[26] Derham, M. et al "The Degradation of Cellulose Triacetate Studied by Nuclear Magnetic Resonance Spectroscopy and Molecular Modelling" in *Polymers in Conservation* Cambridge 1992: 125-137

4.2. Mechanical testing and analysis

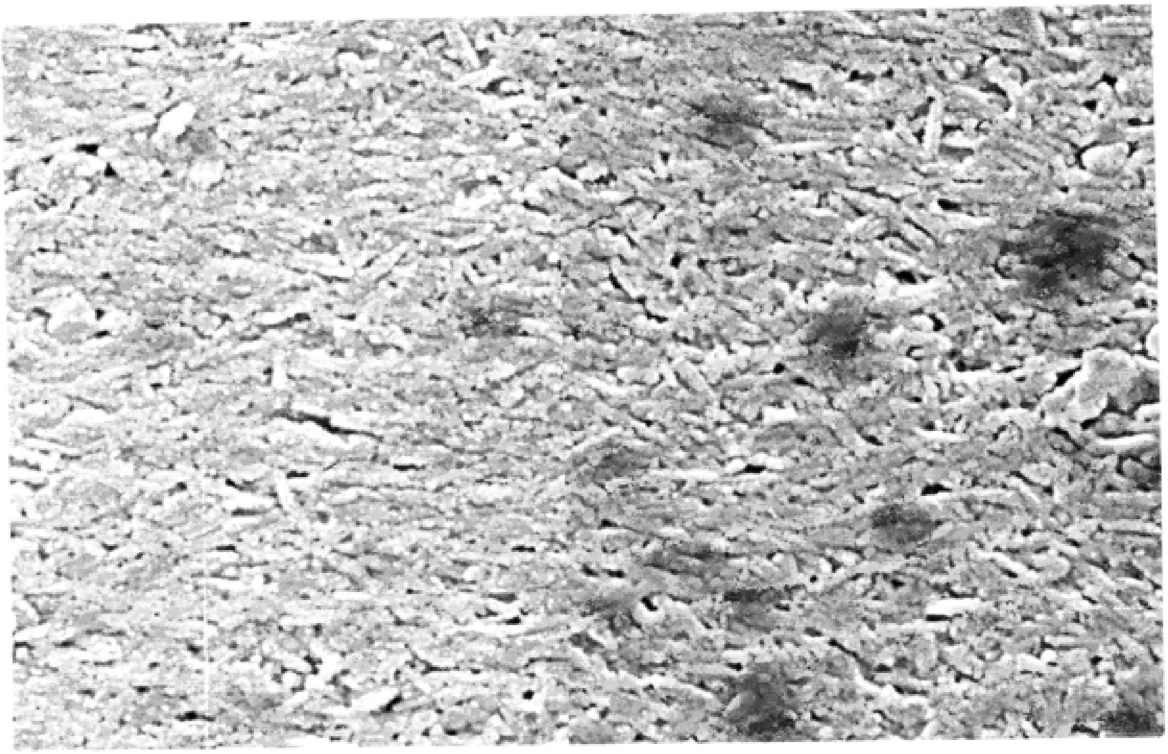
The cohesion or integrity of the coating can be measured by timing how long it takes to rub through the coating with a swab. This can be done by hand, although a consistent technique is needed for repeatability. One manufacturer used an oscillating frame which pulled a short length of tape back and forth between two pads with a weight on top. We've built a rotary swab with a linear feed which reduces clogging.



Adhesion of the coating to the base is indicated by peel strength. Changes may also occur in tensile strength, although this is less apparent than dimensional changes which can have a far more direct effect on tracking.



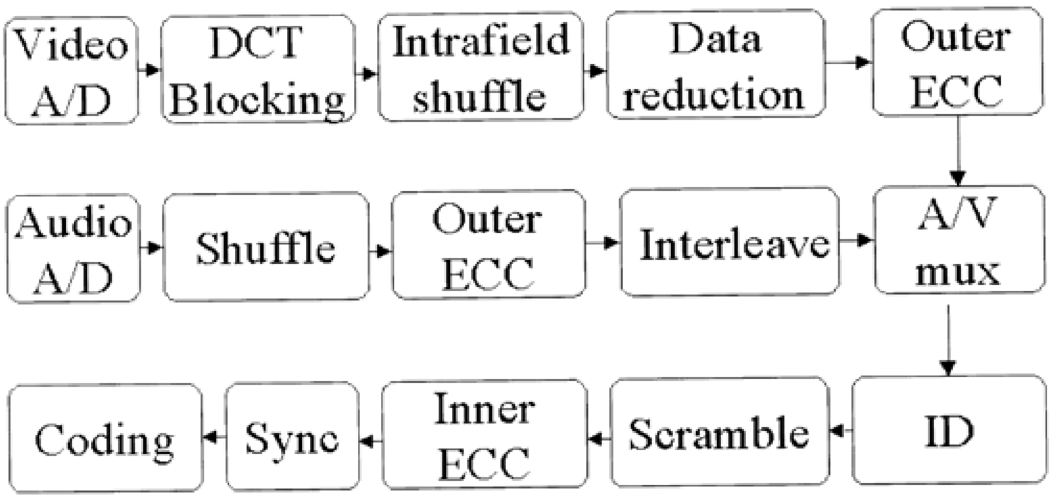
One final method of physical investigation is SEM. It is often possible to detect changes in surface appearance as binders break down, or magnetic materials corrode. In this example the aged tape [right] has a higher proportion of gummy residue from decomposed binder.



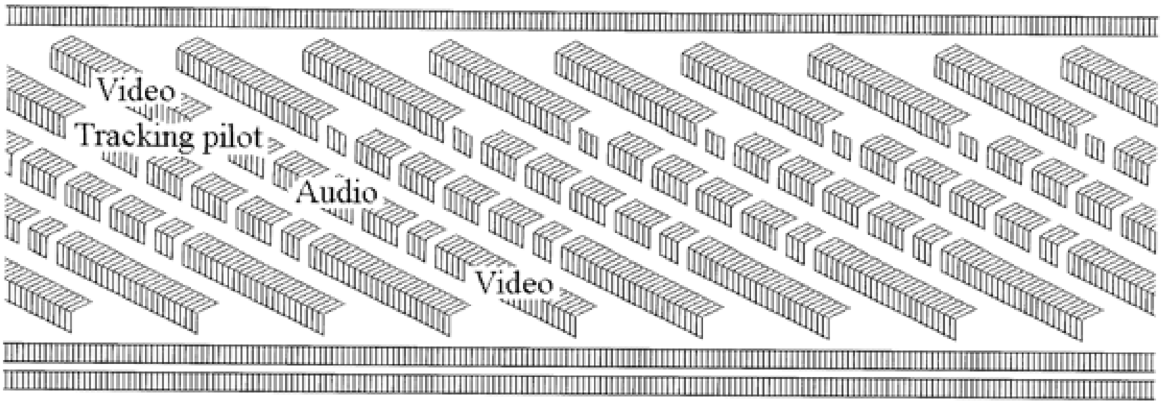
4.3. Signal testing and analysis

Head output vs error checking

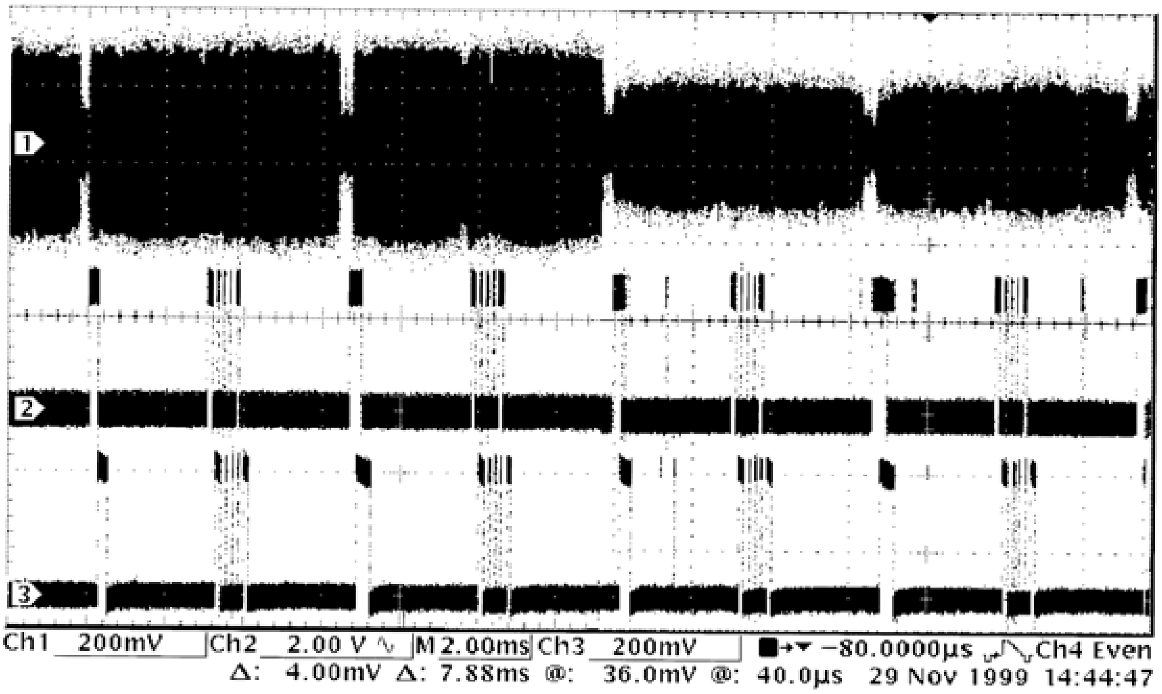
At the most basic level, all that matters is whether we can recover valid data, video or audio, from stored media. By the time data becomes unrecoverable, however, it is too late. We therefore need an early warning system for flagging a drop in condition whilst the chances of data recovery are still good. If we look at the signal path on a typical component DVTR it is fairly easy to determine the points of interest for signal testing.



This is a block diagram of a Sony DVW500P series Digital Betacam machine. A conventional component video signal sampled at up to 13.5 or 18 Msa/sec and quantised at 8 or 10 bit resolution, or input directly as SDI [serial data interface to SMPTE 259 or CCIR 656]. The digital video data is shuffled or interleaved, error correction is added, followed by AV multiplexing and channel code. Bit-rate reduction is common on many formats, although the ideal preservation system should remain lossless. At the beginning of the replay chain are only data and raw rf. At the system output are pictures and sound.



The footprint on the tape bears very little resemblance to the original picture or sound. A single field is spread over 6 consecutive tracks recorded in adjacent pairs with 4 audio blocks in the middle of each track. We can measure this signal and a number of other points in the processing chain with a fairly standard digital oscilloscope having a bandwidth of a few hundred MHz and a sample rate of at least 2 Gsa/s. A normal rf signal straight from the replay heads should have a constant, high amplitude [in this case 5mV]. A degraded rf signal has a lower level and the envelope varies. At the same time a number of low-level errors start to appear. The rf and error flags are readily accessible via test points commonly used by technicians for routine alignment.



For more extensive analysis, data can be exported in .csv [comma separated value] format. We can use the mean or standard deviation for a quick, single-digit comparison between samples. Error data is available via RS-232 or front panel on many machines. It is also possible to measure servo current as an indicator of the tape surface tackiness or dimensional changes.

We are currently conducting accelerated age testing on common formulations of Digital Betacam tapes and DATs. All show similar signs of level attenuation, but to varying degrees. We will need to conduct more extensive analysis to determine whether the metal particles are undergoing a process of oxidative or similar corrosive reaction, or whether there is another explanation for the loss of remanance in the recorded signal. Reduced rf in aged tapes is also attributable to separation losses from coating failure, although this is indicated by a higher incidence of soft errors, head clogging and reduced uniformity reflected in a higher standard deviation of rf samples.

Standardising Tests

ANSI standards for testing CD-R and magneto-optical discs are based upon a fairly simple process of humid ageing and statistical analysis. It should be possible to develop agreed testing procedures for magnetic media as well. The question is whether or not to incorporate multiple parameters rather than a single level of error rate.

What would happen, for example, if we insisted that a tape should survive humid ageing at 55°C, 80 % RH for 8 weeks, or cycling from 5°C, 10 % RH to 55°C, 80 % RH every 24 hours for 3 weeks, and still have a pH above 4, less than 0.4% solvent extractables, and below 10^{-4} bit error rate. As with airbags in cars, we don't want media which are simply optimised to meet a narrow set of test conditions, but which don't perform in real life. According to some practitioners, the best way to ensure good long-term performance is to have low initial error-rates. The trouble is that some recording media start off with low error rates and stay fairly low, but others start off low and go downhill rapidly. The worst case is when they start off bad and get even worse. We haven't found too many which improve with age like a good Coonawarra Cabernet Sauvignon.

Summary

- Media testing is essential for quality control and for continual process improvement.
- Quality assurance on new blank or unexposed stocks and risk assessment on existing collections are just as important as testing and maintenance of machinery.
- Simple tests can and should be performed by all users.
- Thorough analysis should be conducted periodically to compare new and aged media.
- Testing standards would allow interchange or exchange of information and experience
- Media vary and cost doesn't always match performance
- Store tapes dry, avoid dust and pollutants

Discussion

De la salle

Would you rely upon the output from DVD machines to perform error correction?

Ian GILMOUR

Yes, many of their flags are viable. Those that appear on the front of the machine usually indicate a very high level (75-80%). The situation can already be quite serious.

From the floor

Are you referring to the machine that performs playback and recording?

Ian GILMOUR

Yes, all of the error flags are present and are available at specific testpoints.

From the floor

You mentioned barium ferride tape. Do you have anything more to say on that?

Ian GILMOUR

Barium ferrides could be one of the best particles or tapes if used with the best coating and binding. The coercivity would be quite high. In order to achieve the best result, one would have to make an additional recording, especially if one moves from Fuji magnetic tape.

From the floor

Have you experienced any deterioration of binders or PVC substrates?

Ian GILMOUR

That does occur, however it is relatively infrequent.

From the floor

It is interesting that you are taking the same approach as professional analysts for CD and CD-R. You are going directly to the RF signal and extracting as much information from that as possible. That would also show mechanical errors and modulations.

Ian GILMOUR

The idea is the same. We are able to receive quick estimations on errors. The most interesting information comes from machine analysis: one can determine whether tape is warped.

A Participant from the National Archives, Canada

You mentioned earlier that three-quarter inch tape has resulted in a curatorial programme. Could you provide any additional information on that?

Ian GILMOUR

Yes, we were worried about the fact that U-Matics have been used to master CDs by_the record industry. Masters recorded on BVU or PCM 6034 have now become sticky and unplayable. We therefore carried out a small pilot study. Despite usually dry storage conditions, much of the film tested showed a reduced direct radiofrequency levels. Among the tapes that were between ten and 15 years of age, many showed RF levels that were three notches below the norm. We know they were recorded by ourselves or by others. That is why we began looking at the particle layer a bit more closely. They are still pliable, but would not be able to play anything.

Minimal–Invasive Approaches to Magnetic Tapes Life Expectancy Testing

Univ. Prof. Dipl. Ing. Dr. Otto Hinterhofer, Univ. Doz. Dr. Konrad Binder, Dr. Leopold Kranner
Austrian Plastics Institute

Dietrich. Schüller
Phonogrammarchiv of the Austrian Academy of Science

1 Introduction

Since its introduction in the mid-nineteen-thirties, magnetic tape has become a widely used data carrier. Its use ranges far beyond the original application of audio recording. Although things may change in the future and optical carriers will gain ground, magnetic tape is also the predominant carrier for video signals. Finally, its importance for the storage of computer files, especially in mass storage systems, should not be overlooked.

The chemical stability of data carriers is of crucial importance for the integrity and the legibility of the recordings. Although magnetic tape is in general a reliable data carrier, several problems related to its chemical stability have been observed. Most prominent is the so-called "Sticky Tape" or "Sticky Shed Syndrome" which is the result of pigment binder deterioration. Water, omnipresent in the form of humidity in the air, causes hydrolysis, a chemical transformation of the binder, by which its physical properties decline : this results in sticky tape surfaces, tape squealing, and pigment shedding, with all the consequent adverse effects on the reproducibility of the recorded signals. Magnetic tapes (audio and video) of relatively recent production are subject to this phenomenon, and it is not yet known to what extent stocks of magnetic tapes will be affected in the future.

Most of the affected tapes can be re-conditioned to the extent that they become playable, at least once, in order to transfer them to another medium. With further deterioration, however, the rate of successful re-conditioning may drop significantly in the future.

It is estimated that audio archives worldwide are storing around 30 million hours of tapes, video archives around 10 million hours. Most of these holdings are unique recordings of significant historical, cultural and commercial value. Their future transfer onto new, digital carriers is inevitable for the tapes long-term preservation. Because this transfer involves a time factor of 2–3 of the duration of the programme, it will take many years if not decades. As a result of this situation the estimation of the end of life (EOL) of existing tape stocks has therefore become an important issue in the world of audio and video archives[+]. Prediction of EOL will enable the transfer of programmes according to their urgency. Those tapes most likely to fail soon may be prioritised over those of a more stable nature.

This paper reports on investigations carried out within the framework of EUREKA EU 892, Eurocare AVIDA[++] . The Austrian national contribution, of which this paper is a part, was partly financed by the Austrian Federal Ministry of Science and Transport, and we would like to express our gratitude for this support, without which we could not have participated in this project.

2 Technical background

2.1 Construction of the analysed Magnetic Tapes

1/4“-audio- and 1“-video magnetic tapes were tested. As shown in figure 1, these tapes consist of 2-3 layers; the plastic base; the pigment layer consisting of magnetic particles, the polymeric binder material; and the optional back coating.

[+] This issue has been recently taken up by a working group of AES ANSI in order to establish a standard for testing EOL of magnetic tapes.

[++] Partners in this project are the Phonogrammarchive of the Austrian Academy of Science (Co–ordination); the Deutsches Bundesarchiv Koblenz and the Austrian Plastics Institute Vienna

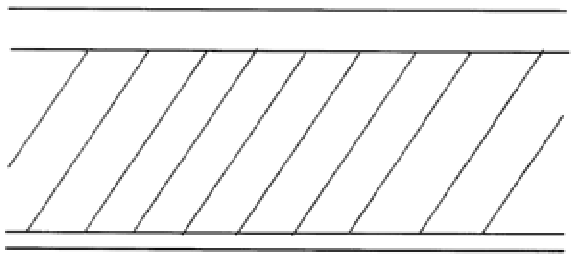


Figure 1: The basic components of magnetic tapes

The plastic base of all tested magnetic tapes was a biaxial oriented polyethyleneterephthalate (PETP). The binder system of the magnetic layer of the tapes consisted of polyester–polyurethane.

2.2 Ageing of magnetic tapes

All components of a magnetic tape (plastic base, magnetic particles, binder material, etc.) age naturally and consequently change their properties; however, the polyester-polyurethane binder system is the component most sensitive to deterioration. This deterioration of the binder system is accelerated by higher humidity and temperature. Polyester, which is used for the cross-linking of the binder system, was found to be much more sensitive to hydrolysis reaction than the polyurethane component. Exposure to humidity (e.g. climatic chambers) cracks the long–chained polyester into short–chained carboxylic acid and alcohol. The reaction is autocatalyzed by the thus formed carboxylic acid and also catalysed by transition metal ions present in the magnetic layer of the tape. Some authors[1] have found that chromium dioxide tapes undergo faster binder breakdown than ferric oxide tapes. The cross–linking of the binder system decomposes into fragments, which migrate to the surface of the magnetic layer. This leads, amongst other things, to the shedding of pigment particles which accumulate on tape guides and, above all on replay heads, swiftly clogging the heads and disturbing the replay process. This phenomenon is well known and has been called the „Sticky Tape" or „Sticky Shed Syndrome".

The resulting changes of the cohesion in the magnetic layer and the adhesion of the magnetic layer to the plastic base have been investigated by means of suitable methods.

3 Experimental Testing

The current work gives an overview of minimal–invasive chemical and physical tests which assess the degradation of magnetic tapes. Intact magnetic tapes of a certain type, naturally or artificially aged, have been compared. The work shows also the problems of artificial ageing for simulating the natural ageing process.

It shows also doubts about the classical Arrhenius–extrapolation for a reliable prediction of EOL and introduces an alternative method.

3.1 Artificial ageing

The Artificial ageing for this paper took place in climatic chambers with the following conditions:

- 60°C/80% r.h.
- 70°C/80% r.h.
- 80°C/80% r.h.

The samples were carefully thermostated from room conditions to ageing conditions to prevent condensation on the surface of the cold magnetic tapes. Before performing all tests after ageing all samples were conditioned for 24 hours at 23°C/50% r.h.

3.2 Physical testing to assess the deterioration of magnetic tapes

3.2.1 Tensile testing of magnetic tapes

The following table 1 shows the test conditions used.

References

1 *E. Nilson and M.L. Samuelson*

Investigations on Computer Tapes for Information Storage

Report: Swedish National Testing Institute, Stockholm

Table 1: Test conditions at tensile tests

Parameters of the tensile test	test conditions
sample length	200 mm
pre-tension	0,2 N
test speed	100 mm/ min
climate	23°C/ 50 % r.h.

The determined characteristics were the „critical elongation" for the removal of the magnetic layer from the plastic base (= breakdown of the binder material of the magnetic layer) and the „maximum elongation" which corresponds with the fracture of the sample (= breakdown of the PETP– plastic base). Magnetic layer removal of the 1"-Video tapes was indicated by the falling-off of an adhesive tape, which had been fixed before the test onto the magnetic layer. However this method was not successful with 1/4"-audio tapes. Instead, for the 1/4"-audio tapes, the removal of the magnetic layer from the plastic base was indicated by a hairbrush which was steadily drawn over the surface of this layer during the tensile test.

3.2.2 Abrasion test on the magnetic layer

This test for surfaces was performed according to DIN 53754 by means of the TABER ABRASER. The magnetic tapes were fixed with a double-sided adhesive film to the flat surface of a square plate with the magnetic layer facing upwards. The plate was fixed onto the rotating sample holder. The abrasion of the magnetic layer is, by definition, finished when the transparent PET-plastic base becomes visible. The abrasion resistance is defined by the number of rotations of the standardized abrasion wheels. The colored back coating was removed to allow the recognition of the point of abrasion.
Table 2 shows the test conditions for measuring the abrasion.

Table 2: Test conditions for abrasion of the magnetic layer

parameters of the abrasion test	test conditions
used type of abrasion wheels	CS 17
speed of rotation	60 rotations/minute
refacing of the abrasion wheels	every 60 rotations with standardized grinding
sample load	5 N
climate	20°C/ 50 % r.h.

3.2.3 Determination of hardness of the magnetic layer

As a consequence of the extremely thin magnetic layer, test methods learned from common material testing are not applicable. The measurements were, therefore, carried out with the help of the Nanoindenter from Nano Instruments. The measured parameter was the resistance against penetration (in nanometer units). Penetration of the magnetic layer was done with a Berkovich-Indentor under oscillation conditions.

Table 3: Test conditions for measuring hardness of the magnetic layer

parameters	test conditions
indentor	Berkovich type
oscillation frequency of the indentor	40 Hz
penetration force	0,4 mN
maximum penetration depth	0,3 µm
accuracy	± 1 nm

3.3 Chemical testing to assess the deterioration of magnetic tapes

3.3.1 Thermogravimetric analysis (TGA) of the magnetic layer

The magnetic layer of the samples was separated by elongation of the magnetic tapes. About 10 mg of the magnetic layer were placed in the TGA–instrument (Type Mettler TA 4000/TC11/TG50-M3), the sample chamber was rinsed with air, and the change in weight was recorded between 23°C and 300°C.

3.3.2 Differential scanning calorimetry (DSC) of the magnetic layer

As in the case of TGA–analysis, these measurements were also performed on the separated magnetic layers of the tapes. About 10 mg of the magnetic layers were placed in the instrument (Type Mettler TA 4000/TC11/DSC30), the sample chamber was rinsed with air, and the specific energy of the reaction was recorded between room temperature and 400°C.

3.3.3 Determination of solvent extractables of magnetic layer

The analysis was executed on the magnetic layers of the tape samples, by removing them from the substrate by elongation. About 200 mg of the magnetic layer were placed in an Erlenmeyer flask and extracted with dried acetone (HPLC grade, dried with molecular sieve). After the removal of the acetone and careful drying, the amount of hydrolyzed polymeric binder was determined by weighing.

4 Results and discussion

4.1 Physical tests

4.1.1 Tensile tests

Because of the hydrolytic weakening of the magnetic layer's polymeric binder, the adhesion forces of the layer to the plastic base were measurably influenced. Some of our results can be seen on sheets 12–15 of our presentation. The natural and artificial ageing generally led to a decrease of the critical elongation, which stands for the breakdown of the binder material. On the other hand there was no general effect of ageing on the PETP–plastic base of the tapes.

In our opinion, this test method is more effective than the method, which measures the adhesion of the magnetic layer to the plastic base according to ASTM D 3330-90. According to our adhesion test results, the magnetic coating did not peel cleanly from the plastic base.

4.1.2 Abrasion tests of the magnetic layer

As shown on sheets 17–20 of our presentation, naturally and artificially aged audio–tapes needed more rotations of the abrasion wheels for deterioration of the magnetic layer than the reference intact audio–tapes. But the 1" video–tapes exhibited an opposite effect in comparison to the audio tapes. In this case the naturally or artificially aged video tapes abrased quicker than the comparable intact magnetic tapes. The layer of the tested 1" video– tapes (about 3 µm) is much thinner than the tested 1/4" audio–tapes (about 10 µm).

An advantage of this procedure compared with other methods[2] is the constant, defined abrasion (refacing of the abrasion wheels, continuous removal of the dust from the surface of the samples during the abrasion test) and running these tests under standard climate conditions (23°C/50% r.h.). It seems important, however, to adjust the refacing intervals of the abrasive wheels to the thickness of the magnetic layer.

4.1.3 Hardness of the magnetic layer

As mentioned earlier, polymeric binder hydrolysis should lead to a loss of cohesion of the magnetic layer and consequently to a reduction of its hardness. Therefore hardness should be an interesting criterion. This is a valuable confirmation of „Nano–hardness" being a criterion of ageing. A special advantage of this method is the very small amount of samples needed, which furthermore need no other preparation.

As shown in our presentation (sheets 21–24), there were significant differences in the hardness of the magnetic layers, between intact and naturally aged audio– and video–tapes at a higher penetration depth. In general we obtained a decrease of the hardness from the magnetic layer in the case of natural aged samples. Comparing the hardness of the artificially aged samples, there was an opposite effect on the hardness of the magnetic layer between audio– and video–tapes, for which no exact explanation could be found at the moment. Perhaps this is a part of for the general problem of imitating the natural ageing process.

4.2 Results and discussion of the chemical tests

4.2.1 TGA–analysis of the magnetic layer

Striking differences were found in TGA–diagrams in the observed temperature region for intact and naturally aged 1/4" audio–tapes (see sheet 28 of the presentation). In the case of 1" video–tapes no similar differences could be found (see presentation, sheet 29). Future explanation for this phenomenon will include the differences of the composition between the audio– and video–magnetic layers.

The advantages of this method are self-evident: small quantities of test materials, high precision and reproducability, and, above all, a quick test procedure.

4.2.2 DSC–analysis of the magnetic layer

Remarkable differences were also found in DSC-diagrams in the observed temperature region for intact and naturally aged 1/4" audio–tapes (see sheet 26 of the presentation). As in the case of TGA-Analysis for 1" video–tapes, we could not find differences between the intact and naturally aged tapes of one type (see sheet 27). The advantages of this method are the same as for the TGA–analysis.

4.2.3 Solvent extractables of the magnetic layer

As mentioned before, the hydrolytic deterioration of the polymeric binder material of the magnetic layer leads to small fragments, which can be extracted by weak solvents, such as acetone. As shown in sheets 30 and 31 of our presentation, there were significant differences between intact and hydrolysed (natural and artificial aged) magnetic tapes. A disadvantage of this method is that other components of the magnetic layer, like lubricants or other additives, are extracted, too. The amount of lubricants inside the magnetic layer should, therefore, be determined separatly. Some authors[3,4,5]

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[2] ***E.F. Cuddihy***

Ageing of magnetic recording tape
IEEE Transactions on Magnetics, Vol.Mag-16; No.4, July 1980

[3] ***H.N. Bertram and E.F. Cuddihy***

Kinetics of the humid ageing of magnetic recording tape
IEEE Transactions on Magnetics, Vol.Mag-18; No.5, September 1982

[4] ***E.F. Cuddihy***

A chemical ageing mechanism of magnetic recording tape have measured the solvent extractable components by using the complete magnetic tape. This procedure, however, seems not to be correct, because of the included amount of hydrolytic binder fragments from the back coating.

5 Conclusion

Tests were made of naturally and artificially aged 1/4" audio– and 1" video– magnetic tapes. These results were compared with those of intact tapes. The chosen climatic parameters, i.e. temperature and humidity, were relatively high in order to obtain deterioration effects within acceptable periods. The temperature levels for artificial ageing were below and in the region of the glass transitition point T_g of the PETP–plastic base, but in general over the T_g of the binder of the magnetic layer.

The height of the test temperature is still under discussion at an international level (as is artificial ageing generally).

The reduced adhesion between plastic base and magnetic layer caused by ageing, was determined by suitable tensile tests. The „critical elongation" for the removal of the magnetic layer showed a more or less significant reduction in all tapes, depending on the duration of ageing. On the other hand the tensile test did not show a relevant deterioration of the plastic base (so called "maximum elongation").

The reduced cohesion caused by ageing was examined using abrasion tests and measurement of hardness. With audio–tapes an increase of the abrasion resistance was found. As has been discussed, abrasion stability by a Taber-Abraser is a direct parameter for the cohesion - the functional connection, however, is obviously more complex. Video tapes showed the opposite trend. Furthermore it was found that naturally aged audio- and video tapes had a lower Nano–hardness than intact tapes.

Artificially aged audio– and video–tapes showed an opposite behaviour of the hardness to the natural samples. This could be a part of the problem of imitating the natural ageing process in artificial ageing processes.

According to material science, inferior hardness and higher abrasion go together with reduced cohesion. In summarizing, this new method seems to be very promising.

The thermo–analytic tests (TGA– and DSC–analysis) showed striking differences in the behaviour of magnetic layers between the intact and the naturally aged audio– tapes. There is a good chance that – in spite of the present inconsistency of interpretation – this new method can be established as an effective procedure in this field in future.

Finally, a remarkable increase of the extractable parts of the binder of the magnetic layer was found after natural ageing, which is in accordance with the interpretation of the molecular decline.

The presentation showed also the problem of the classical Arrhenius–extrapolation of **e**nd **o**f **l**ife (**EOL**). Each testing method leads to another EOL–value. Which EOL–value is the right one ? Is it really correct to take the lowest extrapolated EOL–value for the life time prediction of the tape (suggestion of ANSI IT9–5 and AES)?

Another problem of Arrhenius–extrapolation is the logarithmic time scale, where small deviations of measured results lead to big differences of extrapolated values. And for running these tests generally a lot of sample material is needed, which is a big problem in the case of unique, historical data carriers.

Our suggestion is to make a classification of the tapes instead of the classical Arrhenius–extrapolation in "traffic light way".

After running accelerated ageing tests at for example two conditions, tape testing should be performed with the introduced methods by comparing the results before and after ageing tests. This should be assessed in the following manner:

Red light:

That means, there is a significant change of several testing methods; this highly endangered tape should be transferred as soon as possible.

Yellow light:

There is a significant change in some of the testing procedures; this tape should be transferred.

Green light:

Testing has not shown any significant changes for this tape; there is no danger for the long term stability for this tape.

Jet Propulsion laboratory, California Institute of Technology

5 ***I. Gilmour and F. Fumic***

Recent Developments in decomposition and preservation of magnetic tapes

Phonographic Bulletin No. 61, November 1992

Modérateur / Moderator : Maïc Chomel, Administrateur de la Phonothèque de l'INA

Discussion

From the floor

I have two questions. Firstly, in your first slide, you mentioned that your estimates showed 40 million hours of audio tape and 30 million hours of video tape. Where did you find this information? This is the lowest estimate I have ever heard. Secondly, did you burnish the tapes that you are currently testing in order to simulate them actually having been recorded?

A Speaker

Dietrich Schüller would answer your questions far better than I would since he furnished the information to us. He is the Head of the Archives of the Austrian Academy of Sciences; we are only small chemists. All of our information comes from him.

(Mr. Schüller's response is inaudible, having been made without the microphone.)

The reply was on the lines of: There have been several surveys of the amount of audio and video material held in collections. One was conducted by the Library of Congress and sponsored by Kodak. Another was a UNESCO project conducted by IASA. Any survey is a sample of the total. The figures quoted are approximations based on the results of these surveys.
In answer to your second question, we tested all of the tapes before performing the tests. We obtained the tapes from the Austrian Phonogram Archives, which are the professionals in this field. The naturally-aged tapes may present some failures. However, the "intact" tapes were truly intact.

From the floor

You referred to Committee ANSI 9.5. This joint committee has yet to devise a test method for making a tape as a result of many problems that you described. We would very much welcome your input. You and Dietrich should come to the United States for our next meeting, in June. I would also like to ask a question about the solvent method. How do you deal with the problem raised by Ian Gilmour (extraction of lubricants)?

A Speaker

We designed the lubricant measurement technique as follows: the magnetic layer was separated from the tape substrate and measured the extractable components. You are correct. We definitely extracted the lubricant with the break binder in one way. That is the general downfalling of this method. Does this answer your question? The same problem arose with other types of tape.

From the floor

Could you give your definition of "end of life"?

A Speaker

We first studied the naturally-aged components that had been fully destroyed. Our end of life point was established at around the level of decay. This method proved quite convenient.

Maïc CHOMEL

Je vais maintenant donner la parole à Bernd Hänsch, qui va nous parler de la nécessité dans laquelle se trouvent beaucoup d'entre nous d'utiliser comme étape intermédiaire de la numérisation des supports fragiles comme les CD-R et les DAT audio. Comme nous les utilisons comme supports intermédiaires, il convient de s'interroger sur leur durée de vie et leur fiabilité.

CD-R via DAT as intermediary Audio Formats

Bernd Hänsch
Südwestrundfunk Stuttgart - Germany

Ladies and gentlemen,

I`m glad to have the opportunity to speak to you on this symposium about the comparison of CD-R and DAT as intermediary audio formats.
May I introduce myself. I am working for the Südwestrundfunk in Stuttgart at the system service and planing department, my special area is audio signal processing.
I studied communication techniques at the University of Applied Science in Esslingen, where
I made my diploma in physics. After my studies I started working at the Swiss Firm Studer in Zurich. Since 1991 I have been working for the Südwestrundfunk. The last 5 years I have specialized in digital audio medium.
The audio archive I am taking care of covers about 600thousand carriers. 100thousand of these are digital carriers and only 10thousand of the digital carriers are self-recorded, but they are the most valuable part.

Throughout my preparations for this presentation I discovered that comparing these complex technologies is like comparing apples and pears. What I am trying to say is that it is very difficult to make an objective judgement, which of the two technologies is the better one to put audio on digital media into the archives.
So if we want to make a comparison of these two technologies, one of the few ways to get a result is to compare the block error rate. (BLER)

Introduction
First of all we need to determine and describe the quality of the medium we want to put into the archives. This means the quality of the right after the production process. This is necessary to make reliable statements at future measurements, about ageing for example.
In the following parts I am going to take a closer look on this question.
Other studies to the problem of ageing are made. One of them is presented here in this symposium from Jacob Trock of the Royal Danish Academy of Fine Arts. In his speech to the permanence of CD-R media he says:" It shows that permanence of CD-R media is not only dependent on the media, but also on the condition of how it was written."

About the reproducibility of BLER measurements
First of all the method of the measurement is unquestioned because it is simple to count errors. The error flags are counted by the playing machine itself, respectively by the decoder chips.
All we do at the measurement is count and revalue these error flags.
The problem of understanding the results of the BLER measurements is that we do not count the errors on the media itself but the errors that occur during the playback process.(fig.1.1)

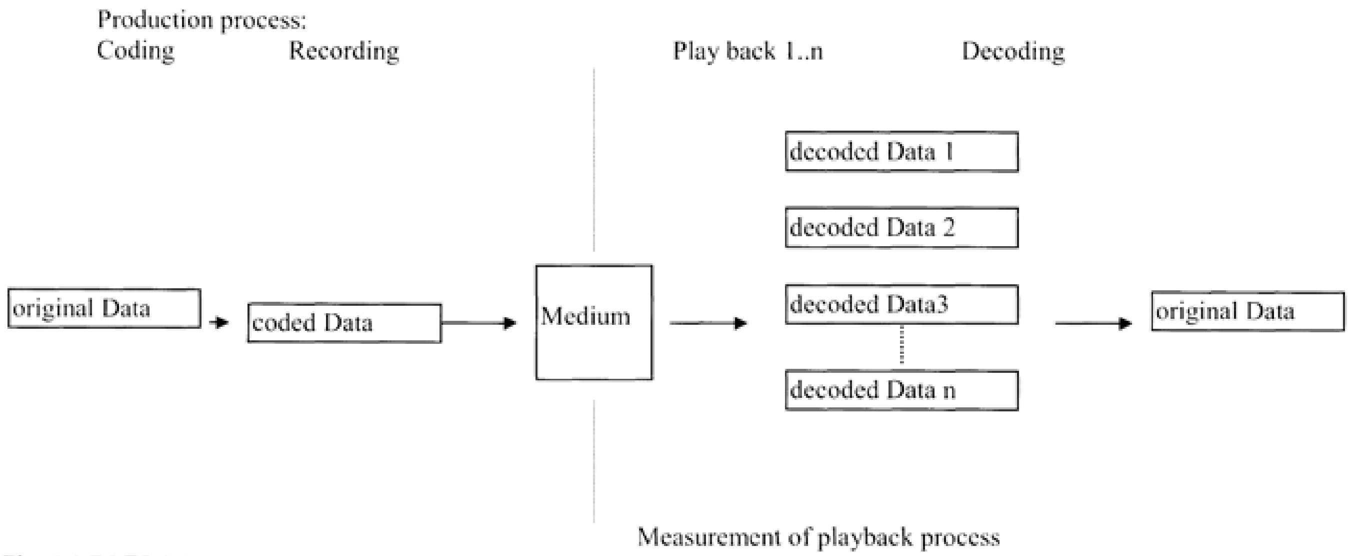
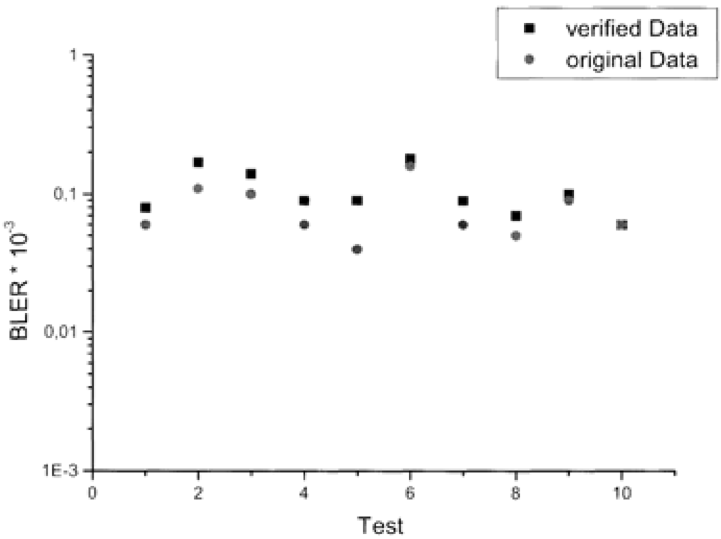


Fig. 1.1 BLER Measurement Process

We took a few samples out of a production series with known block error rates to demonstrate the reproducibility.(fig.1.2)



	Mean	sd(yErğ)	se(yErğ)	Sum	N
verified Data	0,107	0,04165	0,01317	1,07	10
original Data	0,079	0,03635	0,01149	0,79	10

One-Way ANOVA* to col(verified Data) -> col(original Data):

Data	Mean	Variance	N
verified Data	0,107	0,00173	10
original Data	0,079	0,00132	10

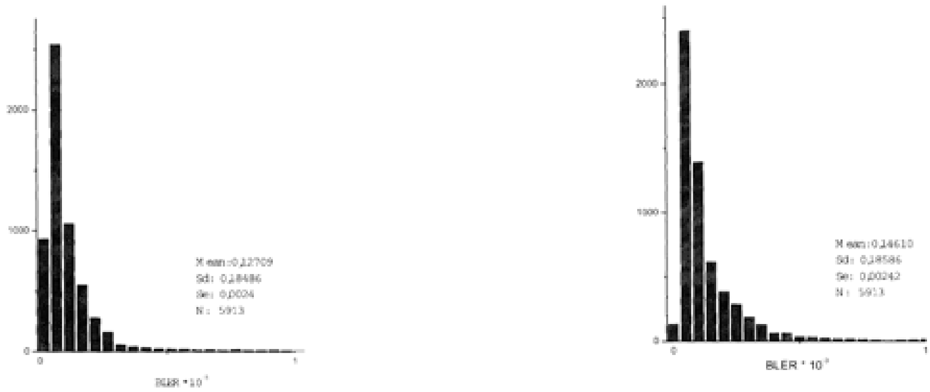
F = 2,56582
p = 0,1266

on the Level 0,5 the average values are NOT significantly different

Fig.1.2 Sample of 10 measurements from the quantity of a production series for the demonstration of the absolute reproducibility of BLER measurements

* Analysis of variance

It shows that we can compare the single measurements only in their tendency. If we want to make absolute statements we need to look at statistically relevant quantities. I would like to show you two examples.
The first example shows a production series where an analogue tape is re-recorded on two DAT copies on two different machines from the same type. For both copies the production environment is comparable. What we want to see is, how close the results are.(fig.1.3)



Independent t-Test over 21 samples of the same serial number of a production series:

Data	Mean	Variance	N
A	0,11914	0,02764	21
B	0,1741	0,04978	21

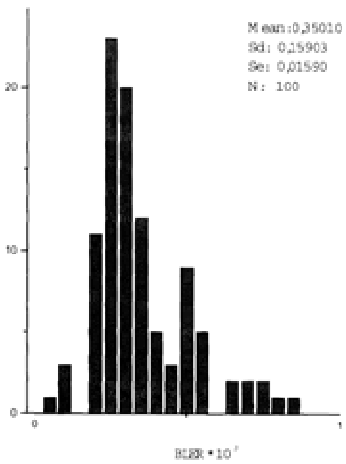
t = 0,90508
p = 0,37084

on the Level 0,5 the average values are NOT significantly different

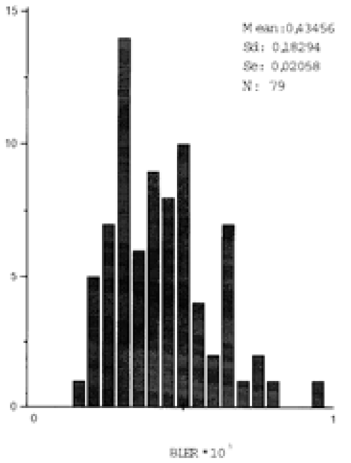
Fig. 1.3 Comparison A and B Copy of a production series

The second example will show a production series of our commercial department. It compares samples of the same production over a longer period of time. The recordings were made on the same machine. What I want to show is the stability of one production process.

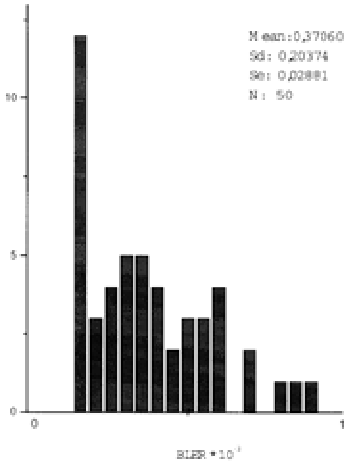
In comparison to the first example we see also that the absolute results are worse, depending on an older generation of used recording machines.(fig.1.4)



Sample of 100 tapes from the production series SDR-commercials spring 1995



Sample of 79 tapes from the production series SDR-commercials autumn 1995



Sample of 50 tapes from the production series SWR-commercials 1999

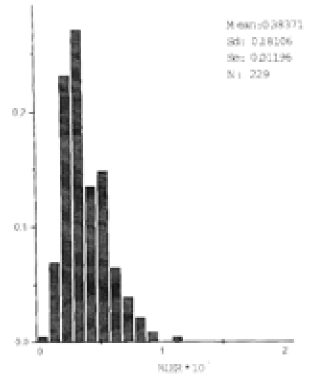
Fig 1.4 Comparison of a production series over a longer time

Examples like this can be used to find limits for BLER on DAT recordings, because there are no standard limits for this technology. On the contrary, there are standard limits of 3% BLER for the CD-R technologies.

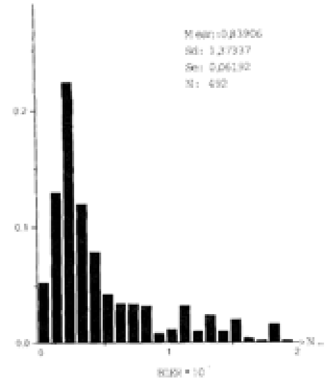
Comparison of typical values from both technologies

In the following we want to discuss typical values from both storage technologies relating to each other. In the archive of the SWR Stuttgart we use only DAT's, therefore we rely for the CD-R Data on a study from the Optical Storage Technology Association. In this study different media were written with different writers to see the compatibility. Their data of BLER represent an average of the commercial standards of CD-R media and writers.

As you can see in the figure below, the reached BLERs are not very different.(fig.2.1)



DAT production series commercials (red)



CD'R OSTA Compatibility Study (blue)

Gauss Fit for Histgm. BLER for 0-0,6:

Mean	SD	Area
0,23303	0,13472	32,20745

Fig. 2.1 Comparison of typical BLER for both technologies

Two further experiments, we did at the SWR, showed comparable results. In the first experiment we checked the variations of the BLER of the same type of CD-R media over a longer period of time. Therefore we used the same CD-R type of the same manufacturer from different years. We recorded them with three writers of different ages.
The mean was 0,02% and the standard deviation 0,036%.
In the second experiment we checked the variations of the BLER for a current type of CD-R media. Therefore we used some current disks of the same manufacturer. We recorded them also with three writers of different ages.
The mean was 0,021% and the standard deviation 0,029%.
It shows that the ANOVA is not significant.

If we take stock of all these facts, both technologies are comparable on the BLER area, especially since they have similar error correction systems.
The following table shows characteristics of the error correction relevant technical data.(tab.2.1)

DAT:

effective recording width	2,61mm
track length	23,501 mm/track
scanning velocity	1567 mm/s
track pitch	13,591µm
PCM Blocks	128 Blocks/track
Block data rate	8533 Blocks/s
Track area	0,319 mm²/track
recording area	***21,27mm²/s***
Block density	***419 blocks/mm²***
Redundancy	37,5%
Transmission rate	2,46Mbit/s

CD-R:

scanning velocity	1200-1400 mm/s
track pitch	1,6µm
Block data rate	7333 Blocks/s
middle recording area	***2,0 mm²/s***
middle Block density	***1762 blocks/mm²***
Redundancy	30%
Transmission rate	2,034 Mbit/s

Table 2.1 Compare error correction relevant system data of DAT and CD-R

If you consider the comparable error correction characteristics related to the different density of data on both media you see a small advantage at the DAT system.

Distinction of both technologies

At different BLER measurements on DAT tapes we saw high values of 5% errors without any effect on the playback. Other playbacks showed interpolations at an error rate of only 1%.
To find out how an interpolation develops we made a measurement of over 1000 cycles of one tape position. It showed that an interpolation is a local error, not appearing in the mean.(fig.3.1)

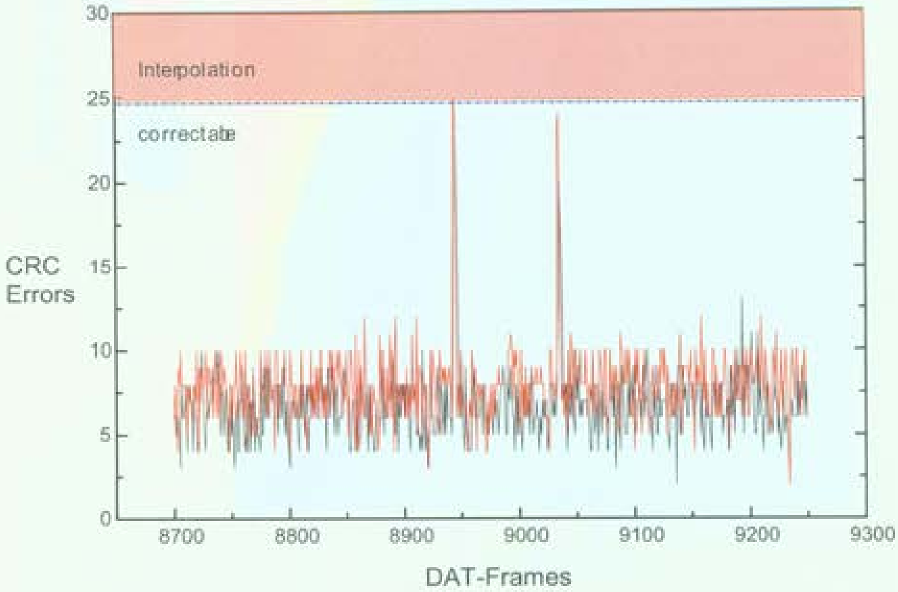


Fig. 3.1 Interpolation on a DAT Tape after 1000 cycles

Our next step is to look at how BLER develops. We will show it with the example of CD-R.
First we take a result from the OSTA-compatibility study.(fig.3.2)

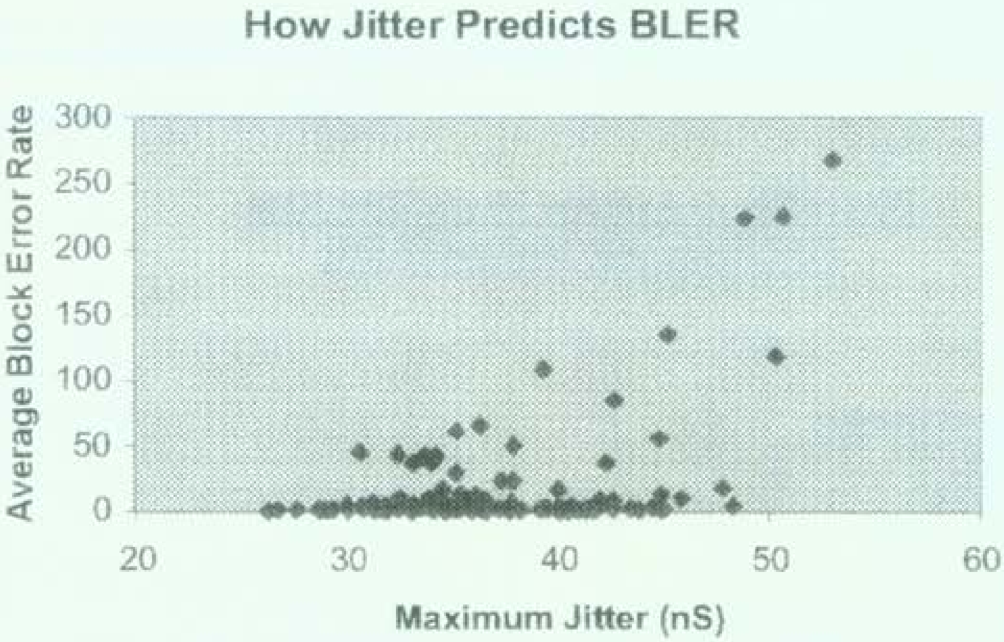


Fig. 3.2 Relationship between Jitter and BLER (OSTA compatibility Study Phase 2)

This graph shows the nonlinearly relationship between Jitter and BLER. Hereby is Jitter a parameter representing the quality of the recording process. For the evaluation of CD-R recordings it is more efficient to take Jitter as a quality parameter instead of BLER.
If we add another, variable to this relationship, the radial noise, a parameter for using, ageing etc., it becomes obvious that it is mandatory to use more sensitive parameters than BLER.(fig.3.3)

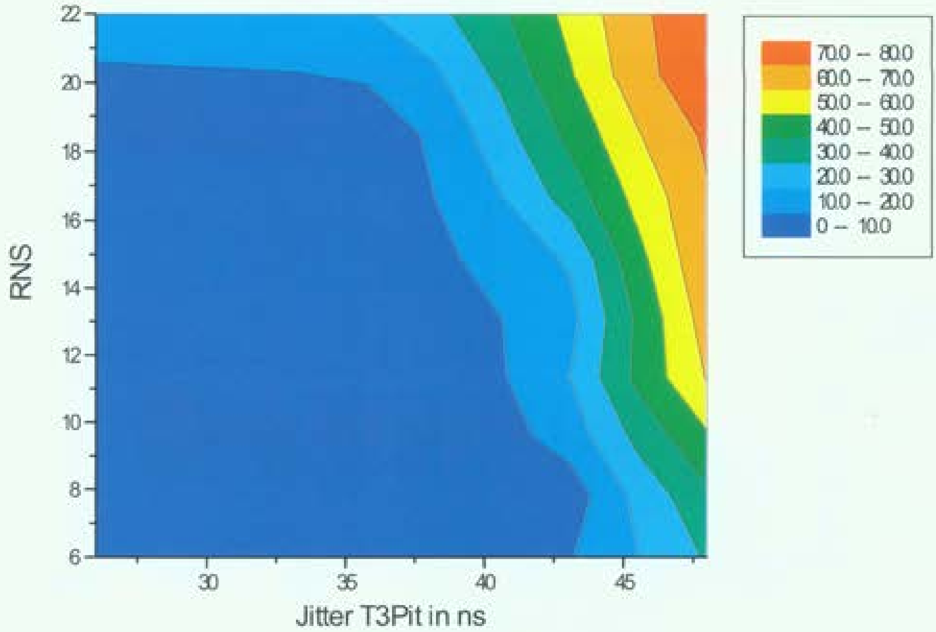


Fig 3.3 Relationship between Jitter as a parameter of production, RNS as a parameter of use and BLER

If we consider all these facts the main use of BLER is to assess the statistical loss of information by maintaining the system parameters, especially the servosystems. The servosystems are necessary to maintain the playback process and they are very different in both systems.
In CD-R you get the servosignals from the original data stream and you have a positionsystem with two dimensions. With DAT you have a reduced degree of dimensions through the mechanical limits and additional pilot signals for the servosystem.
Another example for the independence of the playability of a media from BLER is shown in another graph from the OSTA compatibility study.(fig.3.4)

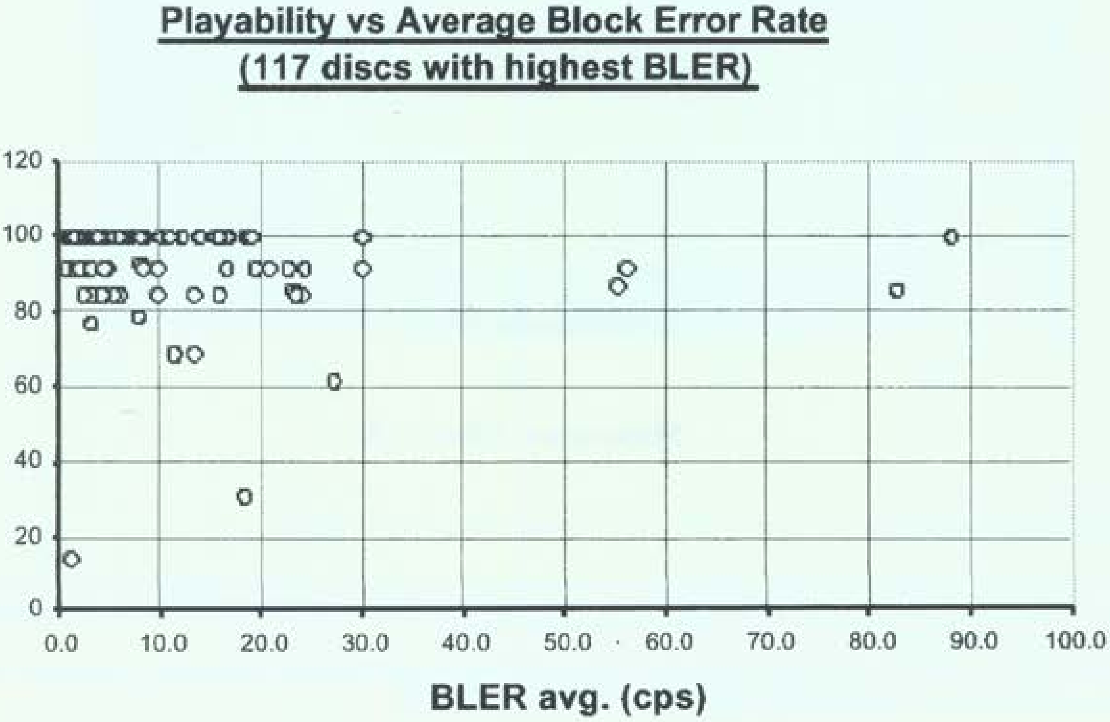


Fig.3.4 Relationship between the playability of CD-R's and BLER (OSTA compatibility Study Phase 2)

Quality of the produced media

Back to our first statement: the necessity of determining the quality of the produced media.
The comparison of the quality of the produced media over several years, for both techniques, is shown in the following graphs.(fig.4.1)

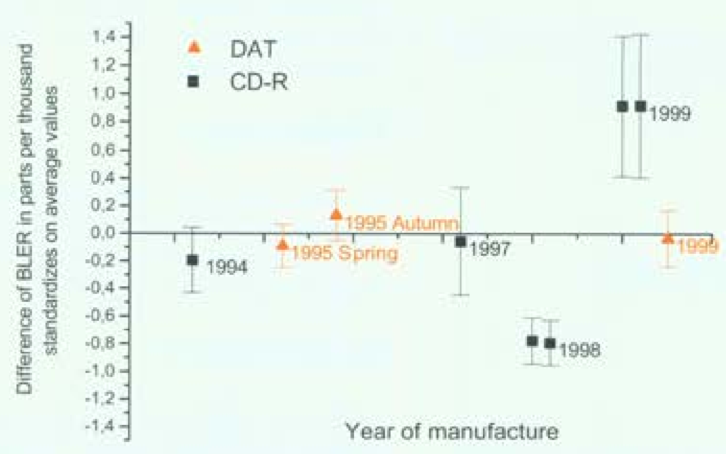


Fig 4.1 Development of production quality over the years

Here you see the data from the production serie of the commercials, as shown above, for the DAT values. And for CD-R you see the experiment of variation of the BLER with the same type of CD-R media over a longer time, as explained earlier.
The DAT system has been pretty constant over the years. The CD-R system, in contrast, differs more. Especially if we relate the writer generation to the media generation.(fig.4.2)

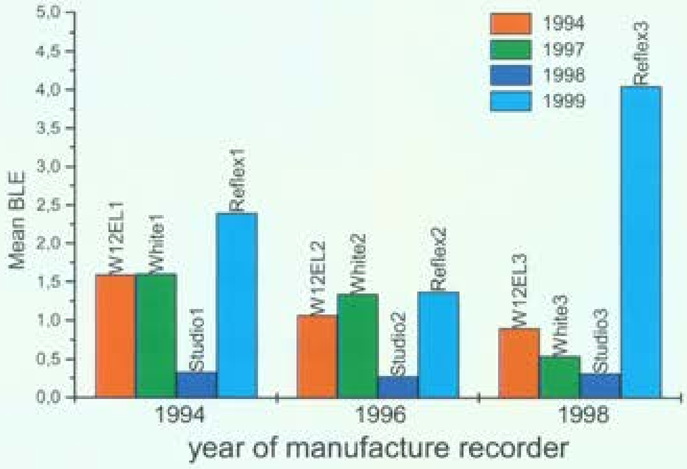


Fig 4.2 Development of production quality over the years for different generations of writer

Conclusions

In the DAT system we see constant quality in the production process and an improvement in the quality of the recording and playback systems.
In the CD-R system we see some modification in the media manufacturing process.
First you can see the improvement of the technology, but then the results of cheaper production for the consumer market. Different writer generations react differently to this development.
There is no professional market for CD-R and also no consumer market for DAT.
That means no high quality CD-R products and no more development for DAT technology.

Ladies and gentlemen, thank you very much for your attention.
I hope you can use these demonstrated data for your own mandatory, regular controls at your own archive.

Discussion

From the floor

Did you try replaying the same CD or CD-R on the same machine with and without the spindle?

Bernd HÄNSCH

No, we did not.

George BROCK-NANNESTAD

You did not?

Bernd HÄNSCH

We only use R-DAT types in our archives. We have performed many experiments on those, but only a few on elements that are not present in the laboratories.

George BROCK-NANNESTAD

I would like to make several points. Firstly, did any of the discs or tapes used exceed the capacity of the error correction system? The error correction systems in CD or DAT systems are only effective up to a certain level.

Bernd HÄNSCH

No. The only unusual errors that we encountered were those which created user problems on the decoder side.

George BOSTON

From what you said, it appears that the choice between CD and DAT is in fact a choice of the "lesser evil". Could you share your views on the survivability of the machines and the format?

Bernd HÄNSCH

Many of us have wondered about the use of CDs and DAT five years ago. Today, we see that there are many other possibilities. However, when one chooses one of these technologies, one must perform one's job very well. We have chosen DAT technology and must therefore strive to maintain our machines as best possible. The problems associated with DAT arise within the machines, during the production process. One must look at the machine and ensure that all of the parameters are constant. When using CD-R technologies, the problems lie in finding the best combination between writers and Real media. If one manages to find the right combination, one must find a way to "freeze" it, or preserve it, in spite of today's constantly progressing technology. After only three to four years, it becomes impossible to find the same material. Both technologies have their own problems. One must look at the whole of the system. Both are satisfactory enough to be used. However, if you aim for professional quality, you must work around a certain number of obstacles.

From the floor

In what ways do you think that the media have deteriorated or become worse? Is that what you meant? You stated that the writers had improved, while the media had declined in quality?

Bernd HÄNSCH

Media are now produced at a lower cost. As for writers, their efficacy varies. My last slide shows this.

From the floor

Are you saying the problem lies in possible incompatibilities between the two systems rather than in the declining performance of the media?

Bernd HÄNSCH

Before 1994, the media consistently improved from generation to generation. The newer generation of writers is also better than that of the past. The reaction is different. The user cannot influence this situation. Customers who buy the new generation of CD-Rs must first test them to be sure that they can be used with their writers.

From the floor

Do the dyes affect this situation in any way?

Bernd HÄNSCH

Yes. Given the extremely high price of the dyes, the process had to be optimised and prices lowered. When one holds a cheaper disc up to the light, it is clear that the dye does not move to the borders immediately. In addition, the dye is not evenly distributed throughout the disc. This, too, is the result of today's cheaper production methods. Lastly, the thickness of the polycarbonate is reduced. When the film is removed from its case, it is too pliant and become concave immediately. Many players cannot handle this since their focus regulation systems cannot correct this defect.

This problem does not exist with DAT since it was not intended for the consumer market.

From the floor

When referring to the CD-R market, do you mean that which wants to write computer and audio CDs?

Bernd HÄNSCH

Yes. Although the technology involved is better than that of other systems, it does not meet professional standards.

From the floor

One fact worries me. You stated that the thickness of the polycarbonate had been reduced. That can only happen if the polycarbonate material's index of refraction has previously increased. You need the thickness of polycarbonates to achieve the right focus. It is also a question of flexibility.

Bernd HÄNSCH

I have not looked into this question specifically. We have simply noted that the later generations always have defects on the outer tracks. We have carried out studies on this problem and have discovered that it is due to the focus possibility. When the offset of the focus is readjusted on the spindle motor, we achieve better values. The playability on the outer tracks clearly improves. I therefore feel that the problem likely came from the polycarbonate thickness.

From the floor

Like my fellow participant, I feel that the thickness necessarily remained the same. Two elements may be the cause of this difference. Firstly, in the recent «jewel» cases, the take-up of the CD is far stronger. It holds the CD back with such strength that a human being cannot remove it, even with two hands. This was not the case in the past. The second element is the fact that users are becoming accustomed to the system. They are now used to grasping the disc with only one hand. In doing so, they inevitably bend the CD beyond the necessary point.

Bernd HÄNSCH

It is interesting to see that the same problem arises with pressed CDs. However, these do not present any compatibility problems with the players. Therefore, I indirectly believe that there are other reasons.

Permanence of CD-R Media

Jacob Trock
The Royal Danish Academy of Fine Arts, School of Conservation, Denmark

Background

From 1996 could documents be delivered to the Danish State Archives solely on Compact Disc Recordable (CD-R)? A decision based upon a report from the Danish Ministry of Research that focused on the changes that take place in the Information Society and the following impact on public administration.

Searching for a topic for my Master Thesis at the School of Conservation, this topic catched my interest at once and I decided to take a closer look at the CD-R media, the technology behind and its permanence. At a very early stage of my work I took contact with Audio Development, the leading company for test equipment for Compact Discs. A close co-operation with Audio Development and The School was initiated and compatibility tests and accelerated ageing tests were performed.

The purpose of all the tests could be modified to three questions: What affects the permanence of CD-R? How do we register the changes? And third: How do we explain the changes? Answering these questions should help understanding the life of CD-R discs and their permanence.

Life expectancy

Many estimates on permanence of CD-ROM and CD-R have been made. The major part of these tests has been carried out by the same companies that produce CD-R media, and in many cases to prove their superiority towards other CD-R brands. Lack of standards for testing gives the companies the opportunity to put influence on the results. It gives reasons to question some of the tests that have been made, especially when comparing competitors. Well, they might be true in some extend, but changing the Recorder, writing speed or production batch could change the results completely.

Comparing different predicted Life expectancies on Compact Discs does not give that clear picture one would like to have:

Media type	Source	BLER Limit	Life expectancy (years)
CD-DA	Philips(1)	Not. spec.	10
CD-ROM	The Yellow Book(2)	220 $s.^{-1}$	5-100+
CD-ROM	William Saffady(3)		25
CD-ROM 3M	3M(4)	220 $s.^{-1}$	500
Optical Media	Jeff Rothenberg(5)	50 $s.^{-1}$	10
CD-R, Kodak InfoGuard	Kodak(6).	50 $s.^{-1}$	217 (100 yr. guar.)
CD-R Mitsui	Mitsui Toatsu(7)	50 $s.^{-1}$	145
CD-R TDK metalstab. Cyanine	TDK(8)		100 (70 yr. guar.)
CD-R Cyanine	Mitsui Toatsu(9)		> 20
CD-R Verbatim DataLifePlus	Verbatim(9)		100+
CD-R	OSTA(10)		70-200
CD-R, phthalocyanine	VTT, Finland(11)	220 $s.^{-1}$	6
		50 $s.^{-1}$	3,5
CD-R, cyanine	VTT, Finland	220 $s.^{-1}$	31,5
		50 $s.^{-1}$	15

Table 1 Different statements on life expectancy on CD-ROM and CD-R media

What decides the permanence?

The CD-R media consist of five elements. All elements have more or less influence on the permanence of the media. A short description of each layer and examples on some experienced problems from accelerated ageing are listed below:

Polycarbonate belongs to the most stable polymeric plastics and is rarely a problem for permanence of the Compact Discs.

The production speed of Compact Discs is sometimes so high, that the disc leaves the moulding machine (stamper) before complete curing, causing inhibited stress that will have influence on the laserbeams ability to read the pits and lands. A disc is normally pressed within 10 seconds.

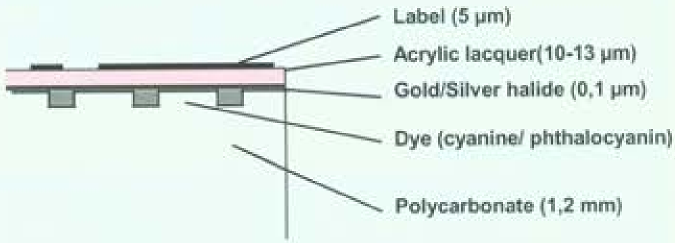


Figure 1 Cross section of CD-R disc

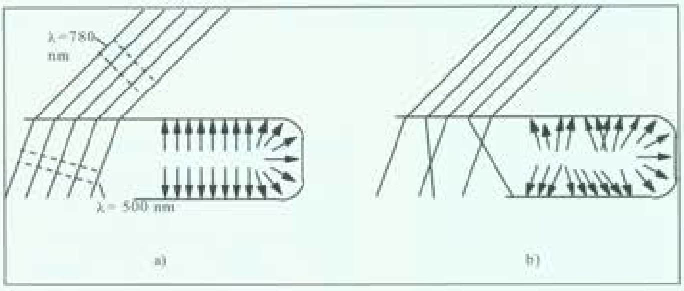


Figure 2 The laserbeams refraction in polycarbonate.
(a) Refraction without stress (b) refraction with stress causing birefringence.

The dye is the most fragile part of the CD-R disc. Four different kinds of dye are used: Cyanine, Metal-stabilised Cyanine, Phthalocyanine and Azo–dye.

Cyanine is the oldest used dye for CD-R media and is patented by Tayo Yuden. When the Orange Book, part II for CD-R media was formulated, cyanine dye was the only dye at the market at that time. This has of course given some technical advantages for the cyanine dye, discussing compatibility. Cyanine has unfortunately shown to be lesser stable that the other dyes for CD-R media. In 1996 TDK presented their metal stabilised dye, that seems clearly more stable than cyanine dye. It is almost impossible to distinguish between metalstabilised cyanine and cyanine, both looks blue-greenish. The phthalocyanine dye, patented by Mitsui, is the most stable dye, but on the other hand more sensitive to what kind of recorders that are used. The colour of phthalocyanine is pale blue. The last type of Dye is the bright blue Azo dye, patented by Verbatim/Mitsubishi. Results from own tests with azo-discs indicate compatibility problems with some recorders.

All dyes, but Cyanine dyes in special, changes in three ways during ageing: Contrast between the simulated pits and lands changes. This has influence on the reflectivity that again gives interpretation problems. Second, the shapes of pits and lands become smaller/longer causing higher Jitter, and third the dye from the neighbouring grooves cause higher Crosstalk.

Until today has gold been the most common metal used as **reflective layer** on CD-R discs. This inert metal does not degrade, but the thin metal layer is very vulnerable to scratches and dust particles between the dye and gold layer. The new silver halide reflective layer is now in many cases replacing the gold layer, only for one reason: it is cheaper.

The **protective lacquer** and the **label** can perform damage to the data, due to contraction during drying after spin-coating/printing in production. Surface presentations of Radial Noise after ageing, clearly illustrates how the label affects the data. High RN can cause problems with tracking.

Analysing the disc

Testing CD-R media is not possible for every one. Professional equipment for testing CD-R media costs something around 450.000 FF and it takes time to be able to get familiar with all the more than 80 different parameters that are used to analyse the disc.

The standard parameter for testing Compact discs is Block Error Rates (BLER), that is the number of errors that occur per second at first level of error correction. This parameter is very useful when analysing changes on a disc, because it summons all kind of defects. BLER is on the other hand almost useless if you want to find out why errors occur.

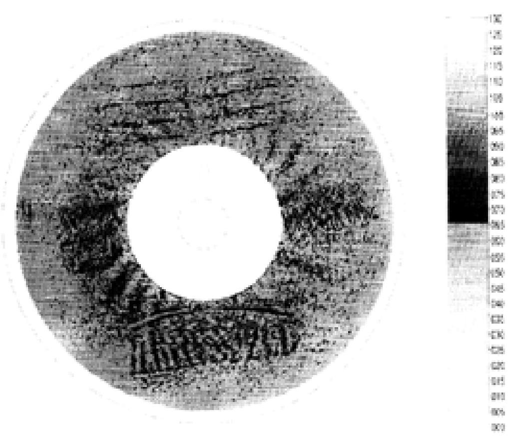


Figure. 3 Radial Noise (RN) Surface presentation of Kodak InfoGuard disc after 56 days at 65oC/85%RH.

Here you need to look closer on the many other parameters that are measured when testing a disc. Test results from Audio Developments SA3 Advanced gives you the ability to get a very detailed picture of critical quality characteristics. You are able to tell if there are compatibility problems, if the recorder is the problem, or if there are problems with the dye, the reflective layer or the polycarbonate.
Testing Compact discs gives you as well other important information like the "Disc Manufacturing Code" that tells you who made the disc and Optimal Recording Power (ORP) that tells the disc how many mW the laserbeam shall use for its initial Optimum Power Calibration (OPC) before recording. Some low end CD-R recorders uses solely this ORP data during the whole writing session without the initial OPC and following Running OPC.

Compatibility test

Compatibility tests between CD-R media and CD-R recorders are not very common. OSTA (Optical Storage Technology Association) has made two compatibility tests where they found no problems with compatibility[12 + 13]. Almost same result came to compatibility tests made by Doculabs in collaboration with National Media Lab[14]. I wanted to see if this really was true by analysing data from 30 recorded discs (5 different labels), recorded on 10 different recorders. Some tests were double tests. This gave a total of 20 different combinations for this compatibility test.
BETA measurements are one of the most important parameters, when making compatibility tests. BETA measurement shows in percent the difference between pits and lands on the disc. BETA tells immediately if the recorder has a functional Running OPC.

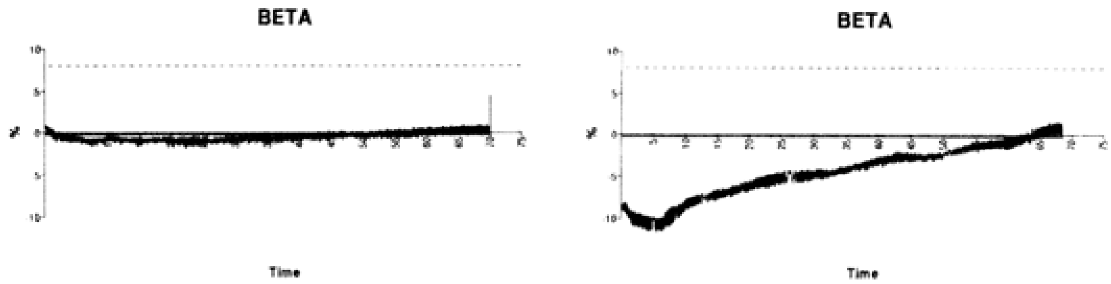


Figure 4 BETA measurements from Pioneer discs, recorded at Pinnacle CD-R recorder with Dynamic OPC, and Pioneer Recorder without Dynamic OPC.

All discs had a BETA variation over 2%, that is the limit in the Orange Book, part II. Too low or high BETA can very well be the reason why a disc can be read in one disc drive and not in another. In worst case in no drive at all even if there are no Block errors. This illustrate the complexity of analysing permanence of Compact Discs and the reason why the conclusion of this test deviates from the other compatibility tests. It depends of what parameters that are focused on and what weight they are given. Compatibility has been improved since this test was performed back in winter, 1996. Constant emerging of new recorders makes compatibility tests like this almost outdated if you want to use it as tool for selecting the best recorder and media.

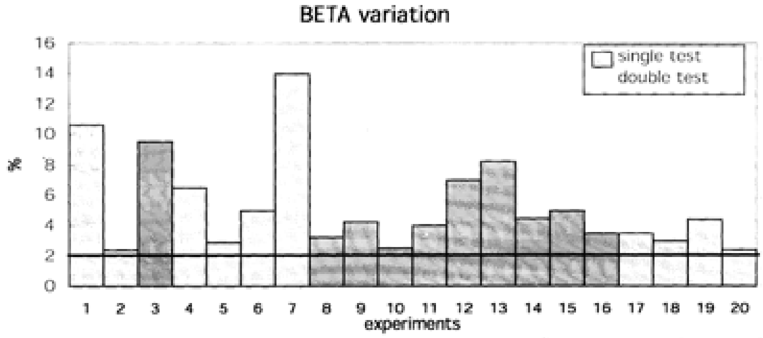


Figure 5 Beta variation from Compatibility test. All tests showed a variation above the 2% as prescribed in The Orange Book part II.

The BETA range for optimum recording is different from Cyanine and Phthalocyanine dye. In order to obtain the best "dialogue" between the recorder and disc, the recorder needs to know something about what kind of dye that are on the disc. In the latest revision of the Orange book, part II, ver. 3.0 is described how information will be placed in the discs ATIP signal, so that it can tell the recorder what kind of dye that are used, and what BETA-range that are recommended. This will surely reduce compatibility problems.

		CD-R Disc				
CD-R Recorder		Pioneer CDM-V74	Mitsui Gold	RICOH	TDK CD-R74	Kodak InfoGuard
Ed2 SONY	CDU9205	Bad	Acceptable			
HP	SureStore 402i	Acceptable	Acceptable			
Yamaha	CDE 100 II	Bad	Good			
SONY	Spressa	Acceptable	Good			
Pinnacle	RCD5040	Good	Good		Acceptable	
Pinnacle	RCD 4X4		Acceptable			
Pioneer	DW-S114X	Bad	Bad			
RICOH	RS-1420C	Acceptable	Acceptable	Bad		
TEAC	CD-R50S		Acceptable		Acceptable	
Philips	CCD 2000					Good

Table 2. Results from compatibility test.

Good: No problems at all, everything within the specifications in Orange Book, part II

Acceptable: Smaller deviations from specifications, with possible influence on permanence

Bad: Some measurements out of specifications. With certain negative influence on permanence

Does the writing speed have influence on the quality of recorded data?

In 1995 Mike Martin & Jack Hyonz[15] did come to the conclusion that phthalocyanine discs were not compatible to 1X writing speed, and cyanine discs to 4-6X writing speed. A small test was made to see if phthalocyanine meanwhile has become 1X compatible, since almost all phthalocyanine discs are labelled 1X compatible

A Kodak Disc was recorded in four sessions with alternately 2x and 1X speed. The disc was analysed before and after two months in a climate chamber at 85% RH and 65 °C. The result was very clear. Phthalocyanine is not compatible to 1X writing speed.

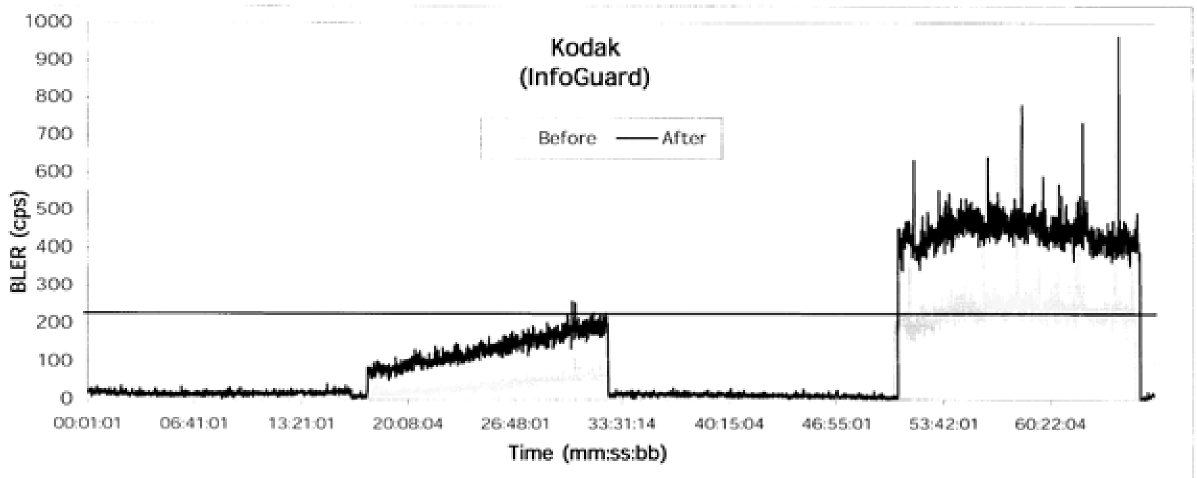


Figure 6 Phthalocyanine disc (Kodak, InfoGuard) recorded in four sessions alternately at 2X and 1X and aged in climate chamber at 65°C and 85%RH.

It was not possible to give a detailed explanation of why writing speed at 1X gave many errors. That writing speed is a problem with phthalocyanine discs, is illustrated by the increase of BLER's from the inner to the outer part of the disc, where the rotation speed slows down from 600rpm to 230 rpm.

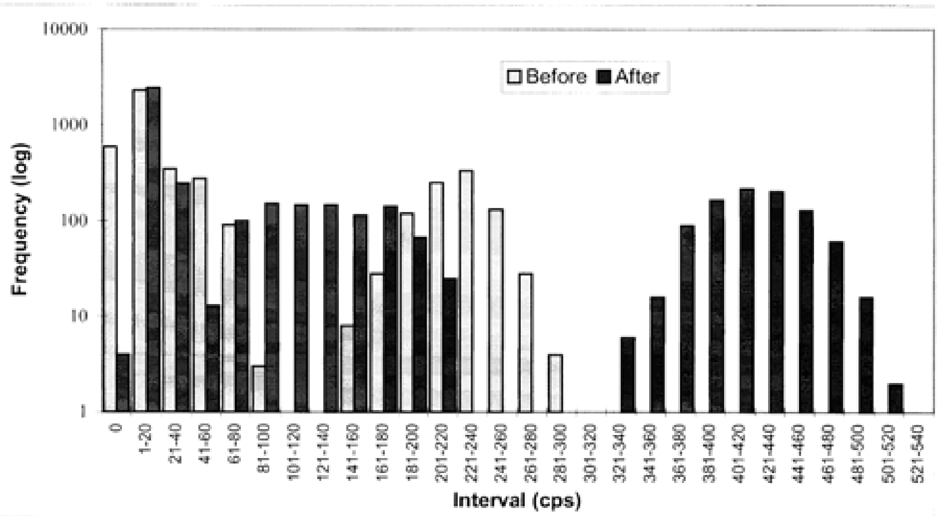


Figure 7 E_{11} distribution on phthalocyanine disc recorded 1X and 2X. Before and after 2 months accelerated ageing at 65^0C, 85% RH.

Is one disc representative in ageing tests?

When you have limited time and resources to make accelerated ageing tests, you have to find shortcuts and methods to make End of Life estimates (EOL) on a single disc. Four observations came handy:

1. Measuring a disc does not give a single result for each parameter. Middle values from a tested disc, represents about 4500 single measurements, that represent a very clear normal distribution with possibilities to use the data in statistical calculations, like standard deviations etc. (fig. 7)
2. Many of my double tests in compatibility tests and accelerated ageing tests were identical when comparing the measurements middle values.
3. Analysing the results from existing accelerated ageing tests on CD-R media indicate that Compact Discs in many aspects act the same way as with

other archival materials like paper, photographs, film etc. Assuming this is true, gives the opportunity to use Time Weighted Preservation Index (TWPI) on CD-R media, described by James M Reilly, Douglas W. Nishimura & Edward Zinn[16].

4. Comparing the change in the BLERavg with the change in other parameters middle value, demonstrated that BLERavg is representative, when analysing the stability of compact discs.

All four observations contain plenty of reservations and exceptions. On the other hand: a qualified guess is far better than just a guess. With that in mind, I started to select discs for accelerated ageing tests, following, as close as possible, the descriptions from ANSI/NAPM IT9.21[17]. 18 discs representing 11different disc labels were exposed to $65^0C/85\%RH$ for two months. A period that equivalates 45 years at $22^0C/55\%RH$. The EOL limit for the tested discs was set to be $BLERavg=20s^{-1}$ as defined by the industry.

Four of eleven disc labels showed almost no change in BLERavg during ageing. The discs were: TDK, Mitsui and Ricoh (phthalocyanine and metal stabilised cyanine). EOL estimates for these discs did not make sense, since it requires significant changes during ageing. Other four discs changed during ageing in a way that made linear regression of BLERavg possible. The last three disc labels performed weird changes in BLERavg that excluded them from use in linear regression analysis.

Some of the tested discs were tentative discs, delivered directly from CD plants and, not yet ready for consumers market. These tentative discs (named product A, B and C) were the most unstable.

Two of the tested discs came from Kodak. Both discs turned out to have dust particles between the polycarbonate and the reflecting layer, causing pinholes in the reflecting layer.

Two different kinds of discs from Verbatim were tested. One of them was Verbatim's own Datalife Plus disc with Azo Dye, recommended by Verbatim for archival purpose. The other disc was actually manufactured by TDK, but with a Verbatim label. It turned out that the TDK disc with metal stabilised Cyanine was far more stable that the Datalife Plus disc.

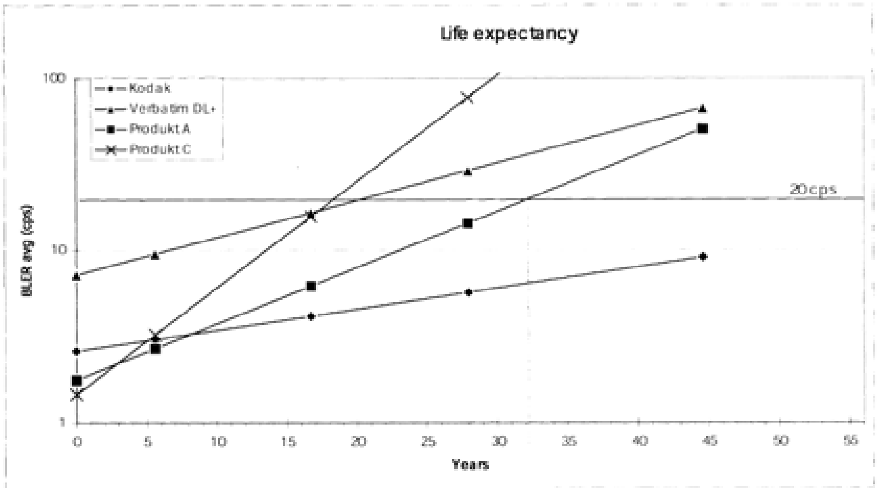


Figure 8 Linear regression of BLERavg from discs manufactured by Kodak, Verbatim DL+ and Product A & C (anonymous).

Conclusion

Phthalocyanine and metalstabilised cyanine is very stable. Using a Recorder that is compatible with a phthalocyanine/metalstabilised cyanine disc and recording at a speed 2X or 4X gives the possibility to create discs that will last for more than a century. Compatibility tests are highly recommended if the recorded discs are intended for archival purpose.

Using the many parameters that follow from test gives rich possibilities to find compatibility problems and in connection with accelerated ageing test the possibility to find the causes for instability.

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Discussion

From the floor

I have two relatively simple questions. You stated that 50% of CD-R are suitable for archival purposes. How many years are required to constitute "archival" use? You mentioned three to 300 years. The amount is probably closer to three years. Secondly, did any of your tests look into light sensitivity, which is also a very important factor in reducing life span?

A Speaker

I did not understand your first question.

From the floor

When you state that some CD-Rs are suitable for archiving, does this mean that one could keep the information on them for 100 years? How often must one re-record in order to keep up with the deterioration level? Can a material be considered "archival" if it lasts only a few years? What are your criteria?

A Speaker

Only professionals can use this equipment for archival use. It is necessary to test the media with the writer very often (upon receiving a new batch of disks, after 500 hours of writing, etc.). Those tests cost approximately USD 100 to USD 150. As regards life stability, the Orange Book states that life span should reach two years in normal office conditions. Very often, the discs are kept in jewel cases or in envelopes. Accelerated ageing is usually directly related to light ageing.

From the floor

I have noticed something strange. The old style of jewel case inlay is printed with a metal pigment that stops light far better than today's models. It is strange that the previous format was discontinued. The manufacturers are perhaps not aware that the older models transmit light less effectively and therefore protect the material better.

Sean DAVIS

I am sometimes involved in the commercial part of the business and was recently in America, working with one of the top mastering engineers. He stated that he always prefers to use writers that work at 1x since the sound quality is better. While I was with him, he discussed with people from Plextor, asking them to focus on that type of writer. Of course, this market is mainly driven by computer people. He did not specify what kind of discs he was using. Nonetheless, given that he is one of the masters in his field, it could be interested to carry out experiments in order to determine whether there is a difference in quality.

A Speaker

When using cyanine discs, 1x speed is better than 2x or 4x. If he is using cyanine discs, 1x may indeed be the best choice for him.

From the floor

Yes, certain writers function at 1x. My comment may refer to something already obsolete: have you carried out any research on the 24-carat gold CDs? When was the last time you tested them?

A Speaker

Are you referring to consumer discs?

From the floor

No, I am referring to 24-carat gold CDs.

A Speaker

Yes, 24-carat gold is used in Kodak discs.

From the floor

That is what is claimed. I am referring to pure 24-carat gold, which is used on high-spaced CDs or the Black CD.

A Speaker

Cyanine discs stir up more concern at the current time since Kodak has decided to move away from the gold layer and looking more at the silver. There is only one reason for that: it is cheaper. Although the discs respond very well during the recording phase, they may age poorly. The Verbatim discs which I tested actually had a silver layer. However, it was impossible to demonstrate that the layer is the reason for the problems encountered in ageing. I am concerned about that.

From the floor

Yet these are actually designed for archival use.

A Speaker

That is what they claim. When I tested the products, I saw that they were actually TDK discs. It had a much better permanence than the GDL plus.

From the floor

I did not understand your clarification of the term "archival". Could you say more on this? Secondly, did you use a standardised test process in your ageing or did you develop your own?

A Speaker

I used many of the recommendations made by the ANSI and ISO test. I followed them as closely as possible given my test conditions. I looked at the error rates, but also at a number of other parameters. I find it very difficult to actually set up rules as to what "archival" quality is. I have an idea of what it should be, but have not defined clear criteria. We still do not know how important the stability of the various parameters will be in the long term.

The CDs that I recommended for "archival" use are those which show little or no change over time. The actual figure may be higher than 50%. In any case, I am very strict in designating those discs.

Eléments de caractérisation de la qualité initiale et du vieillissement des disques CD-R

— —

Jean-Marc Fontaine
BnF – Université Paris 6 - CNRS - France

Actuellement, lorsque des transferts de programmes sonores, d'images fixes, de textes sont effectués sur un support de stockage amovible, il s'agit le plus généralement de disques compacts enregistrables une fois CD-R. Pris entre les objectifs de sauvegarde des informations numérisées, des conditions aléatoires d'enregistrement sur CD-R, et une durée de vie de ceux-ci incertaine, l'utilisateur doit prendre des mesures qu'il faut préciser.
Certes, l'attention se porte aujourd'hui vers les formes enregistrables du DVD, néanmoins il paraissait intéressant de faire le point de certaines expérimentations concernant le CD-R que nous avons menées ces dernières années. Les enseignements recueillis et les méthodologies développées pourraient s'avérer fort utiles pour les formats DVD à venir.

1. Quels mécanismes de gravure des informations sur le disque ? Un produit transparent mais bien opaque !

Avant d'aborder toute notion de comportement au vieillissement des disques, il convient de traiter la délicate question des conditions d'enregistrement.

L'étude de la dégradation des disques pressés nous avait conduit à nous intéresser tout particulièrement à la couche de vernis dorsal, maillon le plus faible de ces types de disques.
Le disque enregistrable une seule fois nous a, quant à lui, très rapidement orienté vers la couche sensible qui se montre beaucoup moins stable que la couche de vernis dorsal : l'espérance de vie des CD-R est plus courte que celle des disques pressés par les caractéristiques même que l'on recherche pour pouvoir inscrire des données.
Si les dispositions des éléments composant le disque sont très bien décrites, il n'en est rien malheureusement des mécanismes par lesquels les données sont marquées sur le substrat pour des raisons évidentes de protection de procédés de fabrication. Pourtant, les transformations provoquées par l'échauffement local de la couche sensible exposée au rayon laser posent de nombreuses questions à quiconque s'intéresse au devenir de l'enregistrement. En effet, l'acte d'enregistrement conditionne, dans une très large mesure et la qualité initiale d'enregistrement, et les possibles évolutions ultérieures.

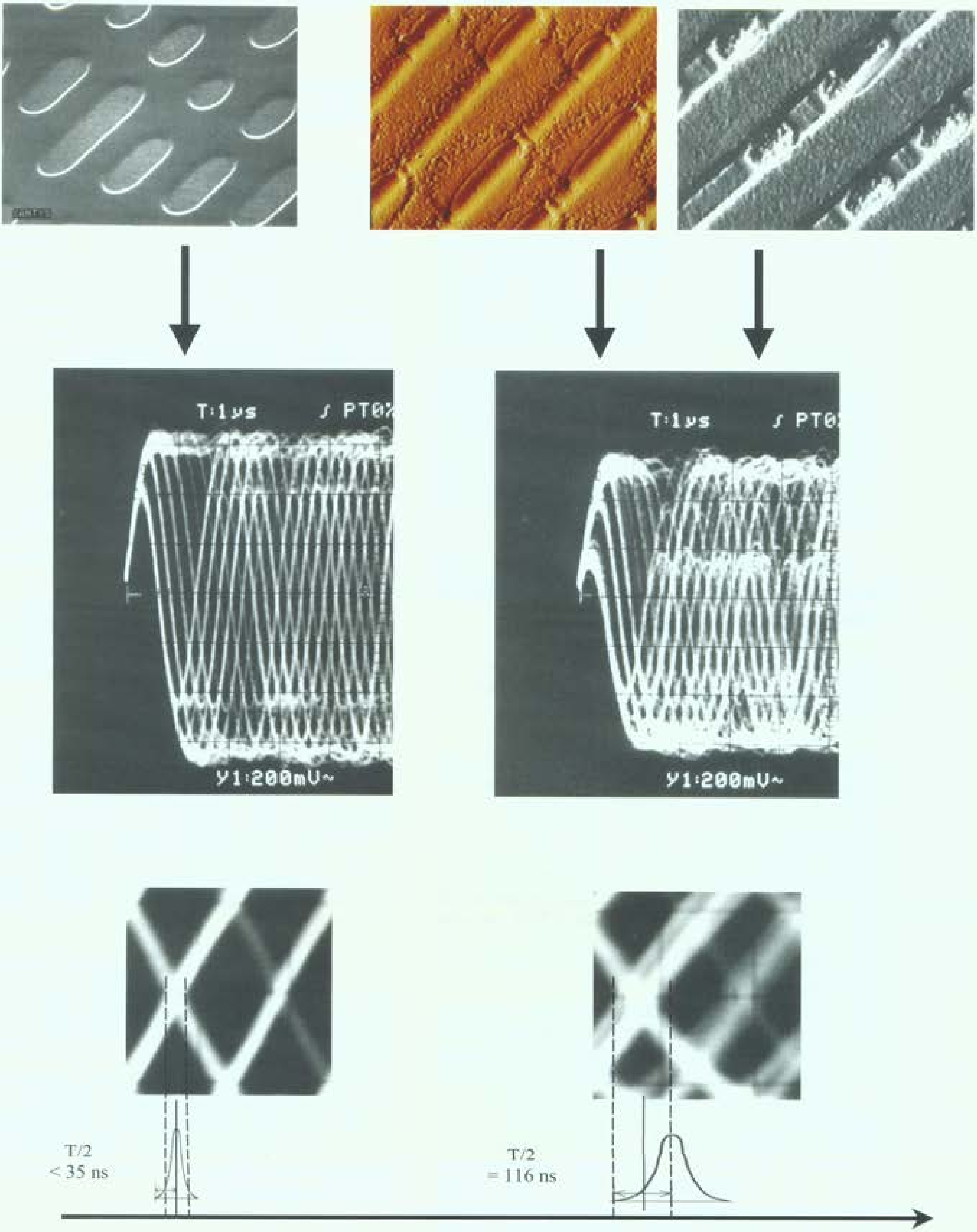
Il convient de rappeler que les "degrés de liberté" entourant la réalisation d'un disque enregistrable sont infiniment plus nombreux que ceux des disques pressés. Il suffit de considérer les phases de formulation, de préparation de la couche sensible, d'application de celle-ci sur le disque. A ces processus de fabrication on ajoutera, pour les pigments Cyanine, l'insertion d'agent stabilisant (quencher) au rôle si important. On perçoit aisément la perplexité de l'utilisateur vis-à-vis d'un disque vierge qui doit effectuer des choix pertinents (quel type de couche sensible, quel type de film réfléchissant,... ?)

Des études menées ces dernières années nous ont permis d'expliciter quelque peu le processus de gravure et de percevoir des modes de dégradation, ceci en faisant varier la puissance du rayon laser d'écriture, en exposant des disques enregistrés à la lumière de type solaire et à la température.
Des investigations ont été menées sur l'ensemble des paramètres mesurés par des systèmes d'analyses des signaux électriques auxquels se sont ajoutées des analyses chimiques (CNEP) et des observations en microscopie à force atomique (AFM).

Bien que portant le nom de couche de colorant (dye layer), le rôle chromatique de celle-ci n'agit que de manière partielle dans le processus d'enregistrement (Cyanine) voire marginale (Phtalocyanine). La déformation de la couche sensible sous l'impact du rayon laser qui atteint 250° C environ diminue le coefficient de réflexion dans des proportion compatible avec la reconnaissance des zones vierges et des zones "brûlées".

La simple observation du "diagramme de l'œil" du signal de lecture nous avait montré que la qualité d'inscription de l'information sur disque pressé était très différente, c'est-à-dire très inférieure à celle inscrite sur disque enregistrable une fois.
Les irrégularités des bords des zones d'impact sont à l'origine des trésauttements (jitter) et des écarts radiaux (Push Pull et bruit radial) beaucoup plus importants que dans le cas des disques pressés, ce qui a d'ailleurs nécessité des révisions du cahier de spécifications (Livre Orange, partie 2).

CD MOULE | **CD ENREGISTRABLE UNE FOIS**



2. Les conditions d'enregistrement, quelques résultats

L'utilisateur ne pouvant agir directement sur les modalités de gravure, son action se réduit au choix des disques, des éléments de la chaîne d'enregistrement et de quelques options qui détermineront la qualité d'inscription des informations sur le disque.

L'occasion nous a été donnée récemment (1999) d'effectuer des tests mêlant différents types de disques, différents types de graveurs et plusieurs vitesse d'écritures, ceci en collaboration avec le LNE (Laboratoire national d'Essais – Paris) et l'INC (Institut national de la Consommation-Paris) dans le cadre d'une large enquête de produits mis sur le marché. Les essais ont montré l'extraordinaire disparité de la qualité initiale d'enregistrement à laquelle tout utilisateur est confronté, les produits disponibles étant destinés à la grande consommation.

Ces essais ont confirmé l'importance du couple disque / graveur. Parmi les produits testés, nous n'avons trouvé ni disque, ni graveur "idéal" : seulement des associations plus ou moins heureuses. Le fait n'est pas nouveau, mais l'amplitude des écarts de qualité de gravure que nous avons mesurée est tout à fait préoccupante avant même que surgissent les questions relatives à la conservation des enregistrements sur CD-R.

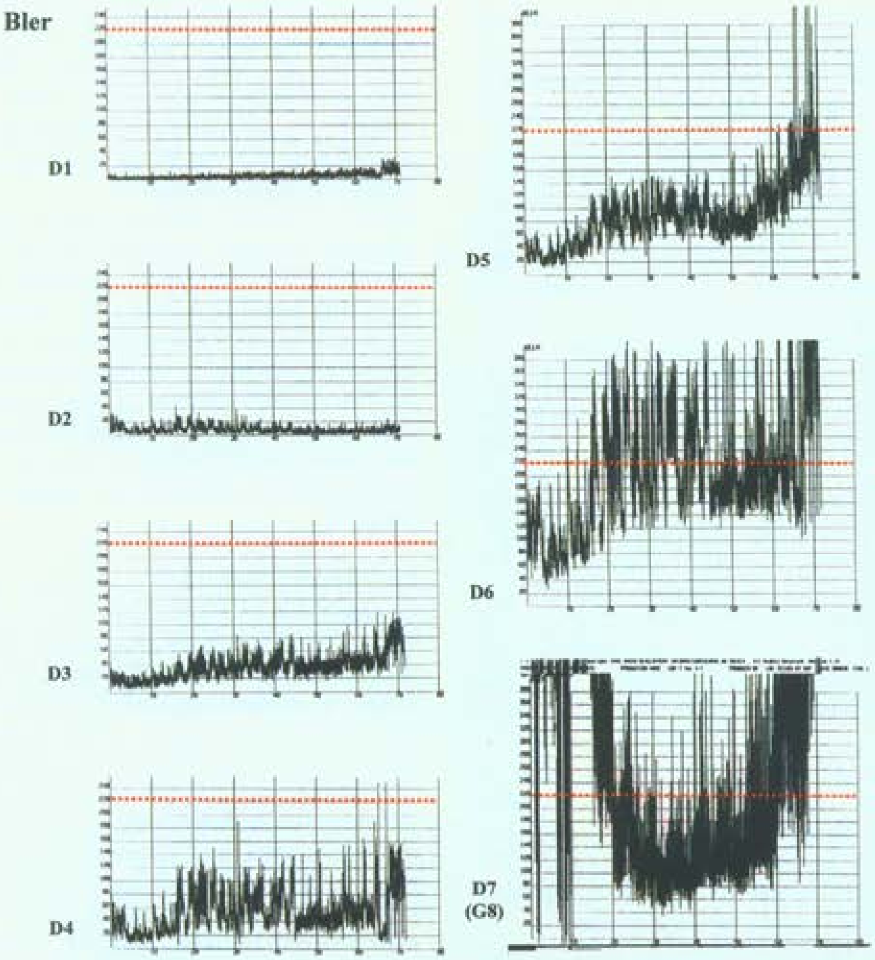
La nature de la couche sensible : Cyanine – Phtalocyanine –Azo, ou bien encore celle du film métallique : or ou alliage d'argent ne se montre pas déterminante quant à la qualité initiale des disques : il faut réussir dans tous les cas la meilleure adéquation entre le type de disque et le modèle de graveurs.

La vitesse d'écriture agit très directement sur la qualité obtenue. Pour une vitesse donnée, les réglages de la puissance du rayon laser sont effectués selon une routine automatique avant lancement de chaque gravure, malheureusement aucun information n'est généralement accessible par l'utilisateur qui reste ignorant des dispositions prises par le graveur, et qui ne peut donc optimiser ses choix. Des essais pratiqués, il ressort que les vitesses supérieures à 4X (6X, 8X, 12X,...) devront être évitées sans validation formelle préalable des résultats obtenus. Il se confirme d'autre part, que les gravures pratiquées à 2X et 4X peuvent être de meilleure qualité que celles pratiquées à la vitesse 1X pour des raisons mécaniques (asservissement de la vitesse de rotation) et de dissipation thermique au sein de la couche sensible.

Enfin, la densité d'enregistrement représentée par la capacité maximale du disque (63 mn [550MB] devenu obsolète, 74 mn [650MB] généralisé aujourd'hui et 80 mn [700 MB] en cours de lancement) intervient également dans la notion de qualité. L'augmentation de densité est obtenue par le ralentissement de la vitesse de gravure à débit constant du flot numérique, et par le resserrement du pas de la spirale. Expérimentalement, nous avons montré que plus la densité était importante, plus les risques d'obtenir une qualité médiocre étaient grands.

Le lecteur. On sera peut-être surpris de ces commentaires réservés exprimés à l'encontre de la qualité des CD-R alors que nombre d'utilisateurs de ce support multimédia ne rencontrent aucune difficulté apparente de lecture. Les performances des lecteurs sont en effet surprenantes : (fractionnement du faisceau laser, efficacité du dispositif de correction d'erreurs...). Il n'est pas rare qu'un disque déclaré défectueux par l'analyse soit tout à fait lisible par un lecteur courant. Mais la qualité de l'information quand il s'agit par exemple de son, n'a pas été clairement établie lorsque les systèmes de correction et de traitement des informations erronées était en situation de quasi-saturation. D'autre part, le potentiel de conservation sera des plus réduits si le disque est enregistré dans des conditions précaires.

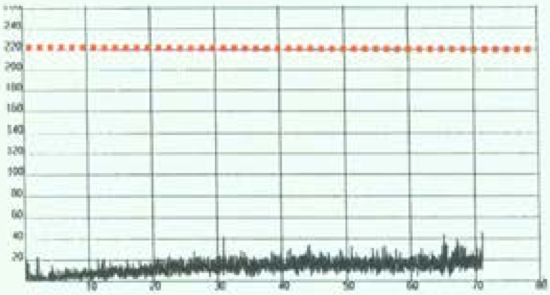
1 graveur, 7 types de disques



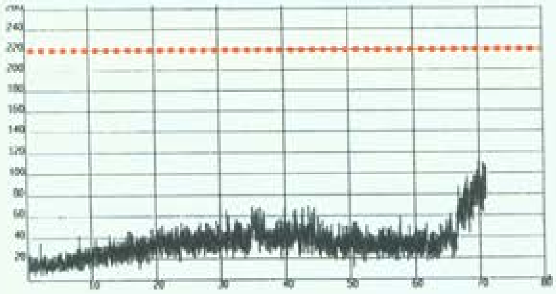

(Les disques représentés ne sont pas classés)

1 disque, 8 types de graveurs

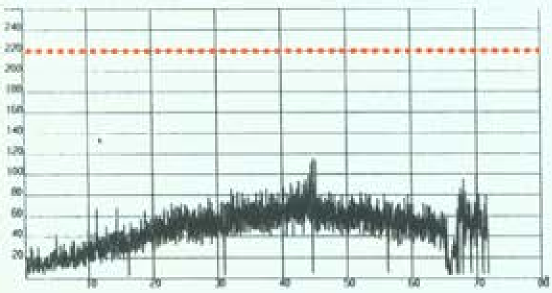
Bler



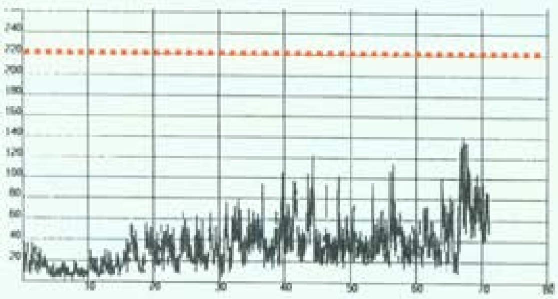
G1



G2

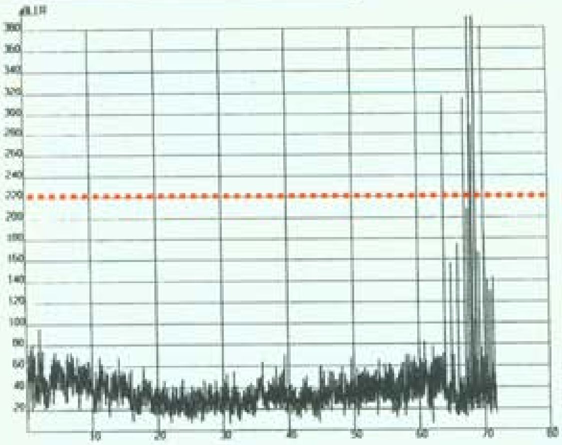


G3

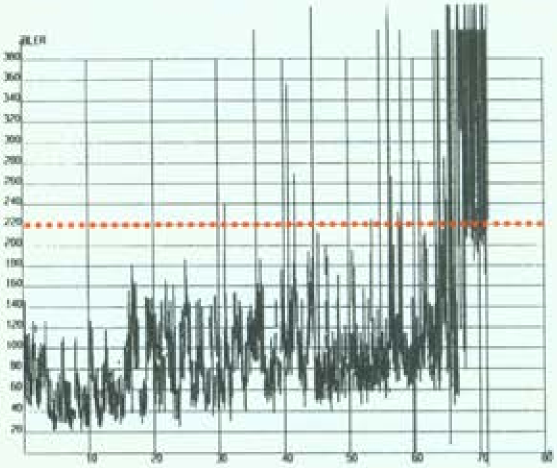


G4

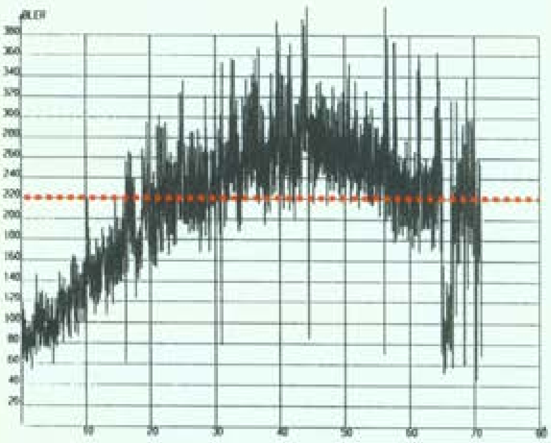
(Graveurs représentés non classés)



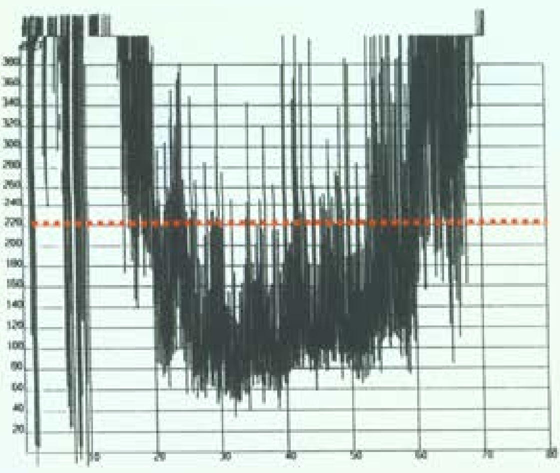
G5



G6



G7



(D7)
G8

3. Un contrôle des disques indispensable

Il faut bien relever la situation paradoxale pour l'utilisateur qui prend une part importante dans la qualité du disque dès lors qu'il pratique la gravure mais qui ne dispose d'aucun outil lui permettant d'effectuer un contrôle immédiat. Situation d'autant plus regrettable que la qualité est incertaine, comme nous venons de le voir.
Le matériel utilisé par les institutions relevant du marché grand public (absence d'offre en ce qui concerne des matériels de niveau professionnel), l'irrégularité, voire l'insuffisance des performances des résultats est à redouter.
La rencontre d'un disque avec un graveur parfaitement compatible constitue, pour celui qui ne dispose pas d'outils de contrôle de qualité, une véritable gageure.
Les mesures restent délicates à mener du fait de l'imbrication de nombreux éléments mis en jeu, de la possible dispersion de certains paramètres mesurés, de l'interprétation des résultats.

3.1. La chaîne des éléments.

Toute mesure de disque CD-R à partir du signal met en œuvre 3 éléments indissociables : le média, le système de gravure mais encore l'analyseur qui est, avant toute chose, un lecteur.

QUALITE du disque = (DISQUE ∩ GRAVEUR) ∩ LECTEUR / ANALYSEUR

3.2. L'analyseur

Les systèmes d'analyse, conçus pour contrôler la fabrication des disques, proposent un très grand nombre de points de mesures effectués sur un très grand nombre de paramètres et la question est de savoir sur quels critères s'appuyer pour mener à bien les contrôles efficaces de qualité initiale et détecter les éventuelles évolutions du disque, ceci du point de vue de l'utilisateur.

Dans le cadre des disques CD-R, la comparaison des résultats produits par différents systèmes d'analyses a révélé une dispersion relativement importante des taux d'erreurs, beaucoup plus importante que dans le cas des disques pressés. Des différences de conception selon la génération du matériel peuvent être à l'origine des écarts constatés (fenêtre de détection PLL, horloge d'asservissement de la vitesse de rotation, bloc optique,...). Les dispersions concernant les taux d'erreurs sur lesquels la plupart des utilisateurs limitent leurs observations sont parfois sources de contestation. Il n'est pas possible de calibrer les systèmes sur ces critères comme cela est pratiqué pour d'autres paramètres à partir de disques de référence. Les algorithmes de décompte et de calculs de correction sont figés, les résultats obtenus dépendent notablement des performances intrinsèques des analyseurs. Des garanties sont apportées par certains types d'analyseurs dits de référence qui s'appuient sur les qualités de l'optique et de la platine mécanique toujours identifiée et sur des procédures d'étalonnage développées. Seulement de tels dispositifs coûtent extrêmement chers (plus de 70 000 €).

De plus, si les taux d'erreurs permettent pour le moins d'évaluer la qualité globale des disques, ils ne permettent pas de situer l'origine des défauts, d'interpréter les dégradations survenues afin que l'utilisateur puisse prendre des mesures adaptées. Nous avons indiqué que l'observation de l'ensemble des paramètres disponibles permettait de mieux comprendre le processus d'enregistrement. Dans le cadre d'étude du vieillissement, cette observation élargie nous renseigne sur les mécanismes de dégradation des disques : mécanique, optiques, évolutions de nature rhéologique, de nature photochimique de la couche sensible. En application, nous dégagerons les indicateurs qui se montrent les plus pertinents pour rendre compte de la qualité initiale puis de l'évolution des disques soumis à différents facteurs d'agression, et de proposer éventuellement l'utilisation de paramètres complémentaires aux taux d'erreurs lors de l'élaboration de modèles de vieillissement.

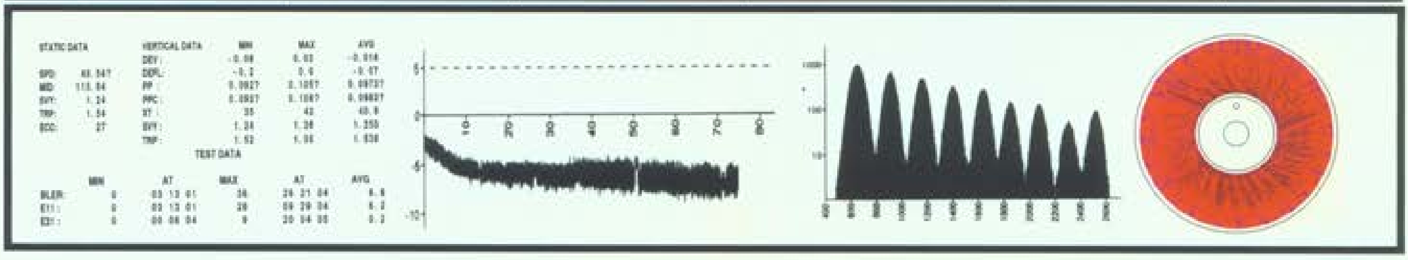
Les paramètres disponibles avec les systèmes complets concernent :

- Les zones physiques enregistrées
- La densité d'enregistrement (vitesse, pas de la spirale)
- Les caractéristiques physiques (propriétés de réflexion, planéité)
- Les erreurs (avant correction et pendant les étapes de correction)
- Le suivi de piste (épreuve de sensibilité, déviations radiales)
- La qualité du signal qui traduit celle des marques (niveau de signal RF, symétrie, jitter).

Les résultats sont fournis selon des tableaux de valeurs remarquables, selon des courbes représentant le déroulement des événements en fonction du temps ou du rayon, et selon des représentations en surface.

WHAT PARAMETERS FOR ARCHIVIST USERS ?

IDENTIFIC.	DENSITY	MECA	MODUL. RF	MARK	ERRORS
Manufact Code	Speed	ECCentricity	Eye Pattern	SYM or Beta	BLER
UPC/EAN Code	Track Pitch	DEFLection	Jitter PIT Dev	PP & PPC	E11
ISRC Code		DEViation	Jitter PIT Hist	Radial Noise	E21
No copy allowed			Jit LAND Dev	Cross Talk	E31
ZONES	**REC. COND**	**OPTICAL**	Jit LAND Hist		E12
SLD	Opt Pw Cal	BIREFringence	I11 – I3		E22
SPL	Opt Rec Pw	REFlectivity	I11 R- I3 R		E32
SPD					CRC
MID					BERL
Track Position					BEGL



4. Vieillissement des disques

Deux objectifs sont donc fixés : examiner les lois de variation du taux d'erreur BLER et celles de l'ensemble des paramètres dont la sensibilité est suffisante pour rendre compte le plus directement des évolutions du disque. Citons 2 types d'expériences effectuées avec un seul facteur d'agression afin de simplifier au maximum les processus de dégradation.

4.1. Photovieillissement

L'exposition à la lumière (Xenotest) a mis en évidence 2 types de comportements très différents selon le type de couche sensible :

- Disque cyanine : pallier d'incubation pendant lequel les indicateurs restent inva riants puis, à partir d'un instant donné propre au type de revêtement, évolution des paramètres d'erreurs selon différentes lois exponentielles. La manifestation des autres paramètres atteste de la complexité des évolutions du revêtement (asymétrie par exemple) et ne permet pas une interprétation satisfaisante des réactions. Le temps de latence peut correspondre à la période pendant laquelle l'agent de stabilisation (quencher) garde son efficacité. Seule une approche chimique permettrait d'expliciter les réactions déclenchées.
- Disque phtalocyanine : présente une sensibilité certes faible, mais non nulle à la lumière. Il se produit une augmentation linéaire très progressive des taux d'erreurs. Les modifications des propriétés de la couche sensible sous l'action d'une dose lumineuse massive suivent toutes une loi linéaire lorsque l'on examine l'ensemble des paramètres (baisse de réflexivité, du niveau RF, augmentation de la sensibilité radiale et du coefficient de symétrie.

4.2. Vieillissement thermique

L'exposition à la température (60°C actuellement, d'autres essais sont en cours) révèle aussi des lois de variation des paramètres bien différentes selon le type de disque étudié.

On observe des augmentations de type exponentiel (accroissement de plus en plus rapide) ou bien au contraire de type logarithmique (tassement des évolutions) pour ce qui concerne des disques cyanine ; l'absence d'évolution dans le cas des disques phtalocyanine doit enfin être notée. Ces différences de comportement traduisent des modes de fonctionnements tout à fait spécifiques à la nature chimique de la couche sensible utilisée.

Remarque : pour les taux d'erreurs BLER, la limite de 3 % d'erreurs maximales (220 impulsions/s) est insuffisante pour rendre compte de l'évolution des phénomènes aussi a-t-on poursuivi la durée d'exposition. Le taux de Jitter viendra utilement compléter les observations effectuées sur les taux d'erreurs.

Le coefficient de réflexion (REF) constitue une donnée initiale importante, mais il reste peu actif en terme d'évolution, de même les signaux de modulation RF (I3 et I11) et d'asymétrie. La sensibilité à l'écart radial (PP) se manifeste de manière suffisamment probante pour être retenu comme critère d'évolution. On notera la difficulté de modéliser les paramètres en observant les lois d'évolution des disques sur les paramètres BLER et PP (cas du disque C1).

4.3. Modélisation du vieillissement

Les normes en cours d'élaboration qui qualifient les disques sur les seuls taux d'erreurs doivent-elles prendre en compte d'autres critères d'évolution ?

La détermination de la loi d'évolution du taux d'erreur BLER en fonction de la durée d'exposition à des conditions climatiques définies constitue un préalable à l'élaboration d'un modèle de vieillissement. Expérimentalement, il a été montré que les familles de couche sensible peuvent se dégrader selon différentes lois d'évolution :

→ croissance linéaire, logarithmique ou exponentielle

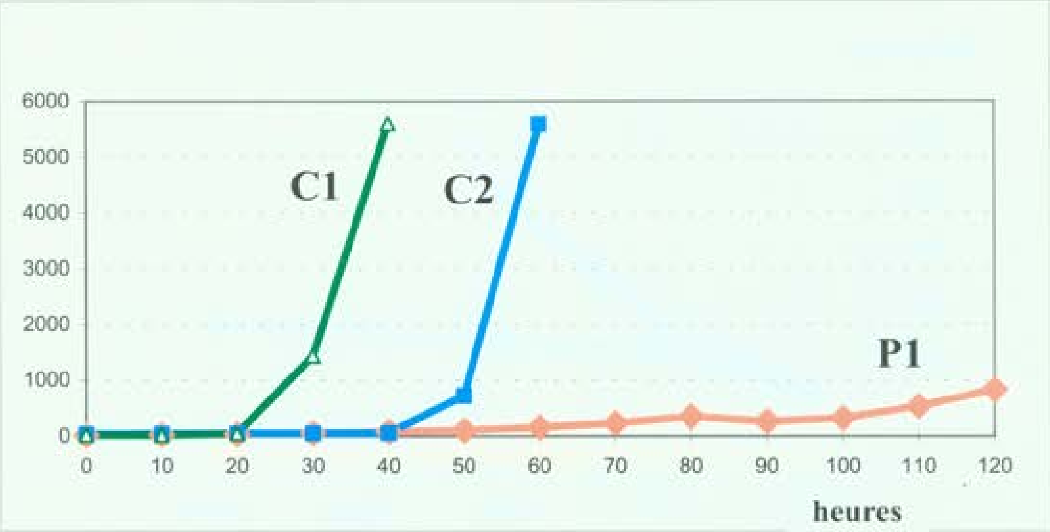
→ multivariation : phase d'incubation, inversion de tendance

Les nuances de formulation et de préparation de la couche (proportion d'agents stabilisants : quenchers lorsqu'ils sont utilisés), son épaisseur peuvent modifier directement le comportement des disques soumis à différents facteurs d'agression.

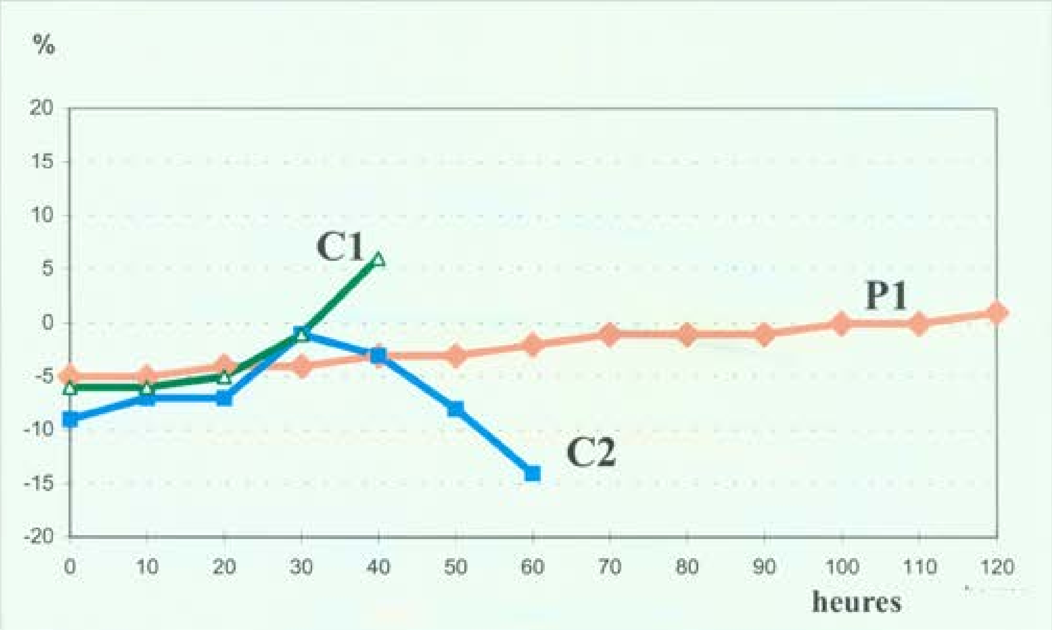
Le modèle de vieillissement sur lequel s'appuient les extrapolations vers les conditions réelles de stockage devra être validé.

XENOTEST

Bler Max

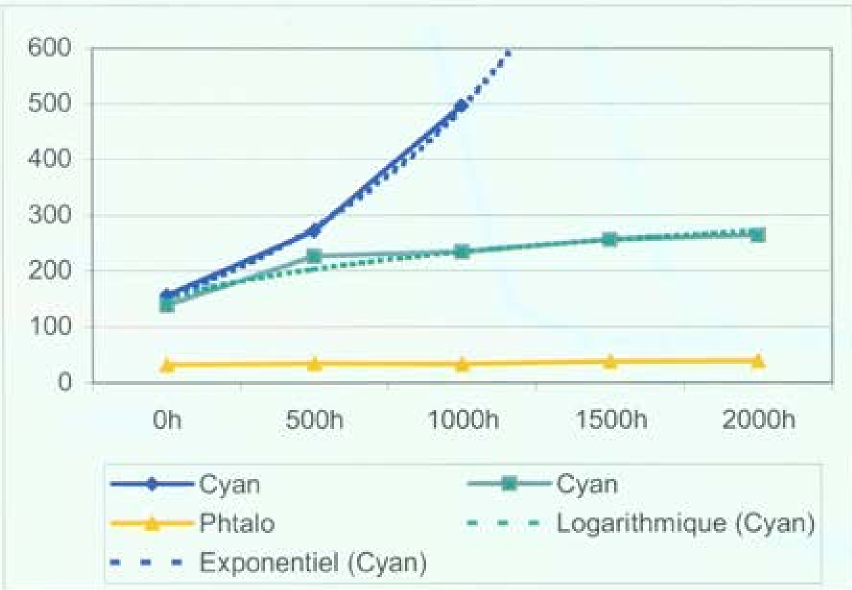


Asymétrie

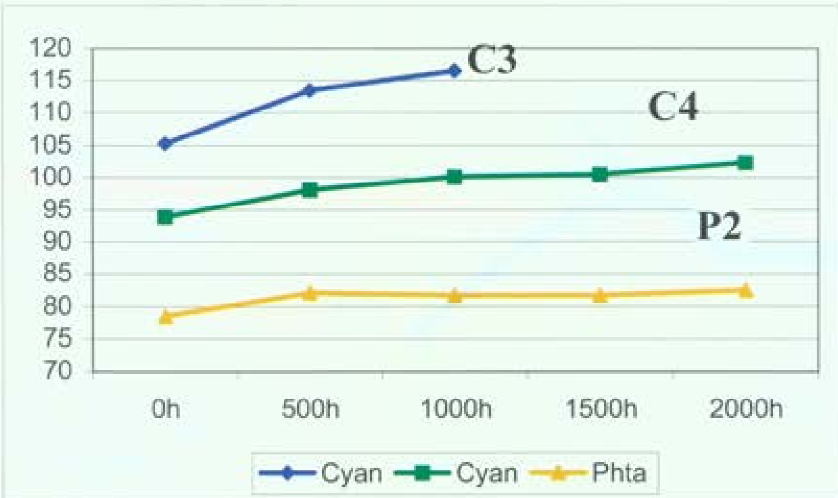


TEMPERATURE 60°C

Bler Max



Push Pull



Paramètres se montrant les plus sensibles pour décrire la qualité initiale et le vieillissement des disques.

	Taux d'erreurs **BLER & E32**	**Jitter**	Coefficient de réflexion **REF moy**	Signal modulé RF **I11 & I3**	Asymétrie **SYM ou β**	Sensibilité radiale **PP**	Diaphonie **XT**
Contrôle qualité gravure	1er rang	1er rang	2ème rang	2ème rang			
Puissance du rayon laser			4ème rang	3ème rang	1er rang	3ème rang	2ème rang
Insolation	1er rang	1er rang	3ème rang	2ème rang	2ème rang	2ème rang	
Température	1er rang	1er rang	3ème rang	3ème rang	3ème rang	2ème rang	

Les cases vides correspondent à des paramètres peu réactifs dans les conditions étudiées

Conclusion

Lancé il y a 10 ans, le disque enregistrable une fois ne semble pas avoir progressé au fil des années quant à sa qualité. Son succès auprès du grand public a orienté la fabrication vers la production de produits qui se sont progressivement banalisés. Pour des applications de sauvegarde de documents sonores, images fixes, texte et données informatiques, il est absolument indispensable d'effectuer des contrôles qualité pour le moins sur la base des taux d'erreurs.

L'analyse des très nombreux signaux électriques issus de certains analyseurs de haute qualité ne nous permet pas véritablement d'interpréter les phénomènes complexes de gravure et les évolutions déclenchées par tel ou tel facteur d'agression ou bien résultant du "vieillissement naturel". Sans études approfondies des processus fondamentaux physico-chimiques, les mécanismes de dégradation conduisant à l'évolution des paramètres mesurés ne pourront être explicités. L'observation de l'ensemble des critères disponibles permet néanmoins une description détaillée des dégradations et d'en situer les origines. Il peut être envisagé d'adjoindre aux taux d'erreurs quelques critères significatifs de l'évolution des disques.

A l'heure où s'effectue le lancement du disque enregistrable une fois DVD-R, nous sommes perplexes sur la qualité d'inscription de l'information d'une part et sur le potentiel de conservation de ce nouveau produit d'autre part, c'est pourquoi nous nous engageons vers l'étude de ce nouveau support qui s'applique également et très largement à l'image animée.

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Discussion

Ed ZWANEVELD

I would like to repeat my question to you, having seen that you have performed a significant amount of research as well. The future most likely holds disgraceful degradation of media recorded on CD-R. My concern is as follows: if the CD-R is one's only source, what can one expect in terms of archival length?

Jean-Marc FONTAINE

Nous avons la chance de bénéficier d'un dispositif qui permet de contrôler la qualité d'origine de l'enregistrement. Partant de là, nous sommes en quelque sorte maîtres du jeu. En éliminant les mauvaises associations de médias et de graveurs, nous pouvons nous donner un certain nombre de garanties.
En ce qui concerne l'évolution, nous avons des indicateurs qui nous portent vers certains types de couches sensibles. La question est celle de la variation des lots de fabrication. Là non plus, nous ne maîtrisons rien. Notre seul recours est la mesure.

De la salle

Dans les lecteurs et les graveurs de CD-R, la température s'élève à 40 degrés. Cela pose problème pour la conservation des CD-R.

Jean-Marc FONTAINE

En effet, les lecteurs et les graveurs ne sont pas ventilés. La température à l'intérieur de ces appareils est supérieure de 10 degrés à la température ambiante. Nous pouvons être préoccupés pour les pays chauds. C'est un problème réel, qui n'est pas résolu à l'heure actuelle. Pourtant, la ventilation est une opération simple. Nous disposons d'un matériel très courant, qui n'est pas du tout fait pour les archives.

From the floor

Do you expect that the philosophy behind archiving digital carriers will change with regards to storage? Once we have sorted out the incompatibilities inherent to digital media and hardware, is it likely that we will be more successful than with analogue sources or films? Do you believe that, within the next five years, archives will be able to deal with sound reproduction? My questions springs from the fact that the medium itself is far more accessible to small archives. Once the error correction problems are solved, the cost of copying a magnetic track, for instance, compared to a CD-R is incomparably lower.

Jean-Marc FONTAINE

Notre propos s'inscrit dans une situation actuelle. Bien entendu, les grandes archives, qui bénéficient de moyens importants, peuvent faire des choix différents. Toutefois, cette technique de transfert sur CD-R est très largement utilisée. Actuellement, de nombreux enregistrements à caractère patrimonial sont transférés sur CD-R. Ce n'est sûrement pas une situation idéale mais il nous faut penser aux institutions qui ont peu de moyens. Je pense qu'en utilisant le matériel adéquat et en vérifiant la qualité de son travail, c'est un dispositif intéressant.

From the floor

My question related to the philosophy behind archiving. Surely, nobody here believes that a CD-R will last that long. Does it need to last that long if technology allows it to be cloned, perhaps every seven years? This is a comment, not a question.

Jean-Marc FONTAINE

Dans cette optique, notre préoccupation actuelle est le développement de l'utilisation du DVD. Techniquement, il nous faut prendre en amont les précautions nécessaires pour allonger les délais de re-transferts. Je pense qu'il est difficile de prôner tel ou tel dispositif. On a parlé aujourd'hui du DAT et du CD-R. Demain, ici même, on parlera de dispositifs de transferts de masse. Tous les dispositifs ont leur place en fonction du contexte, des institutions, et il faut pouvoir réagir en parfaite connaissance de l'ensemble des données techniques.

Maïc CHOMEL

Je vous propose, dans le quart d'heure qui nous reste, de poser des questions aux différents intervenants de l'après-midi. Je donnerai la parole à la fin aux présidents des commissions techniques de l'IASA et de la FIAT pour qu'ils replacent le débat de cette après-midi dans l'ensemble des deux journées.

Bob CURTIS-JOHNSON

My question is addressed to everyone. Do you envision setting up a few regional migrating station that centralise your expertise? Do you think it more likely that the work will be carried out in a number of locations?

George BROCK-NANNESTAD

This very philosophical question is deeply linked to our previous discussion of what "archival" means. No one provided a definitive answer. In fact, there is no such thing as archival. We all depend on machines, the other half of the system, to reproduce. The incompatibilities that we encounter in recording will give lead to a problem with reproduction. Migration is extremely important. We only need a medium that can give adequate results, regardless of blur. As I have stated in writing, today's technology is like a greenhouse or a garden: it must be watered very frequently. Otherwise, it will wilt and die, as will your heritage or patrimony.

Sean DAVIS

I hope I do not appear too depressed in making this statement. We have been concentrating on the lifespan of CD-Rs, yet we seem to have forgotten that it depends on the particular combination of machine and disc. By the time we publish our results, the machines and discs are no longer available. Even if they remain on the market for one year, they quickly become obsolete. The same pattern will probably occur with DVD. We will spend more money on research than on archiving. On the other hand, we could stay with DAT. However, that technology is not destined to develop. It is not a public format and will probably be discontinued with time. Every archive is currently trying to obtain funding to buy many DAT machines in order to have some type of equipment when the first batch wears out. All of this pushes us toward the automatic transfer of data. Otherwise, even if we transfer on a regular basis (every 7 years), it will not be enough.

Ed ZWANEVELD

As I listen to this discussion, I try to imagine what I will tell my national board. I will probably have to say that CD-R is in rapidly evolving. However, since cost-cutting is prevailing over technological improvement, this evolution is negative. I will also tell them that today's system is not truly a system. Neither the writers nor the readers are standardised. Only the discs are relatively standardised, even though the dye solutions and other tricks still make them subject to variations.

Earlier, I used the term "disgraceful degradation". I meant that, despite the fact that this medium is widespread and relatively inexpensive, it can become a real disaster if we constantly need to migrate. Moreover, some discs cannot be played, even when the equipment is new. In 50% of the cases, the media do not work after five years. What will happen if the media no longer play and the source material has become obsolete? Will we be able to trust CD-R as a form of archival media? I am very nervous about this, even though my main work is in research and development. We have a responsibility not to sell products that are not appropriate to the marketplace. This leads me to conclude that archival organisations must give their members a realistic assessment of the state of their art. Archiving is indeed an art, not a technology. They must also define clear criteria and guidelines on choosing equipment. I fear that most archiving organisations, which are forced to use material of lesser quality simply because they have lower budgets, will be very unhappy in a few years. Some employees may even lose their jobs for having made poor choices. That is what I will take away from these event, despite not being a "negative" person at heart.

Maïc CHOMEL

Est-ce que certains parmi vous ne souhaitent pas revenir aux premières interventions de l'après-midi qui avaient trait aux problèmes liés aux bandes analogiques (syndrome du vinaigre, dégradation du liant) ? Etes-vous confrontés à ces problèmes ?

Kevin BRADLEY

CD-Rs are quite useable and quite testable. We have heard this a number of times. However, it is not mentioned that one can perform a number of reasonable and repeatable tests on rather cheap systems, provided they are calibrated against marble CD. One can keep a record of a large percentage of one's collection and know immediately whether the writings are producing high-error rates.

We can no longer escape digital technology. We must migrate and move on. We cannot maintain older formats anymore than those that do not have popular support. CDs are marvellous in that they allow us to automate many of our former processes. A five- to seven- year return cycle is not unreasonable, providing the tests are performed properly. When we used analogue recordings, we realised that some machines did not work well, aligned them and checked them over thoroughly. We would not have marketed the tape recorders had the testing process not been complete. The same principle must apply to both digital technology and DAT. If the initial recording is done properly, the chances of obtaining a reasonable life expectancy improve greatly.

De la salle

L'intervenant précédent a répondu en partie à la question. Je me trouve à la tête d'une collection d'archives sur bandes. Les plus anciennes sont sur bandes Revox. Je sais que dès cette année nous devons passer une partie de nos fonds sur CD-R. Nous sommes une institution, l'Assemblée nationale, qui aura sans doute les moyens, du moins je l'espère, de faire appel aux meilleurs spécialistes français et aux meilleurs laboratoires. Mais je connais de très grandes institutions françaises spécialisées dans l'archivage du papier qui ont des collections sur bandes et qui les transfèrent déjà sur CD, dans des conditions d'amateurisme inquiétantes. Nous sommes, comme gestionnaires de fonds sur bandes, obligés de faire des choix dès maintenant, en sachant que nous pouvons commettre des erreurs.

From the floor

We all realise that this problem will not go away five years from now. The very small archive for which I work will not be able to migrate more than once or twice. We need a longer rate. What political power do you have to encourage managers, politicians and the general public so that today's consumer products remain reasonable?

A Speaker

We must move away from the term "state-of-the-art". The "state of engineering" would be more appropriate.

Dietrich SCHÜLLER

I would like to comment on a number of the questions asked today. Firstly, I question the immediate need for digitisation. Digital technology is not a necessity unless your analogue sources are in total decay (this seems unlikely!). European broadcast tapes are currently in better condition than amateur audio tape collections. Sooner or later, those will deteriorate. Before that point, however, it is important to ask an expert whether it is truly necessary to make the change. I have been witness to many situations in which the new digital copies ended up in much worse condition than the source material.

Secondly, based on what we heard this afternoon, it appears that CD-R are not supposed to be an archival medium in the same sense that audio tapes have been. Those who want to be able to use better CDs must first run expensive or elaborate test procedures. In order to save them that expense, I feel that we must publish media-writer compatibilities on a regular basis. We should also recommend low-cost hardware and software combinations.

It might also make sense to reintroduce the lobby for 63 minutes CD-Rs. This is my personal view. In looking ahead, we must be aware that CD-R and DVD-R are not yet true digital media. Digital media implies that the control and self-generating of the data are performed automatically. The migration must also be performed automatically. We are in a position to archive on a digital basis. However, the price of the process is not affordable to everyone. I foresee the advent of a new technology, which might be called the personal digital storage system. In five years, that technology may play a role similar to that of PCs in the 1980s, when everyone was used to working on mainframes. The new era is upon us. Let us try to bridge the gap between today and a time when we will all be able to afford the new technology. Why jump into digitisation projects that are not really necessary? I understand that problems exist in certain areas. For example, we must work on tapes that are deteriorating, especially those in hot, humid countries. However, my personal experience shows that 95% of today's digitisation efforts are carried out at random and without any quality control. This is obviously not a satisfactory situation.

Jean-Marc FONTAINE

We should not forget about documents that are currently in legal deposit. We must take action to preserve existing digital media, whether on pressed discs and on recordable DVD-R or CD-R.

S'agissant de la situation actuelle concernant l'enregistrement analogique, je rappelle que les fabricants arrêtent la commercialisation d'un certain nombre de magnétophones à bandes qui ne relèvent pas de formats professionnels, en dessous de 19 centimètres/seconde. Pour des multi-pistes amateurs, on ne trouve plus ces magnétophones aujourd'hui. C'est une évolution concrète, qui fait suite aux observations qui ont été faites.

De la salle

En ce qui concerne les magnétophones professionnels, l'INA qui a une importante collection de bandes analogiques (plus de 400 000 heures en support unique) se préoccupe d'acquérir un parc de lecteurs suffisants car aujourd'hui, on ne les achète plus en stock, ils sont fabriqués à la commande. S'ils sont fabriqués aujourd'hui à la commande, ils se vendront fort cher au marché noir dans deux ans... En dehors du syndrome du vinaigre et des risques de contagion très rapides, les gestionnaires de fonds doivent se préoccuper de garantir un potentiel de lecture des originaux pour pouvoir les numériser.

George BOSTON

I have been listening to this debate with great interest. I would like to move away from technology to broach the practicalities of modern life. It was stated that we may have 40 million hours of audio tape and 10 million hours of video tape around the world. That is an enormous amount of material. Dietrich is correct in stating that not all of these need to be digitised; the carriers are still in excellent condition. However, there is another parallel movement: the move away from analogue by the manufacturers. I believe that, within the next 15 years, it will no longer be economically viable to maintain analogue machines. At a meeting in Paris in 1998, the remaining six major manufacturers of analogue audio tape machines stated that have scaled their product line back to one or two analogue models each. Note that there used to be 24 major manufacturers each making a wide range of machines. They promised to maintain spare parts for ten years after they built their last machines. Their tone seemed to indicate that the remaining machines would no longer be made within five years' time. Therefore, I assume that we have 15 years to copy all of our material if it is to remain playable. It is obvious that tape in good condition is of no use to us if we do not have the machines required to play them.

Our only solution is to move towards machines that are available and can support existing formats: the R-DAT and the CD-R. We must come to a decision as to which is the "least worse". Both have their difficulties. We must determine whether one format is less attractive than the other. I am not ignoring video. Video is looking with great interest at DVD as possible solution to its problems. DVD holds an hour and a half television programmes while still maintaining reasonable quality. If DVD machines become widespread and decline in price, they may eliminate video tape machines from the market and become the main storage and recording medium.

I am not enchanted by any of these solutions in the very long term; we will eventually have to move toward computerised mass storage systems, based on tape cassettes of various types. Those have the advantage of being possibly self-checking and self-copying. DVD, R-DAT and CD-R all hold potential problems. We will have to choose which one is the most bearable. I do not foresee any changes in this situation in the near future.

Update on Standards for Information Preservation

Peter Z. Adelstein
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Introduction

The preservation of recorded information has become much more difficult as imaging technology has progressed. In the infant stages of recording information on clay tablets, permanence was excellent and data exists today which are many thousands of years old. However, printed texts on acid paper that are 50 years old have shown serious degradation. As technology advanced, materials such as paper, photographic film, magnetic tapes and now optical disks have been used. With each advance, the preservation concerns became more acute as the media became less stable and the variations between materials increased. Compounding the problem is the increasing volume of data which is being produced. Generally, more and more information is being generated on media today which is less and less stable. Furthermore the variety of media and recording systems is ever expanding. For these reasons, the task of the archivist today in preserving the information of yesterday is very formidable and getting more so.

To provide guidance to curators, archivists and librarians, standards dealing with the preservation of information have been developed over the past 50 years. This presentation discusses several aspects of preservation standards: their value, the standardization process and an update of current activity.

The Value of Standards

There are at least three reasons why standards are important.

1. Many factors are critical to the preservation of imaging materials, and frequently there is not unanimity of opinion as to their relative importance. Such differences usually arise from the varied backgrounds of the individuals involved in the field. For example, the manufacturer is concerned about the behavior of the material; the scientist will tend to stress factors which eliminate any possibility of change; and the administrator is sensitive to the costs involved. Individuals from all these backgrounds are included in the standardization process. Consequently standards represent a consensus which is both technically sound and is practical.
2. There has been greater concern in recent decades about the permanence of images. This is a natural result of materials getting older, and of increasing examples of degradation problems. The importance of image permanence becomes more evident when information is lost. In addition, the rapid development of electronic imaging and digitization of information has caused new concerns. A positive outcome of this awareness has been a renewed focus on image preservation, along with technical improvements and innovations in storage technology. Published standards on materials and storage provide the archivist with ready reference sources which are continually being updated.
3. Standards improve the quality of products available to the consumer. This is very obvious in some fields such as the permissible tolerance for formats and sizes. It is not so obvious in the area of preservation. One such example is the specification that has been published for enclosure materials used for photographic images which ensures that there is no interaction between the two.

The Standardization Process

Acceptable standards can only be developed in a very structured environment. They should not be and are not the product of random or haphazard interest by a specific individual or group. They are only useful if they are prepared by an organization which has credibility. For the past five decades, the initial work on information preservation standards took place in the United States under the auspices of the American National Standards Institute (ANSI) or its predecessor. To broaden the input and augment the technical expertise of this standards body, experts from Canada, Germany, Japan, Switzerland and the United Kingdom also participated in the deliberations. The results were improved standards and more ready acceptance by the international community. However, to formalize worldwide recognition of the ANSI standards, ANSI published documents were submitted to the International Standards Organization (ISO) for its approval and publication.

ISO is the recognized standards body in the world with responsibility for the permanence of images and information. Its headquarters are in Geneva and standards are prepared by various technical committees, the technical committee on image permanence being TC42. Membership of TC42 is through the national standards organization of various countries. For example, France is represented by Association Francaise de Normalisation (AFNOR) and the USA by ANSI. Eleven countries are represented on this committee. All documents on permanence fall under the jurisdiction of Working Group 5 which also has responsibility for test methods on physical properties.

Originally technical committee TC42 only had responsibility for photographic standards and this was the situation for over 40 years. However, images are no longer obtained solely by photographic chemical processes but also by electronic means. Accordingly in

1996 the scope of TC42 was broadened to include electronic imaging and Working Group 5 undertook the task of preparing standards on magnetic tape and optical discs. This was a major decision.

Last year a second critical decision was made in the United States pertaining to the promulgation of image permanence standards. These documents will no longer be published as ANSI standards with subsequent conversion to ISO standards. Instead the appropriate ANSI and ISO working groups have been combined and standards are being published only as ISO documents. This avoids the time consuming process of first publishing an ANSI standard before going to ISO. To facilitate document identification, all ISO standards are being given the new designation ISO 189xx, with the last two digits being identical to the now (or about to be) obsolete ANSI equivalent. The new ISO number, the existing ISO number and the ANSI designation are listed in Table I for reference purposes. There are currently 29 ANSI publications which are being converted to the ISO numbering system of which 18 pertain to permanence. It will be several years before this conversion is completed.

These changes made within the last few years are very substantial. The expanded scope reflects existing technology and was a prerequisite if permanence standards are to remain pertinent. The elimination of ANSI publications avoids the duplication that existed and streamlines the standardization process. It will result in a much shorter elapsed time for an ISO standard to be finalized. It will also avoid concern whether the ISO and ANSI document is the more current and eliminates confusion when there are the unavoidable differences in the texts. The new ISO numbering system vastly simplifies identification. Another significant change is the widespread use of electronic mail which results in much faster communication within the standards organization.

An indicated above, there is ever increasing interest in the preservation of recorded information. This is reflected in the increase in published standards in this field, from only one in 1945 to 18 today and several more are in preparation. These standards cover either the inherent stability of the materials or the storage conditions. For magnetic tape and optical discs there are also hardware and software considerations. An update will be given of each of these factors.

To obtain a perspective of current trends in this field, some of the historical background on image preservation standards will also be briefly reviewed.

Material Specification

A- Photographic Products

The earliest publications on permanence dealt with the composition and specification of the imaging material. One of the first standards was on black-and-white films for permanent records which was published in the United States in 1945 under the sponsorship of the Optical Society of America. Of primary consideration was the avoidance of cellulose nitrate film support and the specification of a maximum residual thiosulfate content. Responsibility for this specification was subsequently transferred to the American Standards Association, then ANSI and the concurrent publication by ISO. In the intervening years, this specification went through 10 modifications and became much more demanding. Today it also includes physical tests on the support, the emulsion layer, the emulsion-support adhesion and an image stability test. Films are also given a "LE" rating reflecting the expected life expectancy in years under normal storage conditions. Companion documents have also been standardized for diazo, vesicular and thermally processed films. In addition, supporting standards have been written on test methods for residual thiosulfate determinations, evaluating the effectiveness of toning treatments on silver image stability and a method to extrapolate high temperature incubation results to practical conditions.

A specification on the stability of black-and-white paper prints is now under active consideration but this will only apply to paper prints in dark storage and not to prints used for display. The stability of RC paper prints under display conditions is currently being investigated. It will be several years before it is published.

Specifications have not been standardized for photographic color materials. The primary obstacle has been the impossibility of determining acceptable levels of color change. These are very dependent upon the nature of the colored image since tolerance varies widely with the nature of the photograph, and also whether there is a comparison image. The task group concerned with this subject worked for well over a decade and in 1990 produced a very useful test method to evaluate color stability. It describes methods to determine both the dark and light stability of color images. The former involves incubating various density patches at a series of temperatures and extrapolating the data to room conditions. The stability of color images to light is very dependent upon the wavelength and intensity of the illumination. Five different light stability tests are described which are intended to duplicate indirect daylight exposure, incandescent tungsten illumination, exposure to fluorescent lighting and to the intermittent lighting of a slide projector, and to outdoor exposure. Detailed descriptions are given on the treatment of the dark stability and light stability results and the various parameters that should be calculated. This standard goes into detail about the recommended color density patches that should be measured, and methods for correcting differences in the background density. The test method was a much-needed standard which brought a great deal of stability to the subject of color image evaluation. It is currently undergoing a minor revision.

B- Magnetics

Standards on the permanence of magnetic information is very needed but is much less advanced than in the fields of paper and photographic permanence. In part this is the result of the later two being mature technologies with over 100 years of scientific advances and many years of activity in standards. In contrast, the age of magnetic tape technology is close to 50 years, but work on the permanence of such recordings was only started 10 years ago.

Magnetic media appear quite similar, composed of a base coated with a magnetic layer. Since the 1960s all magnetic materials are coated on polyester which has excellent stability. The magnetic particles are generally iron oxides, chromium dioxide, or metallic particles embedded in a polymer binder. Today practically all products use a polyurethane binder. It might appear that it is relatively easy to characterize the life expectancy of a polyurethane layer coated on a polyester base. However, this is certainly not the case and has presented major problems to the standardizing body.

Magnetic tape is used in recorders and players which require it to be transported from hubs and reels over rollers and magnetic heads in a tremendous variety of configurations. Moreover, tape is relatively thin, varying from 10 to 50 µm, the thinner material providing greater data compaction but less physical protection. The net result is that tape life is usually controlled by physical failure, and this physical failure can be manifested in many ways depending upon the format, the recording device and the playback equipment. A critical feature in magnetic systems is the close spacing between the magnetic head and magnetic medium. This is required for optimum output, but it causes head wear, binder wear, or both. In some situations, tape fails by binder debris clogging the magnetic heads while in others it may be due to high friction and the resulting lack of uniform transport. A tape specification must include a considerable number of physical tests. Such a specification requires agreement on the physical properties to be included, the test equipment and procedure, the means of accelerating the test or incubation conditions in order to estimate life expectancy, and the determination of limits for failure.

A subcommittee was organized in the United States in 1989 under the auspices of ANSI. During five years of deliberation, this subcommittee recognized that the critical physical properties are binder cohesion, binder-base adhesion, friction, clogging of magnetic heads, dropouts, and binder hydrolysis. Magnetic properties of interest are coercivity and remanence. These decisions in general were consistent with conclusions from individual investigations. Test procedures for adhesion, friction, and hydrolysis were agreed to, but cohesion, head build-up, and dropouts are difficult to measure requiring extensive development work. The latter is also very system dependent. There was also agreement that some of these tests could be used to predict tape life whereas others would specify minimum requirements that tapes must pass.

Unfortunately, involvement by tape manufacturers had decreased to the point where there was no longer a critical mass to continue this activity. This lack of activity may possibly be due to the general acceptance that magnetic tape has a limited life expectancy. However, this leaves the consumer without a recognized specification to compare tape products and the manufacturers without a standardized procedure to evaluate tape life. The only option for the user is to purchase tape with recognizable brand names.

C- OPTICAL DISCS

Within the last 15 years there has been the development and explosive growth of information distribution and storage using optical disc technology. These materials have been designed in many configurations and for many applications. However, all share the common characteristic that they are read by light and are only machine-readable. Since this is a relatively new technical area, the scarcity of standards on permanence is not surprising. Standardization activity was also started in 1989, at the same time as work on magnetic materials.

Unlike magnetic media, optical discs are manufactured not only in a variety of sizes, but they can also be composed of very different materials. The most common substrates are either polycarbonate or glass. The image recording layer features various organic or inorganic coatings since they can operate by several different mechanisms. For example, write-once discs can record information by ablation of either a thin metallic layer or a dye/polymer coating, by phase change, by metal coalescence or by change in the surface texture. Read-only discs have the surface modulated by molding of the polycarbonate substrate, and erasable discs are based on magneto-optical or phase change properties. Despite this vast dissimilarity in composition, optical discs have an important advantage over magnetic materials with respect to predicting their life expectancy. Optical discs are recorded and read by light and do not come into contact with moving or stationary parts of equipment. Therefore their useful life is mainly determined by the properties of the material itself, and, unlike magnetic tape, physical wear and tear is less of an issue. This has resulted in the use of incubation methods to predict the longevity of discs by several investigating laboratories. All these studies used an electronic readout signal to mark the course of disc degradation.

This approach was used by the standards group and test methods were prepared to predict the effects of temperature and humidity of CD-ROM, MO and CD-R discs. It should be emphasized that these three documents are test methods, not material specifications. The difference is that the latter gives test requirements for all aspects of permanence that a material must meet to be given a life expectancy rating, while the former is only a single test procedure.

Optical discs can fail by a number of different mechanisms, such as relaxation of the substrate causing warping, changes in the reflecting layer by corrosion, cracking or pinholes, changes in the reflection of any dye layers by light, pressure or crystallization, or breakdown of the disc laminate by adhesion failure and layer separation. The test methods are quite explicit in stating that it is only valid if the dominant failure mechanism at the accelerated conditions in the test method is the same as during usage. It also does not address material changes due to light or to exposure of corrosive gases.

Another property of concern in the stability of discs, not addressed in these test methods, is the effect of temperature and humidity cycling. Temperature cycling may be critical because the different component layers have different thermal coefficients of expansion, resulting in large stresses between layers with the possibility of cracks, adhesion failure or deformation. Humidity cycling is likewise important because of differences in dimensional changes due to moisture absorption. Potential problems due to humidity cycling are more important for discs than for magnetic tape because of the greater thickness of optical discs and consequent greater times required for moisture equilibrium. The importance of temperature-humidity conditioning times has been recognized in the three test methods, and staging times are specified.

D- COLOR HARDCOPY

The tremendous growth in recent years of computer use and the resulting digital color hardcopy output has raised many questions about the permanence of these materials. Accordingly this subject is being addressed in the standards groups for the past four years. Materials of interest include inkjet, thermal dye transfer and color electrophotographic materials. These images not only pose concerns about their chemical stability but also about physical changes. Among the latter are waterfastness, fingerprint susceptibility, abrasion, smudge resistance, and image transfer. Dark and light stability tests also have to determine the possibility of lateral migration of the image and the maximum temperature materials can be subjected to without undergoing a phase change or partial coagulation. All these problems are being addressed but it will be many years before a specification or test methods are finalized. This field is further complicated by the ever changing technology. However, unlike the work on a magnetic tape specification, there is wide interest in this topic and strong participation by manufacturers.

E- LIFE EXPECTANCY

As indicated previously, the material standards have defined a life expectancy of imaging materials when stored at 21°C 50% RH. These estimations are given for materials that pass the specification tests and are listed in Table II for comparison purposes. It must be recognized that these values are at best estimations and are generally based either on anecdotal experiences or incubation tests. Also listed in this tabulation is the current thinking for black-and-white prints that are not displayed. Similarly the values for color images and magnetic tape were not obtained from specifications since none exist but from recognized publications in the field and they are given in Table II. Due to the wide variety of materials, the absence of specifications, and the limited information in the literature, values are not given for optical discs and digital color hardcopy.

Storage Conditions

It is a well-accepted fact that good storage conditions will prolong the life of materials. Even recording materials with relatively poor keeping properties will have their useful life extended by storage at low temperatures and low humidities. Over the past decade, much greater attention is being given to the environmental conditions of storage as it is recognized that this may be the only means of preserving information. Published standards are now available for all the major types of media.

The standard for photographic film describes two types of storage: medium-term storage, which is intended for the preservation of information for a minimum of 10 years; and extended-term storage, which is intended for the preservation of information for 500 years. The recommended temperature and relative humidity are given for each type. Extended-term storage for films on cellulose ester base and for color films requires cold storage conditions in order to obtain a 500-year life. Since both cold storage and low relative humidity extend the useful life of photographic film, higher humidities can be recommended if the storage temperature is reduced. In no case, however, does the recommended relative humidity exceed 50% RH. Recommendations are also given for packaging, storage rooms, and fire protection. There are descriptive annexes that discuss the distinction between storage copies and working copies, and the advantages and disadvantages of sealed enclosures. Information is provided on the deleterious effects of air pollutants and quantitative data is presented on the relationship between temperature and relative humidity on cellulose triacetate base degradation. This standard presents the best information available to date on photographic film storage. Similar documents exist for photographic paper prints and glass plates. Again low temperatures are required for color images. Very low humidities are not recommended for glass plates because of the danger of emulsion cracking.

Fortunately, storage information is published for the materials used in digital imaging. However, the distinction between medium-term and extended-term storage is not made for magnetic tape and optical discs because of lack of reliable data.

The maximum life to be expected for magnetic tape is given as 50 years. Presumably lower temperature storage would extend this life but there is concern that they might cause lubricant separation. It should be noted that the life expectancies of 500 years for photographic film and 50 years for tape are greater than those given in Table II because the storage conditions are more stringent than 21°C 50% RH.

A comparison of the recommended maximum temperature and relative humidity for the extended-term storage of the various media are listed in Table III. Some of these values are not based on hard data but on practical experiences and logic. However, they represent the best and current thinking of those knowledgeable in this field.

In addition to the documents that deal directly with the environmental storage conditions, there are a number of publications that augment these standards. One such standard gives specifications for enclosures and containers used in direct contact with both black-and-white and color photographic images. Recommendations are provided for plastics, metals, adhesives and printing inks found in enclosure materials. The advantages and disadvantages of various enclosure types are described and potential problems with seams in envelopes are given. Another standard provides a test method known as the Photographic Activity Test. Photographic enclosure materials such as paper, mat board, and plastics can cause changes in the photographic material with which they are in contact. These changes may only occur over a very long storage period. This test predicts the potential harmful effects of an enclosure material by incubating the material in question with a colloidal silver image detector and also with a stain detector. This procedure gives information about the potential of the enclosure material to cause image fading, stain growth or mottle.

There is currently activity on two additional standards which are not directly related to storage but are very pertinent to the utility of materials for digital imaging. One is a document on the care and handling of magnetic tape and it is expected that a document will be finalized in 1 – 2 years. The second is a treatise on the recording, playback and migration of CD discs but it will be many years before it is completed.

Hardware and Software Considerations

A major concern in the recovery of information on magnetic tape and discs is the preservation of the necessary hardware and software. This is an area where standards have not been written and work is not underway. Unlike photographic products, these materials can only be machine read, and the problem this poses has been recognized for many years. As equipment is used, parts wear out and must be replaced. Equipment repair is only possible if components are still manufactured or can be cannibalized from other equipment. If past history is any guide, the hardware will become obsolete within a relatively short time. Systems in this field are undergoing constant change, and it is very doubtful that replacement hardware will be available after several decades. There are two approaches to the long-term preservation of digital information.

1. For many years it has been understood that preservation of digital electronic information means refreshing from obsolete onto newer systems. Digital preservation depends upon this reformatting and not on preservation of the physical media. This concept was expressed as a change to thinking in terms of life cycles. Permanence of digital storage should be considered as a measure of the length of the renewal period. Unlike analog information, digital recordings can be copied without any loss in quality. This lead to the optimistic conclusion that digitized information can be preserved forever provided attention is given to periodic recopying. However, the cost and complexities of refreshing digital information presents a real threat to information life. Deliberate or inadvertent failure to do so because of expense or administrative or technical difficulties can result in data loss. Refreshing or reformatting may be a recurring cost which should be considered in operating a library or archive. Extending the life of the media as long as possible will reduce this cost.
2. A number of institutions and publications suggested that human readable copy may be the material of choice for preservation, while at the same time maintaining electronic images for viewing, editing, and distribution. Human readable copies could be either paper records or photographic reproductions. This approach is also expensive and would only be practical for material which should be preserved for centuries.

Undoubtedly different archives will use different combinations of the reformatting or preparing human readable copies, depending on factors such as the size of the collection, the quantity of existing records considered of permanent value, the demands for access, and cost considerations.

In the face of the continued evolution and consequent obsolescence of playback hardware and software, consumers might wish that the standards committees would create a single readability (i.e., hardware-software) standard that all future electronic products must adhere to. However desirable this approach may be from a storage prospective, it is not practical in the long term because it would inhibit the development of technology, would retard improvements, and would never be supported by the manufacturers. From a user's viewpoint, neither the creation of a single readability standard nor the approach of maintaining obsolete playback hardware will guarantee the survival of digital information. The only practical approach is a well-managed program of refreshing and migrating stored data from one system to a newer one as obsolescence proceeds or the use of another more stable media such as paper or film for preservation purposes only.

Summary

The interest in and concern for the preservation of recorded information is much more intense and focused than in the past. This is due to at least two factors. As materials get older, the information becomes more valuable while at the same time incidents of lost information become more numerous. In addition, the tremendous increase in the variety of materials used to capture images and information has made these problems more acute. The problems facing the archivist, librarian and curator today are much more complex and serious. This has been reflected in standardization activities. One result has been major changes in the scope and procedures followed in writing standards. Major areas where there is current activity are the preparation of specifications for traditional black-and-white photographic prints and color digital hardcopies. Work is also proceeding on handling recommendations for magnetic tape and the use of optical disks. An unresolved but serious problem is the obsolescence of hardware for machine readable electronic information.

Table I

Numerical Designations of Information Preservation Standards			
New ISO No. *	**Existing or Obsolete ISO No.**	**ANSI No.**	**Title**
Material Specifications			
	10602	IT9.1	Stability of Processed Black-and-White Film
	8225	IT9.5	Stability of Processed Diazo Film
	9718	IT9.12	Stability of Processed Vesicular Film
18919	14806	IT9.19	Stability of Thermally Processed Microfilm
Work in progress	—	—	Non-display Stability of Black-and-White Prints
Test Methods for Material Specifications			
18917	417	IT9.17	Determination of Residual Thiosulfate
	12206	IT9.15	Effectiveness of Silver Image Chemical Conversion
18924	15640	IT9.24	Test Method for Arrhenius Predictions
18909	10977	IT9.9	Methods for Measuring Color Image Stability
18921	18921	IT9.21	Method to Estimate Temperature and RH Effects on CD-ROM
	—	IT9.27	Method to Estimate Temperature and RH Effects on CD-R
	—	IT9.26	Method to Estimate Temperature and RH Effects on MO Discs
Work in progress	—	—	Methods to Evaluate Color Hardcopy Stability
Storage Specifications			
18911	5466	IT9.11	Film Storage
18920	6051	IT9.20	Print Storage
18918	3897	IT9.18	Plate Storage
18923	15524	IT9.23	Tape Storage
	—	IT9.25	Optical Disc Storage
18902	10214	IT9.2	Enclosures and Containers for Photographic Images
	14523	IT9.16	Photographic Activity Test

*Blank spaces indicate ISO adoption of new designation has not yet been made or been started.

Table II
Life Expectancy of Imaging Materials

	Life Expectancy at 21°C 50% RH Years
Black-and-White Images on Cellulose Triacetate Support	100
Black-and-White Images on Polyester Support	500
Diazo Images on Polyester Support	100
Vesicular Images on Polyester Support	100
Thermally Processed Images on Polyester Support	100
Non-display Black-and-White Prints	100
Color Photographic Images	40*
Magnetic Tape	10-30**
Optical Discs	—
Digital Color Hardcopy	—

* Source is *Storage Guide for Color Photographic Materials,* J.M. Reilly, 1998, Image Permanence Institute, Rochester Institute of Technology, 70 Lomb Memorial Drive, Rochester, NY 14623-5604.

** Source is *Magnetic Tape Storage and Handling*, J.W.C. Van Bogart, 1995, The Commission on Preservation and Access, 1400 16th Street, NW, Suite 740, Washington, DC 20036-2217.

Table III
Environmental Conditions for Extended-Term Storage

	Maximum Temperature °C	*Maximum % RH*
Photographic Film		
Black-and-White on Triacetate Base	2	50
	5	40
	7	30
Black-and-White on Polyester Base	21	50
Color	-10	50
	-3	40
	2	30
Photographic Paper		
Black-and-White	18	50
Color	2	40
Photographic Glass Plates	18	40
Magnetic Tape	23	20
	17	30
	11	50
Optical Discs	23	50

Modérateur / Moderator : Isabelle Giannattasio

Discussion

Ian GILMOUR

This presentation was extremely interesting. Without being too cynical, I would like to point out that manufacturers might try to produce materials that combat the elements measured in your tests. The same is already true in the car industry: the manufacturers invented air bags so that people could drive into walls. I am not sure whether I understood the problem correctly. Enclosures are simply be tested for acidity; the manufacturers are aware of the issue.

George BROCK-NANNESTAD

Ian Gilmour's question was in effect the following: will manufactures deliberately produce agents to make their products pass the tests, thereby possibly foregoing actual performance quality?

Peter ADELSTEIN

Since I am not a producer myself, I cannot provide an answer. If the manufacturers introduce material that allows them to pass the tests, it is probable that the changes will be beneficial to some extent. I cannot imagine a modification would not fulfil both criteria.
Yesterday, someone asked whether he should feel depressed as a result of all the incompatibilities between hardware and software. He should definitely feel depressed. I do not understand why so many people are smiling in the audience: a lot of digital information will be irreversibly lost. When information is lost on purpose, that is fine; much of the information available today is of little use. However, when it is lost against our will, it is very negative. In countries with limited resources, material must be reformatted every ten years. Using the aforementioned 300-year hypothesis, archive administrators will have 30 opportunities to lose the information. It takes just one war or one economic crisis to totally change the world's priorities. When emergency situations arise, reformatting becomes less of a priority and the information is lost.

From the floor

I unfortunately missed part of your presentation. Did you discuss your co-operation with the Audio Engineering Society?

Peter ADELSTEIN

No. We are indeed working with ANSI, the group that established standards on the optical disc, on the topic of digital information. Although the group is interested only in sound, it does work with the same material as we do and our relationship has proved very valuable.

Gerry GIBSON

AES is organising an event in Paris in February 2000. Those of you who do not often have the opportunity to attend its events in the United States will be able to hear the results of its recent work.

Bob CURTIS-JOHNSON

Can you briefly describe what might be an effective mechanism for achieving an accurate global survey so that we might establish a global standard on magnetic tape readers? Could we determine which machines are most frequently used so that we can set manufacturers in the right direction?

Peter ADELSTEIN

I do not know. I am not sure that would influence manufacturers. Tapes are commodities with very low profit margins. They must invest hundreds of thousands of dollars to earn sums that are minimal in the end.

Gerry GIBSON

UNESCO is very interested in this question. The Library of Congress agreed to carry out the survey and Kodak provided the funding. The latter does not wish to make any information public before the study is completed. We have gathered information from a representative base of 500 archives (national and local, small and large). The estimate mentioned earlier (40 million hours of audio tape and 10 million hours of video tape) was based on this information. Naturally, that figure will have to be updated. Thus far, the response rate is 45% to 50%.

Peter ADELSTEIN

Bill Murphy, from the Library of Congress, also performed an excellent study on a similar topic a few years ago. It gave a clearer idea of the magnitude of the problem. Gerry Gibson and myself are trying to spark more activity around this topic. It is essential that specifications be issued on magnetic tape if customers are to make the best choice possible. For the time being, the only advice heard is that one should not buy tapes that do not have a manufacturer's label. That is obviously insufficient. Users also need to know which of their tapes are degrading and which will last many years. AD strips are activated by acetic acid. The acid produced by magnetic tape is carboxylic acid, a compound for which there is no counterpart AD strip. We truly need some kind of indicator.

Isabelle GIANNATTASIO

Le prochain exposé nous sera présenté par Joëlle Garcia, Jean-Marc Fontaine et Dominique Marzet. Joëlle Garcia est responsable au département de l'audiovisuel de la Bibliothèque nationale de France de la section des documents électroniques, après avoir été responsable de la conservation dans ce département. Elle est également présidente de la section audiovisuel et multimédia de l'IFLA. Jean-Marc Fontaine est ingénieur de recherche du ministère de la culture et responsable du programme sur la conservation des documents audiovisuels – programme établi par une convention entre la Bibliothèque nationale de France, l'Université Paris VI et le CNRS. Dominique Marzet est chargé de conservation au département de l'audiovisuel de la Bibliothèque nationale de France. Ils vont vous présenter les difficultés et les méthodes pour s'y reconnaître dans la documentation concernant la conservation des supports audiovisuels.

La recherche d'information scientifique et technique en matière de conservation des supports audiovisuels

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Département de l'Audiovisuel de la Bibliothèque nationale de France - France

Jean-Marc Fontaine
Bibliothèque nationale de France, Département de l'Audiovisuel - Université de Paris VI - C.N.R.S. - France

Dominique Marzet
Département de l'Audiovisuel de la Bibliothèque nationale de France - France

Paradoxalement, l'information scientifique et technique n'a jamais été aussi abondante et n'a jamais paru aussi facile d'accès, pourtant la profusion et la diversité des sources sont un obstacle à la localisation et à l'exploitation de données pertinentes. Comment en effet repérer, sélectionner et utiliser les divers types de sources disponibles : documents primaires ou secondaires, inédits ou édités, hors ligne ou en ligne, etc. pour aider à la conservation des documents audiovisuels Quant on entreprend de réunir des informations sur la conservation des documents audiovisuels, plusieurs questions viennent à l'esprit. Quelles compétences réunir, pour quels objectifs ? quelles méthodologies pour quels usages ? Mais finalement, toutes les informations sont-elles vraiment accessibles ?

1. Les compétences et les objectifs

La documentation joue un rôle absolument essentiel dans les activités de l'ingénieur chargé de contribuer à la définition des mesures de préservation de l'information, quelle soit de type sonore, audiovisuel et multimédia. Que ce soit pour les enregistrements anciens, les enregistrements actuels et les dispositifs à venir, la nécessité de réunir de manière continue et de capitaliser les connaissances scientifiques et techniques est fondamentale.

La recherche d'information rencontre un certain nombre de difficultés dont la plus importante provient, à notre avis, de la dissémination des informations renforcée par la multiplicité des champs d'étude concernés. Cette difficulté peut s'illustrer au travers d'une classification de bibliothèque. Voici les différentes grandes classes concernées par le champ de notre étude et la multiplicité des subdivisions à l'intérieur de l'une d'entre elles sciences de la nature et mathématiques (probabilités, physique, mécanique, son, lumière, électricité, magnétisme, chimie, etc).
Dans un premier temps, l'attention s'est portée presque exclusivement sur le support, dans la continuité en quelque sorte de la gestion des documents traditionnels ; pour s'étendre ensuite à l'ensemble constitué par le système d'enregistrement / lecture autour du support matériel. La tendance serait aujourd'hui de privilégier le système d'acquisition / accès sans affecter une place considérable à un support dont la fin de vie est programmée avec l'abandon du format. Mais un tel concept ne peut être généralisé : par exemple, la question posée par la conservation des enregistrements relevant du dépôt légal privilégie la conservation des supports et des systèmes d'accès à l'information. Nous nous plaçons ici plus particulièrement dans ce cas de figure.
La gestion de telles collections s'appuie sur des données techniques très nombreuses et complexes. La notion de préservation de l'information intègre l'ensemble des aspects relatifs aux matériaux et aux modalités d'inscription-lecture des informations. Trois grands domaines peuvent être relevés :
- les connaissances fondamentales en matière d'enregistrement de l'information
- les technologies : mise en œuvre des principes théoriques
- les sciences humaines : communication de l'information à l'individu.

La chaîne des traitements comporte schématiquement les éléments traduisant images et sons en signaux électriques, les codages, l'organisation des données (format), l'inscription de celles-ci sur un support et toutes les opérations réciproques jusqu'aux moniteurs acoustiques (haut-parleurs) et visuels (écran). Nous devons prendre en compte tous ces éléments, à des degrés divers certes, en fonction des actions engagées.

- le support : état du substrat et de l'inscription de l'information, estimation de durée de vie, stockage, conditionnement ;
- les traitements physico-chimiques ;
- la lecture des documents : restitution des informations. Compatibilité, qualité de l'information. Traitement du signal : décodage, restauration des informations dégradées ;
- les procédures de transfert : choix du système cible, du format, évaluation des performances.

Il est indispensable de réunir les éléments permettant de considérer l'ensemble des aspects de la conservation des informations enregistrées (le support qui porte en lui les opérations d'enregistrement et d'inscription de l'information, le dispositif d'accès à celle-ci, et enfin les vecteurs de diffusion). La question de la conservation des documents sonores et audiovisuels ne peut être traitée qu'en envisageant la totalité des éléments qui entrent en jeu pour une question donnée.

On ne développera pas ici les contradictions entre les objectifs poursuivis par les industriels d'une part et par les usagers travaillant sur le plan de la conservation d'autre part. Les phases de lancement de nouveaux systèmes et leur retrait du marché ont un impact capital sur la continuité d'accès à l'information. Il est extrêmement difficile d'anticiper les évolutions et les mutations du marché. Les investigations à ce niveau exigent une vigilance continue à l'égard des tendances technologiques. Par ailleurs, il serait illusoire de prétendre réunir toutes les informations nécessaires pour résoudre un problème dans la mesure où les données pertinentes peuvent avoir disparu, être protégées ou inaccessibles. L'autre écueil peut-être la constatation, après l'exploitation de toutes les ressources possibles, qu'il n'existe que peu, voire pas du tout, de littérature sur le sujet recherché. C'est ainsi le cas des méthodes de nettoyage des disques 78 tours et microsillons : ces deux supports n'étant pas des supports professionnels, industries et laboratoires n'ont semble-t-il mené aucune étude approfondie sur le sujet (au contraire des bandes magnétiques au sujet desquelles la littérature est considérable).

L'activité éditoriale joue un rôle important dans la vie d'un chercheur. Le suivi bibliographique dans son domaine est pour lui une source fondamentale pour juger de l'évolution des connaissances et des axes de recherche.

Les besoins des chercheurs sont de trois types :
- la recherche quotidienne d'information : appel à la documentation de proximité ;
- la recherche courante d'information pour connaître l'actualité scientifique dans le domaine à différents niveaux : revues généralistes (Science, Nature, etc.), revues spécialisées dans les disciplines, interrogation de bases de données sur le sujet ;
- la recherche exhaustive afin d'initier ou de faire le point sur des travaux en cours : recours à des bases de données exhaustives et rétrospectives.

En considération des multiples sources d'information, du temps nécessaire pour les localiser, les acquérir et les exploiter, les scientifiques ne peuvent pas faire l'économie de recourir à l'expérience des documentalistes. L'idéal est un dialogue entre le documentaliste de formation (et d'esprit scientifique) travaillant étroitement avec les ingénieurs et scientifiques ayant reçu un enseignement en documentation. le scientifique n'a ni le temps, ni la formation initiale nécessaires pour faire lui-même toutes ses recherches ; le documentaliste ne sera pour sa part efficace que s'il trouve dans le scientifique un interlocuteur avec qui discuter des besoins documentaires, orienter et trier les informations. C'est à ce prix que la documentation s'intégrera naturellement et quotidiennement dans le travail du scientifique. Par ailleurs, une collaboration documentaire entre les établissements scientifiques est indispensable pour centraliser les informations.

2. La multiplicité des sources

Nous avons brièvement évoqué la multiplicité des domaines concernés et des compétences. Penchons nous sur la multiplicité des types de sources pour mieux saisir la complexité de la démarche.

Les chercheurs sont confrontés à différents types de sources :
• les sources primaires d'information comme les ouvrages, les périodiques, les thèses, etc.
• les catalogues permettant de trouver ces sources sur place ou à distance via Internet
• les sources secondaires d'information qui signalent et analysent les sources primaires : bulletins signalétiques ou analytiques, divers « abstracts » sous forme imprimée, sur CD-ROM ou dans les banques de données en ligne.

2.1 Des documents écrits

Ils se divisent en deux catégories :

Les documents publiés en grand nombre dans le cadre des circuits commerciaux :
- ouvrages spécialisés, synthèses
- encyclopédies, anthologies, bibliographies
- périodiques grand public, revues de vulgarisation
- brevets
- normes.

La « littérature grise » i.e. tout document dactylographié ou imprimé produit à l'intention d'un public restreint et diffusé hors des circuits commerciaux de l'édition :
- actes de colloques, conférences, congrès, conventions ;
- tirés à part ou preprints, commercialisés ou bien communicables auprès des auteurs ;
- périodiques publiés par les associations professionnelles, guides, précis ;
- thèses, mémoires, rapports de stage : les thèses sont répertoriées en France depuis 1972 (1983 pour la santé) et repérables par le cédérom Docthèses ; aux USA Dissertation Abstracts Online répertorie plus de 90% des thèses américaines ;

- projets de normes ;
- supports pédagogiques, cours, etc. ;
- documentation à caractère technico-commercial, dossiers de presse, etc. ;
- manuels d'instructions techniques d'appareils, de systèmes ;
- cahiers de spécifications élaborés par les concepteurs ;
- rapport d'étude interne dont la publication est plus ou moins confidentielle ;
- archives de sociétés ou d'organismes très impliqués dans le développement de systèmes (cahiers des charges) ;
- archives industrielles ;
- témoignages des acteurs qui ont participé à la conception et à l'exploitation des supports et matériels de lecture.

2. 2. Des bases de données

La publication scientifique est en pleine expansion : on estime que le nombres de titres de revues scientifiques double tous les cinq ans. Les bases de données sur cédéroms ou sur Internet permettent d'optimiser la recherche d'informations déjà publiées.

On y trouve des informations de type factuel (informations sous forme de texte intégral, données numériques, annuaires, dictionnaires, etc.) ou bibliographique (informations secondaires sous forme de références bibliographiques).
Parmi les bases qui font référence pour les domaines concernés par la conservation des documents audiovisuels, on peut citer :
- Science citation Index (multidisciplinaire)
- Current contents (multidisciplinaire)
- Pascal (multidisciplinaire en sciences exactes)
- Chemical Abstracts (chimie)
- Inspec (physique)
- Lisa, Library and Information Science Abstracts (sciences de l'information et bibliothéconomie).

Le producteur rassemble, analyse et décrit les documents (c'est-à-dire ajoute des descripteurs ou mots-clés significatifs) et en fait un résumé (parfois le résumé est celui fait par l'auteur du document primaire) et les met sur un serveur détenu par une société commerciale qui possède l'infrastructure technique pour héberger ces bases. L'information secondaire est fabriquée par les producteurs de banques de données à partir des informations primaires.
Les différentes informations sont organisées en champs :
- auteur de l'article, de la thèse, de la communication ...
- titre ;
- adresse du laboratoire ;
- source: références de la source primaire d'information (nom et n° du périodique etc...) ;
- descripteurs ;
- résumé.
Le champ descripteur décrit et permet de retrouver le contenu de l'information. Les descripteurs sont mentionnés dans un lexique (dictionnaire alphabétique des termes d'indexation) ou dans un thésaurus (classification hiérarchique des termes d'indexation : termes génériques et spécifiques). La recherche est menée dans les champs et les index selon la logique booléenne. Le mode d'indexation des documents reflète bien souvent l'orientation éditoriale du produit et représente un bon indice pour mesurer la pertinence d'une source pour telle ou telle recherche.
Afin de mener une recherche efficace qui évitera les écueils du bruit (échec du au signalement d'un trop grand nombre de documents non pertinents) et du silence (échec du au non signalement de tous les documents pertinents) il faut connaître les commandes du serveur et se former à son langage d'interrogation. D'une source à l'autre, les modes d'interrogation sont bien souvent inégaux (ex. : possibilité d'accéder ou non à l'index).
Cette formation est d'autant plus nécessaire que le l'accès et la consultation sont payants.Le client paie l'accès à ces bases qu'elles soient en ligne (contrat) ou sur cédérom (abonnement). Le coût d'interrogation est variable : il est estimé dans une fourchette de 200 à 2000 francs HT de l'heure auquel s'ajoute le paiement des termes de recherche et des références visualisées et entre 5000 et 1 500 000 francs HT d'abonnement par an selon le titre et le type de licence (réseau ou monoposte).

2.3. Des informations accessibles par l'Internet

Internet fait partie des outils de recherche en documentation. Ce nouvel outil présente des caractéristiques de fond et de forme qui ne facilitent pas son usage. Le réseau est principalement caractérisé par un concept de liberté.
Pour avoir connaissance des nouvelles informations sur un site déjà répertorié comme de la disparition ou de l'apparition de nouveaux sites, il faut s'astreindre à une veille documentaire, la plus régulière possible en relançant ses requêtes. Si l'on a affaire à un grand nombre de sujets de recherche, comme c'est le cas en matière de supports audiovisuels, cette demande peut s'avérer longue et difficile.
En plus de la publicité officielle, du bouche à oreille ou de l'utilisation des sélections de sites déjà disponibles sur Internet, le recours aux moteurs de recherche est un passage obligé. Si l'on en croit plusieurs études, ces logiciels de recherche ne signaleraient tout au plus qu'entre moins de la moitié et un sixième des informations disponibles sur Internet. Il est de plus en plus souvent question d'un « Web invisible ». On dénombrerait aujourd'hui l'existence de plus de 1500 moteurs de recherche. Seuls quelques méta-index compilant les résultats de plusieurs moteurs, semblent tirer leur épingle du jeu en améliorant potentiellement les résultats. Pour faciliter l'accès à toutes les informations disponibles, il existe depuis environ deux ans, des logiciels « agents de recherche » (Topic, Périclès, Noémic ou Tétralogie) qui, sur la base d'une requête, passent au crible l'ensemble du Web y compris les pages payantes ou sécurisées, les banques de données et les forums de discussion. Cet outil se révèle

particulièrement coûteux (plusieurs dizaines de milliers de francs). En un ou deux jours, il serait capable de récupérer quelques 600 000 documents en format texte ou HTML (environ 5 Go de texte brut).
Un site peut avoir disparu ou changé d'adresse et les sites encore présents sont parfois depuis trop longtemps laissés sans mises à jour. D'autre part, conséquence du mode de fonctionnement du moteur utilisé, il n'est pas rare de se voir proposer plus d'une centaine de sites inintéressants avant de trouver les informations recherchées.

Les technologies permettent aujourd'hui le développement de la presse scientifique en ligne. Sur Internet sont accessibles des revues, des lettres et des bulletins d'informations, des pré-publications, des rapports de laboratoires, etc. De ce fait, la demande d'accès à l'information délocalisée se généralise. Par ailleurs la hausse continuelle du coût des abonnements des revues scientifiques et la diminution des budgets d'acquisition dans de nombreuses bibliothèques incitent les utilisateurs à se tourner vers les documents en ligne. Le délai trop important entre la rédaction d'un article et sa publication (due à l'inflation éditoriale) trouve ici une solution.
On trouve sur le réseau des revues existant déjà sur papier; l'édition électronique permet des recherches sur les titres, résumés, textes, un mode de lecture hypertextuel, la recherche dans les archives, l'association de forums de discussion sur certains sujets, des informations rapides sur les prochains numéros. Il existe également de nouvelles revues, créées exclusivement sur le réseau par des éditeurs à la demande de certaines communautés scientifiques, presses universitaires, chercheurs ou encore sociétés savantes. Elles permettent une diffusion accélérée des résultats scientifiques dans certaines disciplines. Par ailleurs on trouve également des revues existant déjà sur papier et n'offrant qu'un signalement du contenu (éditorial, sommaire) sur Internet avec éventuellement quelques articles intégraux comme produit d'appel. Des compléments d'articles de revues sont mis en ligne dans des disciplines très spécialisées pour permettre la diffusion de certains travaux nécessitant l'usage de l'ordinateur (modélisation numérique).

Les internautes disposent par ailleurs sur le Web de plusieurs espaces dans lesquels, en direct ou en différé, ils peuvent dialoguer. Parmi eux : les listes de diffusion et les groupes news (newsgroup).
Les listes de diffusion sont un excellent moyen pour échanger des informations sur des sujets très précis. En France comme à l'étranger, il est possible d'échanger ses opinions sur les logiciels documentaires, les nouvelles versions d'un logiciel, les qualités et défauts d'un nouveau graveur de CD-R, comme sur les performances techniques du DVD. Le sérieux des listes est parfois garanti par une charte et la présence d'un modérateur. La charte fixe les règles d'utilisation de la liste, notamment en ce qui concerne le respect des règles juridiques nationales et internationales garantissant en particulier les droits d'auteur. Ces listes diffusion offrent beaucoup d'avantages : de bonnes garanties sur le sérieux des informations diffusées, une occasion de récupérer des informations inédites et de première main, la fin éventuelle d'un sentiment d'isolement en participant à une communauté virtuelle unie autour d'intérêts semblables, l'enrichissement de ses contacts professionnels qui peuvent être à l'origine de collaborations fructueuses, etc.
Les groupes « news » sont quant à eux fondés sur un autre mode de fonctionnement puisqu'on y accède par la consultation active d'un serveur sur lequel sont stockés les dialogues entre internautes. Documentairement, les groupe news semblent moins enrichissants que les listes de diffusion : tout internaute y a accès, tous les excès peuvent y exister, les contributions sont souvent brèves et les sujets rarement approfondis.

Internet semble ainsi une solution de recherche privilégié pour résoudre le problème de la diversité des sources. Mais peut-on vraiment tout trouver en ligne aujourd'hui ?

3. Peut-on tout trouver en ligne aujourd'hui ?

Grâce à la faiblesse des coûts pour construire puis héberger un site, il est aujourd'hui possible à chacun de créer ses pages sur Internet et d'y faire figurer des informations fondées, argumentées et vérifiables ou non. Dans cet espace de liberté, le sérieux scientifique du contenu n'y est aucunement garanti, quel que soit le domaine concerné. L'usager doit faire une évaluation des informations au moyen d'une grille d'analyse composée de questions sur les administrateurs du site, l'identification des auteurs, la qualité des textes et des illustrations, la fréquence des mises à jour du site, le respect des droits d'auteurs, etc.
On ne manquera pas non plus de fréquenter les sites d'industriels (fabrication de matériaux ou de supports) dans lesquels il est parfois possible de trouver d'intéressantes informations techniques sur les produits et les tendances du marché. Certains sites d'amateurs, de collectionneurs peuvent se révéler des sources d'informations valables.
Internet est aussi marqué par une grande instabilité : disparition de sites, changements d'adresse, disparition de contenu à l'occasion d'une mise à jour.De nombreux projets dans le monde, le plus souvent à l'instigation de grandes bibliothèques et universités, ont pour but, dans le respect des droits d'auteur et du copyright de collecter et conserver les sources d'information disponibles sur le Web afin qu'elles continuent d'être accessibles au public (on peut citer le projet PANDORA « Preserving and Accessing Networked Documentary Resources of Australia » de la National Library of Australia et les rencontres du projet InterPARES « International Research on Permanent Authentic Records in Electronic Systems » organisé par la University of British Columbia's *School of Library, Archival and Information Studies »)*. Pour se prémunir contre la disparition brutale d'informations, il convient

de les imprimer ou de les décharger sur le disque dur de son ordinateur. Ce déchargement a d'autre part l'avantage de permettre un accès hors ligne donc sans facturation téléphonique et sans délai d'accès.

Il convient aussi de souligner que cette liberté peut être dissuasive pour les candidats à la fourniture d'informations. Les données (textes, photographies ou enregistrements sonores) une fois téléchargés peuvent être exploitées par des internautes peu scrupuleux : utilisation sans faire valoir les droits de citations, copyright et autres droits d'auteur. A travers des normes internationales ISO, des règlements et des outils informatiques, la communauté mondiale tâche d'ordonner ce monde des données pour que puisse y régner le respect du droit des auteurs. Textes, images et sons peuvent dès à présent être informatiquement équipés de fichiers permettant leur identification et leur origine. A l'heure qu'il est, tout ne semble pas être encore près pour garantir au mieux les droits des auteurs sur le réseau et lever les réticences. Internet connaît encore des zones de « non-droit ». Le fournisseur d'informations en ligne court également le danger de l'intrusion quelle qu'en soit l'intention. En somme, il est probable que certaines informations ne figureront jamais sur le réseau tant qu'il ne sera pas suffisamment sécurisé.

Actuellement, les informations disponibles directement sur Internet et concernant la conservation des documents audiovisuels sont le plus souvent généralistes. Les sites abordant les sujets les plus pragmatiques, ceux-là même sur lesquels s'interrogent bon nombre d'institutions à vocation patrimoniale, sont pour la plupart l'œuvre de collectionneurs (presque exclusivement anglo-saxons) qui font état de leurs expériences sur leur propre collection d'appareils de lecture (vieux phonographes comme lecteurs de bandes magnétiques) et de supports (cylindres, disques 78 tours ou microsillons) : mode de lecture sur appareils d'origine, réparation et maintenance, transfert des enregistrements, nettoyage, etc. Si l'institution qui a une mission patrimoniale lui faisant devoir de n'intervenir sur les supports que sur des bases scientifiques et déontologiques n'y trouve pas son compte, ces sites peuvent néanmoins présenter l'avantage de suggérer des pistes de recherche à défaut de donner des réponses immédiates. En matière d'actualité en technologie de pointe sur les supports et les machines, par l'intermédiaire de très nombreux sites commerciaux, Internet a aussi l'incomparable avantage de présenter les catalogues en ligne permettant souvent commandes et paiements électroniques d'un produit spécifique.
Si ce bilan apparaît un peu mince aujourd'hui, il n'en reste pas moins que le Web est un moyen inégalable comme outil de communication entre personnes séparées par des milliers de kilomètres. Via le courrier électronique, listes de diffusion et groupes de news sont des vecteurs essentiels pour l'échange d'informations de première main, pour le désenclavement des chercheurs en information et pour le développement des collaborations nationales et internationales au sein d'une communauté scientifique virtuelle.

Conclusion

L'expérience semble démontrer que, en matière de recherche d'information très spécialisée, les difficultés d'accès restent encore grandes. La recherche d'information scientifique et technique sur la conservation des supports audiovisuels exige de s'attacher à un nombre considérable de disciplines, de sources d'informations souvent disséminées requérant des techniques de recherches adaptées. Tout n'est pas publié ou aisément disponible, tous les sujets n'ont pas encore été sérieusement étudiés.Cette complexité induit un investissement humain et financier difficile à concevoir à une époque où la révolution d'Internet semble mettre l'information immédiatement à portée de tous. L'avancée dans la connaissance des documents et des moyens de les sauvegarder passe par une coopération renforcée entre les métiers, les disciplines, les institutions et les pays.

DISCIPLINES CONCERNEES

CHIMIE

Chimie physique, chimie physique
Chimie inorganique, chimie organique
Caractérisation. Processus de dégradation
des polymères. Traitements

PHYSIQUE

Mécanique du solide, acoustique, optique,
chaleur, électricité, électronique, magnétisme.
Etat de la matière. Traitements

TECHNOLOGIE

Ingénierie. Systèmes d'enregistrement et de
reproduction du son et des images.
Traitement du signal.
Numérisation, compression, contrôle qualité

COGNITION

Perception sensorielle,
visuelle, auditive
Qualité de l'information

DOCUMENT

Conservé, prêt à diffuser

CLASSIFICATION DECIMALE DE DEWEY

Rubriques concernées par la conservation des documents sonores, audiovisuels et multimédia

000. Généralités

120. Théorie de la connaissance, causalité, genre humain

300. Sciences sociales

500. Sciences de la nature et mathématiques

600. Techniques (Sciences appliquées)

700 Les arts. Beaux-arts décoratifs

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500. Sciences de la nature et mathématiques

518 Probabilités et mathématiques appliquées

518.5 Statistique mathématique
518.52 Théorie de l'échantillon
518.53 Statistiques descriptives, analyse multivariée, analyse de la variance et de la covariance

530 Physique

530.4 Etat de la matière
- 530.412 Propriétés (Elastiques, électriques, magnétiques, optiques, thermiques)
- 530.413 Catégories (Solides métalliques et non métalliques, polymères, ...)

530.7 Instruments de mesure, de contrôle, d'enregistrement
530.8 Mesures (Analyse dimensionnelle, essais, tests)

531 Mécanique classique, mécanique du solide

531.1134 Rhéologie (déformation)
531.3 Dynamique des solides (cinétique et cinématique)
531.38 Déformation, contraintes et tensions
531.382 Elasticité (déformation temporaire)
531.385 Plasticité (déformation permanente)

534 Son et vibration connexes. Acoustique

534.1 Génération du son
534.2 Propagation du son
534.3 Caractéristiques : fréquence, intensité; amplitude

535 Lumière visible (optique) et phénomènes paraphotiques

535.2 Optique physique
535.3 Propagation, absorption, émission de la lumière visible
535.5 Faisceaux et polarisation
535.6 Couleur
535.8 Application. Spectroscopie

536 Chaleur

536.3 Rayonnement. réflexion, absorption
536.4 Effets de la chaleur sur la matière. Changement d'état
- 536.41 Dilatation et contraction

536.5 Température. Thermométrie

537 Electricité et électronique. Electromagnétisme

537.6 Electrodynamique et thermoélectricité. Courant électrique

538 Magnétisme. Propriété. Substances magnétiques

538.44 Ferromagnétisme

540 Chimie et sciences connexes

541.2 Chimie théorique
541.224 Liaisons chimiques, valences, radicaux
541.3 Chimie physique
541.34 Chimie des solutions. Solvants
541.361 – 541.368 Thermochimie. Changement d'état. Dissociation thermique
541.393 Réactions particulières. Hydrolyse, oxydation, polymérisation. Réactions irréversibles, réversibles
541.394 Cinétique des réactions

542 Laboratoires, techniques, appareils, équipements

543 Chimie analytique

543.081 Microanalyse et semi-microanalyse
543.083 Méthodes mécaniques
543.085 Méthodes optiques
543.086 Analyse thermique
543.087 Méthodes électromagnétiques. Spectrométrie de masse
543.089 Analyse chromatographique

544 Chimie qualitative

545 Chimie quantitative

546 Chimie inorganique

546.3 Métaux, composés et mélanges

547 Chimie organique

547.043 Composés azoïques
547.86 Colorants et pigments

551 Géologie, météorologie, hydrologie générale

551.5 Météorologie
551.525 Température
551.527 Rayonnement. Rayonnement solaire
551.57 Hydrométéorologie. Humidité

579 Micro-organismes, champignons inférieurs, algues

579.5 Champignons inférieurs. Eumycophytes. Mycologie.

Discussion

De la salle

Avez-vous une base de données interne à la Bibliothèque nationale de France ? Si oui, utilisez-vous un vocabulaire contrôlé en thesaurus pour les documents que vous avez entrés dans la base de données ? Il faut savoir que les informations que vous avez étudiées et entrées dans la base de données ont une valeur ajoutée beaucoup plus grande. Il ne faut pas toujours rechercher le web, il faut utiliser ce que l'on a déjà fait.

Joëlle GARCIA

Nous n'avons pas actuellement de base de données car nous manquons de temps pour la constituer. C'est en cherchant à résoudre les problèmes concrets qui se posent dans la gestion des collections que nous sommes amenés à effectuer des recherches. Il est vrai que, dans mon exposé, j'ai beaucoup insisté sur Internet. Mais nous nous sommes rendu compte que, pour avoir une information pertinente, il convenait encore aujourd'hui d'utiliser tous les types de sources à notre disposition et que certaines étaient extrêmement difficiles à trouver. Aujourd'hui, Internet est un moyen d'accéder plus facilement à certaines informations mais ne remplace en rien une recherche exhaustive.

De la salle

En général, les bases de données recensent les informations depuis 1972. Or nous avons besoin d'informations provenant de vieux manuels ou de vieux magazines des années 50.

Joëlle GARCIA

Effectivement, les bases de données recensent des informations récentes. On peut trouver parfois des reprises de contenus numérisées qui permettent de remonter plus en arrière dans le passé.

Kevin BRADLEY, National Library of Australia

It is indeed a complex task to keep track of these problems. Are you familiar with the National Library of Australia's efforts in preserving access to digital information? One person works full time at documenting the information that is already available and setting up a gateway that allows for access to related items. These kinds of initiatives could help us all if taken up at the international level.

Michelle AUBERT

J'anticipe un peu sur ce que nous allons dire demain en fin d'après-midi, mais puisque nous abordons ce sujet, je pense qu'il serait très utile que toutes les personnes qui ont connaissance de sites appropriés nous le fassent savoir pour que l'on puisse inclure la liste de ces sites dans les actes de ce symposium.

Ian GILMOUR

I endorse the National Library of Australia's approach. Regarding information on the Internet, it would seem that the quality of the information is inversely proportional to the scope of the market. At the consumer level, there is more mis-information (regarding CDs, CD-Rs, domestic tape) than real information. Much of it is anecdotal and misleading. At the other end of the scale, user groups are extremely informative, but are by nature highly selective. One of the difficulties we have encountered is distinguishing active information and countering the mis-information that is promulgated widely.

II
TRANSFERT ET RESTAURATION DES ORIGINAUX IMAGES ET SONS

TRANSFER AND RESTORATION OF ORIGINAL IMAGE AND SOUND

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Modérateur / Moderator : Jean-Louis Bigourdan (Image Permanence Institute - USA)

Jean-Louis BIGOURDAN

Cette session est consacrée à l'évaluation de l'apport des nouvelles technologies pour les archives. Deux points de vue seront présentés, le point de vue universitaire et celui des archives. Les quatre intervenants de ce matin vont traiter de l'apport des nouvelles technologies sur différents types de matériaux : les enregistrements photographiques, les enregistrements audio mécaniques, les enregistrements magnétiques. Les quatre intervenants sont chacun des pionniers dans leur domaine. Vous pourrez leur poser toutes les questions que vous voulez.

Le premier intervenant, Bernard Besserer, est ingénieur en génie électrique, maître de conférences à l'Université de La Rochelle depuis 1993. Il enseigne dans le domaine de l'architecture des ordinateurs, des interfaces homme/machine et du multimédia. Depuis 1995, il poursuit des travaux sur la restauration des documents cinématographiques. Aujourd'hui, il va nous parler de la restitution des couleurs sur les films cinématographiques.

Restitution numérique des couleurs de films

Xavier Trochu, Majed Chambah & Bernard Besserer
L3i (Laboratoire d'Informatique et d'Imagerie Industrielle) Université La Rochelle - France

Introduction

Depuis un peu plus de cent ans, les films jouent un rôle important dans notre vie quotidienne comme documents, mémoire, moyens artistiques, archives, information,... Ils représentent un patrimoine d'une valeur culturelle importante et doivent être traités avec le même respect et la même attention que les autres œuvres artistiques.

Des dégradations dues à divers facteurs affectent toutes les catégories de films même les plus récents (manipulation brutale, conservation dans des conditions non optimales,...). La restauration traditionnelle des documents cinématographiques se fait par des moyens mécaniques et photochimiques, mais ces techniques ne peuvent corriger tous ces défauts. D'autant plus que pour les films couleur, la décoloration ou l'affaiblissement des pigments colorants est irréversible. Dans la plupart des cas, une version avec des colorants affaiblis est le seul exemplaire existant du document. D'où l'intérêt de restituer numériquement les couleurs des vieux films [BRA81, GSA95]. Nous exposons ici les étapes que nous jugeons nécessaires pour aboutir à un traitement le plus automatisé possible.

Chaîne de traitement pour la restauration numérique des films

La chaîne de traitement dédiée à la restauration de films cinématographiques [CST97], illustrée par la figure 1, a pour fonction de numériser un film, le traiter de façon informatique puis de reporter les images sur film. Cette chaîne peut aussi servir pour toutes les opérations de post-production, comme les effets spéciaux.

Les principaux éléments de cette chaîne sont structurés autour d'un réseau haut débit. Les réseaux de type S.A.N (Storage Area Network), comme le SSA ou le Fiber-Channel, permettent d'interconnecter les éléments de la chaîne, garantissent un débit élevé pour les échanges de données et facilitent le partage des ressources.

Pour toute opération ayant trait à la couleur, la chaîne scanner - stations de travail - imageur doit être calibrée chromatiquement. Si cela est assez aisé pour les stations (écran de type Barco, sondes de mesure, profils ICC, etc...), le calibrage reste un processus plus expérimental pour le scanner et l'imageur.

Bref rappel sur la composition d'un film

Un film est constitué de cristaux d'argent dispersés dans de la gélatine (l'émulsion) qui enrobe en couches fines un support (la base ou support du film). L'exposition et le développement de ces cristaux forment l'image photographique qui est à un moment donné formée de particules discrètes d'argent. Dans un processus couleur où l'argent est éliminé après le développement, les colorants forment des nuages de teinte centrés sur les sites des cristaux d'argent développés [EAS96].

Un film est constitué de différentes couches [EAS92] (voir figure 2) :

- La première couche d'émulsion est composée de sels d'argent sensibles au bleu et au violet.
- La couche suivante, composée de colorants jaunes, fait fonction de filtre : elle arrête le bleu. Ce jaune intercalaire sera détruit au cours du traitement.
- La couche suivante, orthochromatique, n'est sensible qu'au bleu et au vert. Mais comme elle ne reçoit plus de bleu, le vert est le seul à impressionner cette couche.
- Une intercouche de gélatine transparente et non sensibilisée sépare la dernière couche des autres.
- La dernière couche, sensible au rouge et au bleu, ne reçoit plus de bleu. Le rouge est donc le seul à impressionner cette troisième couche sensible.
- Le support plastique n'a qu'une fonction mécanique. Il est recouvert d'une couche anti-halo.

Numérisation d'un film

Un film négatif développé comporte trois couches comportant des colorants cyan (C), magenta (M) et jaune (Y) correspondant respectivement aux intensités de rouge (R), vert (G) et bleu (B) reçues.

La numérisation du film [KEN94] s'effectue souvent sur le négatif et doit créer une image positive (RGB) plus facile à manipuler de façon informatique. Le processus de numérisation doit donc déterminer les quantités de lumière rouge (r), verte (g) et bleue (b) qui seront absorbées respectivement par les couches cyan (C), magenta (M) et jaune (Y) du film. Pour les scanners à matrice ou à barrette CCD monochrome, la numérisation s'effectue en 3 passes : On éclaire le négatif en utilisant tour à tour une lumière monochrome (rouge :R , verte : G puis bleue : B). Le capteur CCD du scanner (placé de l'autre côté du film) mesure la quantité restante de lumière après avoir traversé le film (R', G', B') (donc la lumière non absorbée par le film). Il est ainsi possible de déterminer la quantité de lumières rouge (r) verte (g) et bleue (b) absorbées par le film, proportionnelle à la densité des pigments, et formant les plans RGB de l'image positive résultante.

$r = R - R'$	*où R : lumière émise par la source, R' : mesurée par le CCD.*
$g = G - G'$	*où G : lumière émise par la source, G' : mesurée par le CCD.*
$b = B - B'$	*où B : lumière émise par la source, B' : mesurée par le CCD.*

Remarque : La sensibilité d'un capteur CCD variant en fonction de la longueur d'onde, nous considérons ici que cet équilibrage a été effectué. Dans un but de calibrage chromatique complet de la chaîne, nous avons effectué des mesures spectrales sur la lampe et les filtres du scanner que nous avons utilisé pour nos travaux, en l'occurrence une machine Klone de Cintel. L'appareil de mesure utilisé est un thermocolorimètre Minolta (figure 3). Les illuminants primaires, obtenus par des filtres à bande étroite placés successivement devant la lampe du scanner, sont quasiment monochromatiques, comme l'indique la position des ces illuminants dans le repère de la CIE. (figures 4 et 5). C'est d'ailleurs une condition essentielle pour un processus de sélection : **avoir un reflet numérique des informations contenus dans les différentes couches chromatiques.**

Corrélations parasites

Les formules précédentes ne sont correctes que si les trois couches d'émulsion du film négatif (CMY) n'absorbaient que leurs couleurs complémentaires correspondantes (c'est à dire RGB), mais en réalité il y a des absorptions indésirables. En effet [GLA76] la couche cyan n'absorbe pas seulement la lumière rouge mais aussi -à un degré moindre- la lumière verte et bleue. La couche magenta absorbe la lumière verte, la lumière bleue et très peu de rouge. La couche jaune quand à elle absorbe la lumière bleue, peu de lumière verte et très peu de rouge. Ces absorptions indésirables sont appelés *side-absorption* par les anglo-saxons.

Ces absorptions sont mises en évidence par les graphiques de la figure 5. Le graphique du haut représente le spectre d'émission du scanner, mesuré grâce au thermocolorimètre, en superposant les mesures effectuées après avoir intercalé le filtre rouge, le filtre vert puis le filtre bleu devant la lampe. Le graphique du bas de la figure 5 représente un exemple de spectre d'absorption des colorants pour un film négatif. On remarquera, par exemple, que le colorant magenta (M) absorbe encore les longueurs d'onde inférieures à 450 nm (lumière bleue).

Le tableau 1 indique de façon simplifiée les absorptions parasites des différentes couches pour un film négatif standard, pas ou peu altéré.

L'image positive bleue (b) provient de l'absorption de la lumière bleue (B) de la part de non seulement la couche jaune (Y) mais aussi de la couche magenta (M) et cyan (C).

L'image positive verte (g) résulte de l'absorption de la lumière verte (G) par la couche magenta (M) et de l'absorption parasite de cette même lumière verte par la couche cyan (C). L'image positive rouge (r) provient essentiellement de l'absorption de la lumière rouge par la couche cyan (C).

Bien sûr, les absorptions parasites dépendent du type de pellicule, du lot de fabrication, éventuellement du vieillissement de celle-ci, ainsi que longueurs d'onde des illuminants du scanner.

Il est bien plus intéressant de constater que, dans le cas d'images dont une ou deux couches sont « affaiblies », l'importance des corrélations introduites par ces absorptions est encore plus marquée. En effet, les couches

Emulsion	Lumière Bleue	Lumière Verte	Lumière Rouge
Cyan	★★	★★★	★★★★
Magenta	★★★	★★★★	☆
Jaune	★★★★	★	☆

Tableau 1 : importance des absorptions parasites

dont la densité est faible absorbent peu la lumière, les couches dont les colorants sont intacts (mais censées laisser passer la lumière pour la longueur d'onde considérée) ont donc une influence proportionnellement plus importante par leur absorption indésirable.

Il s'agit d'une **corrélation** entre les 3 plans R, G et B. La correction ou les manipulations informatiques ne peuvent donc s'effectuer plan par plan, mais doit tenir compte des informations RGB simultanément,. Il est donc intéressant d'effectuer une correction préalable à toute manipulation plan par plan.

Suppression des corrélations parasites

Dans le cas d'une image dont les colorants sont dans un état de conservation correct (peu d'affaiblissement), l'élimination des images parasites (corrélations parasites) peut s'exprimer de la façon suivante :

Conserver le plan rouge (r), car les couches autres que la couche cyan (C) n'absorbent pratiquement pas la lumière rouge.

Rectifier la valeur des plans (g b) dont les lumières ont été absorbées par plus d'une couche. Par exemple : on diminue la valeur du plan (b) car il y a des absorptions indésirables de la lumière bleue (B) et on y ajoute une proportion du plan rouge (r) et vert (g) pour compenser l'absorption de la lumière bleue (B) par les couches cyan (C) et magenta (M).

Notre matrice de correction se présente comme suit :

$$\begin{bmatrix} r \\ g \\ b \end{bmatrix} \times \begin{bmatrix} a & c & d \\ e & b & c \\ e & d & b \end{bmatrix} = \begin{bmatrix} r' \\ g' \\ b' \end{bmatrix}$$

$$\textit{où} \quad a \approx 1,\ e \approx 0 \ \textit{ et } \ e < d < c < b < a$$

En appliquant cette matrice à une image accusant une dominante dans une couleur (par exemple une dominante verte due à la dégradation de la couche cyan (C) et jaune (Y)), l'image résultat accuse une dominante encore plus marquée.

Ce résultat est normal et prévisible, car les plans bleu et rouge contiennent une influence parasite du plan vert. En supprimant cette influence, l'écart de densité entre le plan intact et les plans altérés s'accentue.

Il faut toutefois remarquer que les indications données dans le tableau 1 ne sont plus valables lorsque qu'une ou plusieurs couches de colorants sont fortement affaiblies.

Recherche automatique des corrélations parasites

Connaissant l'existence de ces corrélations parasites, nous souhaitons les supprimer ou les minimiser dans notre représentation informatique, afin d'obtenir le reflet numérique le plus précis possible de la densité des colorants résiduels dans chaque couche CYM.

Nous explorons actuellement diverses méthodes permettant de déterminer de façon automatique **un indice de corrélation** entre les différents plans, indice de corrélation autre que la corrélation « naturelle » liée au contenu de l'image.

Basées sur des analyses statistiques de données, comme l'ACP (Analyse en Composantes Principales), ces méthodes mathématiques permettent de déterminer une matrice de transformation qui, appliquée sur l'image, minimise la corrélation parasite entre les plans.

Bien sur, l'efficacité de telles méthodes dépend du contenu de l'image. Si l'image présente très peu de couleurs (le cas extrême étant une image en niveaux de gris), il est évident que les 3 plans RGB seront fortement corrélés (il s'agit d'une corrélation liée à la nature de l'image).

Une autre approche consiste à exploiter de façon informatique des espaces colorimétriques comme l'espace *Lab* ou *Luv*. Les méthodes d'analyse mises en œuvre montrent en effet que l'intensité de l'image est porteuse du maximum d'information. Dans les espaces *Lab* ou *Luv*, l'intensité est projeté sur un axe indépendant de l'espace de représentation ; les informations colorimétriques sont projetés sur les autres axes, permettant une manipulation indépendante de celles-ci.

Affaiblissement des colorants

En vieillissant les films s'exposent au phénomène de décoloration (dont les causes peuvent être diverses et non exactement identifiées). L'affaiblissement des colorants de l'une des (ou de deux) couches se traduit par l'apparition d'une dominante. Les figures 6 et 7 illustrent l'effet de modèles supposés d'affaiblissement des couleurs sur la courbe caractéristique de la densité en fonction de l'exposition.

Il n'y a pas actuellement de modèle universel d'affaiblissement des colorants, celui-ci dépendant des fabricants, des conditions de développement, de conservation de la pellicule, etc [FRE93, GSB95]

On considère généralement deux modélisations possibles : le premier suppose que le degré d'affaiblissement soit proportionnel à la quantité de colorant (concentration) dans le film ce qui se traduit par un changement de la pente de la courbe caractéristique [BRA81] (illustré figure 6). Le deuxième modèle suppose que l'affaiblissement est uniforme pour toutes les densités et se traduit donc par un décalage des courbes caractéristiques (figure 7).

Une action de recherche associant informaticiens et chimistes sera nécessaire pour progresser sur ce domaine ; il est sans doute nécessaire de disposer de données densitométriques originales des émulsions étudiées (avant que le phénomène d'affaiblissement se fasse sentir).

Il est important de noter que toutes les opérations précédentes s'effectue par calcul matriciel, y compris le modèle d'affaiblissement intégrant un décalage des courbes (matrices de taille 3 x 4) En multipliant les matrices entre elles, on obtient une matrice résultat unique. Une seule opération (donc des besoins faibles en calculs) entre l'image et cette matrice permettra ainsi de corriger l'ensemble des défauts pouvant se cumuler, comme l'équilibrage du scanner, les corrélations parasites, etc…

Restitution des couleurs originales

Evidemment, le modèle d'affaiblissement des colorants est le plus souvent inconnu. Nous expérimentons différentes méthodes pour pallier ce manque d'information. Nous utilisons les deux modèles cités précédemment, et nous essayons d'en déterminer les paramètres.

Des opérations préalables ont permis de supprimer ou de minimiser les corrélations parasites lors du processus de numérisation, l'influence de ces corrélations se faisant particulièrement ressentir lorsque certaines couches sont altérées. Nous supposons alors que les informations numériques contenus dans les plans R,G,B de notre mémoire informatique reflètent correctement les informations réellement présentes sur le film.

L'altération d'une ou de plusieurs couches de notre film ont provoqué un déséquilibre chromatique, mais nous ne disposons ni d'une référence (chartes, coins sensitométriques, éléments de la scène dont la couleur est identifiable, comme certains costumes, etc...) ni de données sur l'affaiblissement des colorants.

Dans un premier temps, nous avons tenté d'équilibrer *de visu* l'image (l'œil averti d'un technicien...), et nous avons apparié de façon informatique zones affaiblies et zones corrigées.
Nous arrivons très rapidement à un système surdéterminé. En effet, en effectuant plus de 3 appariements, le nombre d'équations est plus important que le nombre de variables à déterminer. La résolution d'un système surdéterminé (n>3 appariements (Pi, P'i) non alignés) estime la matrice de transformation M au sens des moindres carrées.
L'opération est linéaire, la matrice ainsi obtenue permet une correction ...; la matrice ainsi déterminée dépendant beaucoup des points choisis pour l'appariement et de la correction « manuelle » entreprise.
Avec le but d'automatiser le processus et/ou d'assister l'opérateur, nous recherchons des méthodes informatiques permettant d'effectuer une balance chromatique. Pour cela, certains éléments de la scène nous intéressent particulièrement comme :

Les zones achromatiques de l'image (quantités plus ou moins égales de R, G et B). On compte exploiter les zones achromatiques denses (ombres) et claires (le problème restant l'identification des objets « blancs »).
La teinte chair, le cas échéant,
Le bleu du ciel, le cas échéant.

Toutes les méthodes exposés précédemment sont des **méthodes linéaires**.

Amélioration de la dynamique de l'image

Après numérisation et correction, la dynamique de la représentation numérique de la (ou des) couche(s) altérée(s) est souvent faible, comme l'illustre l'histogramme figure 8.
Si les opérations décrites précédemment permettent de rétablir partiellement l'équilibrage chromatique, l'image manque de « saturation » et apparaît palote ; la dynamique de l'image numérique doit être rehaussée, notamment pour permettre un passage correct dans l'imageur.

Toujours dans un but d'automatisation ou d'assistance à l'opérateur, on s'intéresse alors aux histogrammes des différents plans. L'histogramme illustre la répartition de la population des pixels sur l'échelle des valeurs possibles (la dynamique).

Il existe deux méthodes assez brutales pour améliorer la dynamique d'une image par manipulation de son histogramme : l'égalisation d'histogramme et l'étirement d'histogramme.

Une égalisation d'histogramme repartit uniformément les probabilités d'apparition d'une valeur numérique donnée (figure 9). Le contraste est rehaussé, La discrétisation de l'espace (256 valeurs possibles pour une numérisation sur 8 bits par plan) provoque l'apparition d'aplats de couleurs. C'est une opération non-linéaire.

Un étirement d'histogramme ne redistribue pas les probabilités, mais porte la dynamique au maximum (ou entre deux seuils). La forme générale de l'histogramme n'est pas modifiée (figure 10). C'est une opération linéaire qui peut être mise sous forme matricielle.

L'usage brut de ces méthodes introduit forcement des déséquilibres chromatiques. **Nos recherches portent sur un usage paramétré de ces techniques**, respectant au niveau des histogrammes un ensemble de points clés, comme la teinte chair, les zones achromatiques, ... Ces points clés seront, dans un premier temps, fixés par un opérateur, mais nous espérons une détermination automatique de ceux-ci dans le futur.
D'autres méthodes de rehaussement de la dynamique (utilisation de notions spatiales pour éviter des aplats de couleur par l'usage de tramage -*dithering*- sont également à l'étude).

Nous n'avons pas encore expérimenté l'usage des espaces colorimétriques comme le *Luv* ou le *Lab* pour cette tâche ; nous avons, pour l'instant, traité les informations plan par plan.

Conclusion

Les compétences du laboratoire L3i dans le domaine du traitement d'image sont appliqués à la restauration des documents cinéma-tographiques depuis 1995. Nos premiers travaux dans le traitement numérique des films couleurs tendent vers la suppression automatique des corrélations parasites induites lors de la numérisation, problème dont l'importance est significative lorsque certaines couches colorées du film sont affaiblies. Puis nous nous efforçons de compenser le vieillissement du film, avec très peu de connaissances *a priori* Enfin, diverses techniques sont étudiées pour augmenter la dynamique de l'image afin de « revigorer » les couleurs après équilibrage.
Afin de mener ces activités de recherche, la collaboration avec les professionnels du film est nécessaire, leur compétence et la disponibilité d'équipement lourds (scanner « cinéma ») étant indispensable. Nous espérons un investissement plus important des fabricants de pellicule et de chimistes dans nos futurs travaux.

Remerciements

Nous remercions la société Centrimage, la CST ainsi que la région Poitou-Charentes pour leur soutien à ces travaux.

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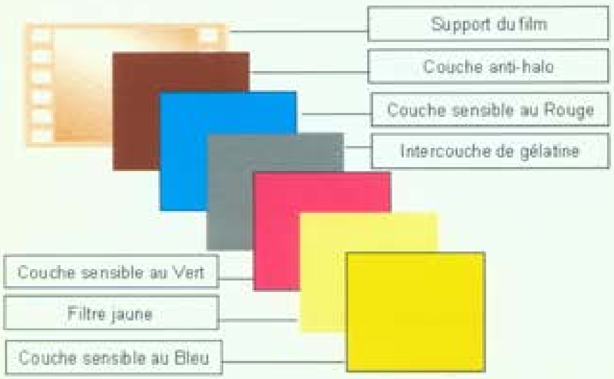
Figure 1: Chaîne de traitement numérique du film



Fiqure 2 : Structure du film

Figure 3 : Mesure spectrales de la lampe et des filtres primaires du scanner Klone de Cintel à l'aide d'un thermocolorimètre Minolta

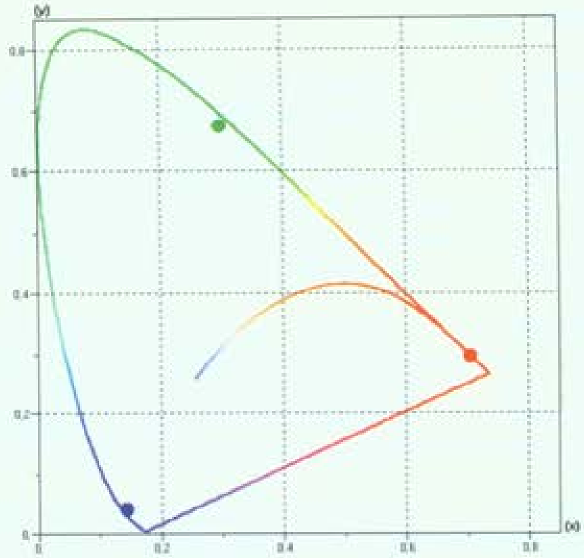


Figure 4 : Illuminants primaires du scanner représentés dans l'espace CIE

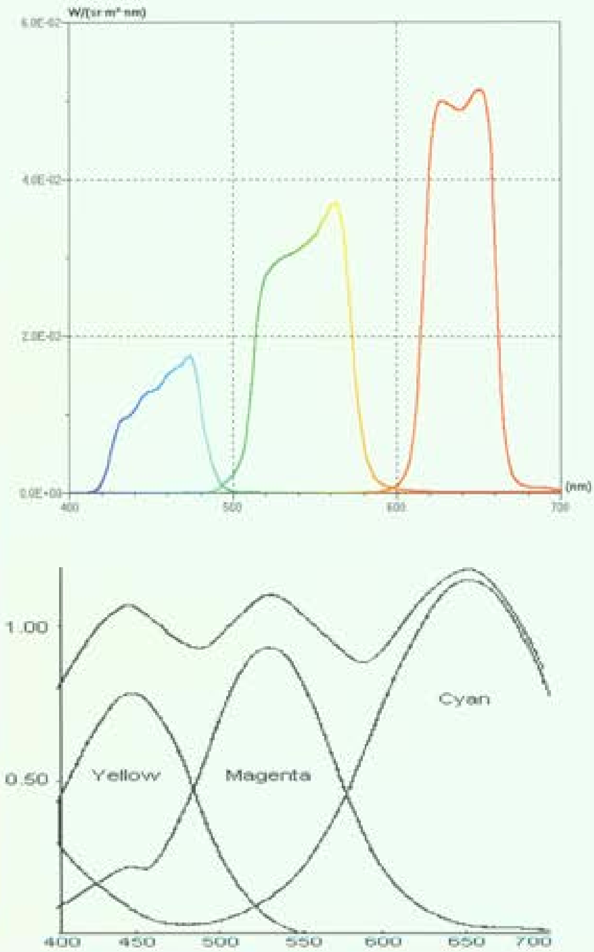


Figure 5 : Spectre d'émission des illuminants primaires du scanner comparé au spectre d'absorption d'un film couleur

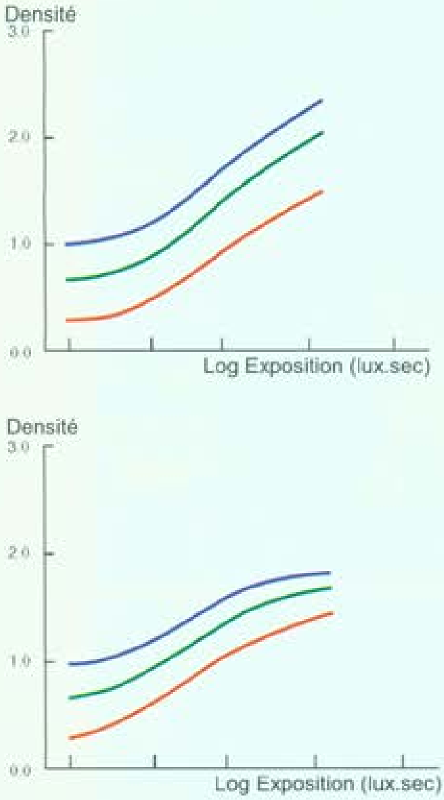


Figure 6 : Modèle de "vieillissement" avec changement de pente

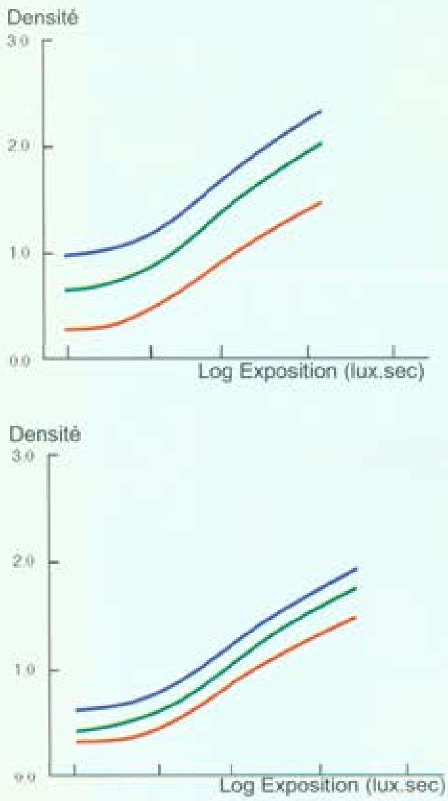


Figure 7 : Modèle de "vieillissement" avec décalage (offset)

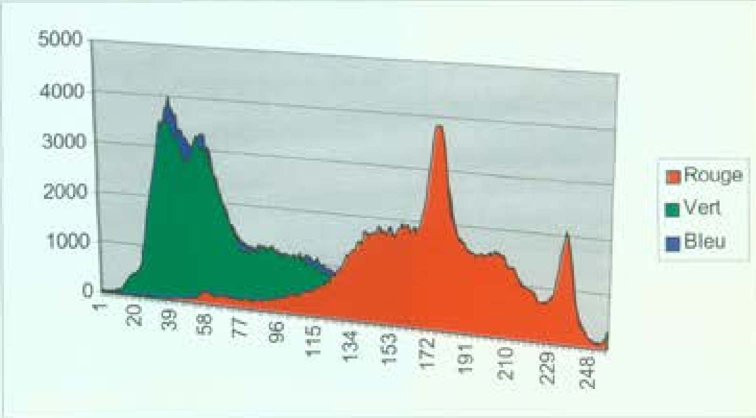


Figure 8 : Histogramme d'une image présentant une forte dominante rougeâtre. La couche cyan étant affaiblie, elle est peu dense (sur le négatif) ; la lumière rouge est donc peu absorbée, et de nombreux pixels de l'image numérique on une valeur de rouge trop élevée.

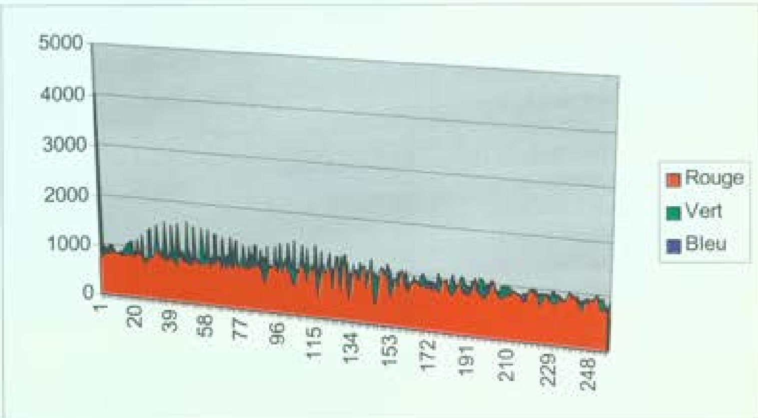


Figure 9 : Egalisation d'histogramme. On fait l'hypothèse que tous les niveaux de la dynamique sont représentés de façon égales

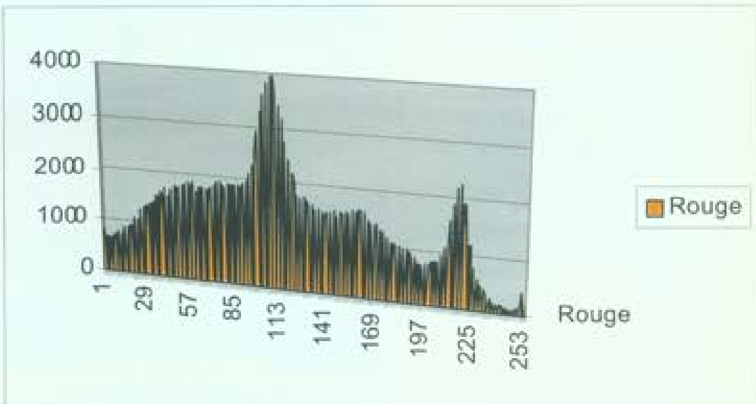


Figure 10 : Etirement d'histogrammme, c'est à dire une augmentation de la dynamique sans modifier la forme générale de l'histogramme

Figure 12 : Image après suppression de corrélations parasites. La dominante s'est encore renforcée ; c'est pourtant un reflet plus exact de l'état des couches du film

Figure 11 : Image brute obtenue après numérisation. Cette image issue de « violettes impériales » montre une dominante verte très marquée. Une mesure au thermocolorimètre a montré que la couche cyan est partiellement altérée, et que la couche jaune a pratiquement disparue.

Figure 13 : Image après suppression des corrélations parasites, corrections partielles du vieillissement supposé du film et redistribution « intelligente » de l'histogramme en vue de renforcer la vivacité des couleurs.

Discussion

Ed ZWANEVELD

It is obvious that your work is extremely important for lower-cost restoration of faded materials. There is clear need for representation of typical fading patterns for the various film stocks. One possible resource is the set of surveys performed by Eastman Kodak amongst motion picture laboratories. These were used to evaluate the processing patterns of different laboratories. If the manufacturers have kept the original plots and typical characteristics of those stocks, they could give you considerable insight into the fading patterns. The results would help us all save time and money. I am delighted to see this type of highly urgent work being accomplished so well. You deserve all of the support you can attract. Good luck.

Bernard BESSERER

Merci pour votre soutien. Il est vrai que, si nous disposons d'échantillons avant/après vieillissement, cela peut nous aider. Comme je le disais à la fin de mon exposé, nous souhaitons collaborer avec des chimistes et avoir des contacts avec des sociétés comme Kodak, Agfa, etc. qui disposent d'un certain nombre d'informations qui ne sont pas publiées (échantillons de vieillissement, mires photographiées avant/après vieillissement...). Le milieu universitaire n'est pas constamment en contact avec le milieu industriel. Je compte bien profiter de manifestations comme ce JTS pour nouer des contacts.

Jean-Louis BIGOURDAN

A la dernière conférence de l'AMIA, lors d'une session du comité de conservation, Patrick Henry qui travaille chez Kodak a fait une présentation. A partir d'échantillons anciens auxquels il avait accès, il a établi des modèles mathématiques du vieillissement naturel. Je vous suggère de venir à une conférence de l'AMIA, qui se déroule chaque année au mois de novembre, pour établir des contacts avec le milieu industriel.

From the floor

I would like to launch a working group within AMIA for all those interested in this specific area. You do not necessarily have to be members of AMIA. Simply write to me so we can offer our support. We all have a number of contacts. Personally, I have worked in Holland, Australia and Hollywood. We might be able to convince manufacturers to work with us.

Jean-Louis BIGOURDAN

Le prochain intervenant, Harald Brandes, est responsable des techniques de préservation et de restauration à la Bundesarchiv en Allemagne. Il va nous parler de l'apport du numérique pour résoudre les problèmes de restauration des films cinématographiques. Harald Brandes est membre de plusieurs commissions techniques, dont la FIAF.

Digitisation : a solution for old, current and new problems in Film restoration?

Harald Brandes
Bundesarchiv - Allemagne

For many film archivists digital tools seems to be dangerous, because using these techniques the images and sounds from the film get seperated from its original media and start a new 'existence' on moreless complicated computer systems. This fear increases when these digitized pictures and sounds should get restorated digitally and layed back onto magnetic tapes or other information carriers.

At the end of my paper I will get back to these fears. To begin my presentation first I want to report from the common praxis in everyday business in the Bundesarchiv.

The Bundesarchiv so far uses digital techniques for several projects of different kind.

The first film we restored in digital ways was the very first German film ever shown in a theatre, the "Wintergartenprogramm" produced by the brothers Skladanowsky in 1895.

This restoration job has already been done in 1994, so it won't meet recent standard technology, the type of scanner used has been an Oxberry scanner which still is the same model today, the related software from Silicon Graphics of course has developed a lot and the film recorder a Solitaire nowadays would be a more modern type, too.

The original film material used to be 63mm film and originally the Skladanowsky brothers produced a 35mm reduction print. In 1994 this material was scanned on the Oxberry scanner with 2750x2000 dots and printed back onto 35mm Dupe Negative with a resolution of 3600X2660 dots.

The reason why we at all treated this material with digital restoration tools was the extremely bad quality of the original material, showing more scratches than image information and the general image steadiness was very bad.

The result is acceptable even by today's standards, anyhow some details would be done in a different way today, especially we would reject the idea of the reanimation of the sequence "Serpentintanz" from 8 remaining stills. In any case the Digital Image Technology was definitely the only technique to improve the quality of the aged and damaged material and gain back some of the impression the sequences originally had.

Example 1 "Serpentintanz" Original

Example 2 "Serpentintanz" one missing frame, computer animated image

No matter what techniques are being used in an archive, archivists and technicians have to respect two fundamental requirements. first: to restore the original shape of any given material. Second: to regain the complete original version of a film the way it once was produced. Restoring film towards its original quality doesn't only become possible since the introduction of Digital Image Processing – the new tools are so powerful that there is a new difficulty: the over-using of digital tools to an extent where you start getting away from the original. Feature film and non feature film material must be restored without changing their original content or the original technical character or 'look'. The more powerful restoration tools become the more responsibility lays on the restoration staff and the archive.

These days the Bundesarchiv is running different digital restoration projects using different technical solutions. Once more there is a project with early film material from the Skladanowsky brothers. As the original format in the archive collection we have some "Reisefilme", this material was produced in 1869. The all in all condition of the material is weak and the picture quality sometimes is very poor. At the end of digital treatment we wish to have a new 35mm material matching the look and quality of the original as much as possible.

It is very well known, that archives are a lot of material with aging and therefor fading colors, so in the Bundesarchiv. Using the high resolution scanner from Oxberry we are currently working on the colour restoration of "Frauen sind doch bessere Diplomaten". The first tests from this restoration project are impressive and we are quite confident to regain the original colour quality at the end of the process printed out on 35mm colour negative. In addition to the Negative we will keep the related digital data.

Example 3 "Frauen sind doch bessere Diplomaten" faded original

Example 4 "Frauen sind doch bessere Diplomaten" restored version

The third project: in co-operation with some private companies we are producing Digital Betacam broadcast tapes from old DEFA films. During this program we finished 295 feature films and non feature films only in 1998 and 1999. Most of these original materials from the former East Germany are in a very bad physical condition full of scratches, dirt, broken perforation and bad splices because the negative materials have been used for a lot of printing processes. Usually these prints are dry prints of course and the print processes back then followed no particular quality specification. Terribly enough also the people were "fulfilling a plan schedule", not thinking of and caring about saving films for the future. Therefor the result today is dramatic: the more important and more ambitious a film of the GDR film production company DEFA was, the more damaged are the according original negatives today and mostly the alternative materials are useless for restoration or not existing at all. Unfortunately the GDR leaders were more interested in the money made with the film material from export sales then in keeping the material under proper conditions.

A high percentage of the materials we are keeping in our vaults, I suppose the situation in other archives is similar for various reasons, are not at all comparable to a new original negative or to a really perfect projection print at least. Beside the damages found in the material when we got them of course we also have to fight against all sorts of problems related to ageing of film material in general: degradation of the film base, colour fading, variation in emulsion densities, which is visible today in strong ensity fluctuations with black-and-white materials, or even more disturbing random colour flicker with colour material.

The effort to eliminate as many of these problems as possible during a printing process is one considerable part of the archive work, but because of the related photographic procedure there are technical limitations. The use of digital restoration offers a whole new range of restoration possibilities, as to be demonstrated with the following examples:

The source film material had a lot of dust and other particles included into the material while printing the title sequence. This problem cannot be solved by any process in a film lab, because the elements are photographically part of the picture and no analogue technique is able to change this. This sequence can only be cleaned by using digital restoration procedures, which are getting available in various requested resolutions today.

Example 6 "Grube Morgenrot"

1a original

2a restored version

Similar to the first example in this film a lot of dust and other particles are printed from the Negative into the following film generations and no traditional laboratory process is able to remove them. By using the digital technique we are getting back the original quality.
To remove artefacts like negative dust or positive dust electronic filter systems like the VS4 or the DVNR (both are electronic filter systems) can be useful to a degree, but additional manual retouching is always necessary in amounts relating to how damaged the film is.

Very often Original Negatives are terribly damaged, some frames are missing and other frames are broken or torn apart. This problem was solved digitally by taking the missed frames from an alternative material that in this case was useless while out of focus. So if the color grading of both materials makes them look as similar as possible, your eye will only notice a very light lack of sharpness during the move, but the scene is represented in original length and move. Using analogue traditional lab technology jobs like this should be extremely difficult, maybe impossible to replace one, two or three frames only. Changing a complete scene would be the common laboratory solution, but using a material which is not in focus, will than lead to another problem: the replaced scenes would be very much visible.

"Goya" was originally a 70mm production and unfortunately we are not keeping the Original Negative. The Master Positive has a very irritating color flicker the result of a bad raw stock and a colour deteriorating process. Problems like this can not be solved by any photographic laboratory technique. A very new and not yet released software is able to solve the problem in an automatic and real time procedure. After processing the film through this tool the images are getting back a reasonable colour stability.

Another example from "Mode in Paris": the nitrate original is a very nice and valuable hand coloured 35mm positive shrunk to a degree of more than 2%. Very often it gets very difficult to print shrunk film material. Even in specialized film-printers transportation and registration pins may cause unsteady images in the new printed film material. Only an additional adaptation of the printer technology may solve the problem, often this is not possible. Once more, using digital restoration tools it is possible to perfectly stabilize unsteady images. In many cases it is possible by using the mentioned filters or it has to be done manually. The result is a steady image.

Similar to the last example this old tinted nitrate has a high shrinkage and it was not possible to print on Internegative Film without steadiness problems.
For test reasons the nitrate was transferred on an Ursa Diamond and it was surprising that the telecine technique without any restoration tool is able to "print" a much more steady picture.

The quality of historic optical sound tracks is often very poor. Depending on the density of the used material as much as the quality of the lab technique itself there are distortions in the more dynamic sections of the sound, very much heard with loud voices or dynamic musical parts. More than that it is always to deal with scratch, dust and dirt which give you a crackling sound that was not part of the recorded sound when the film was produced. A typical example for these very common defects is the optical sound from the film "Das singende klingende Bäumchen". Using analogue technique it is possible to improve the quality a little but much more successful are digital restoration procedures. In three sometimes four complete procedures it is possible to get rid of defects digitally without loosing any of the recorded frequencies or dynamic range of the sound signal. The result must be as near as possible a representation of what was recorded by the artists while making the film.

In reality there is no actual proof for the authenticity of what these results are. In most cases the direct comparison to the original sound is not possible. Anyhow sound restoration is a very common and accepted thing to do these days.
Even in the world of archives the processing, enhancing, the restoration of sound is becoming more and more normal and very rarely there is even checked if original signal was lost, for it just sounds better.
Obviously restoring sound using digital sound processing seems to be less of a problem in terms of restoration ethic?
What is the reason? Is it because sound is not visible, or are people just having more tolerance with their ears than with their eyes?
From the technical point of view there is no difference between sound and image processing. For both, digital image or sound restoration the visible or the audible information is taken away from its original carrier and be brought back to another media, in between being enhanced or cleaned inside a world of digits.

It is impressive to see the results of digital restoration, but most of the examples from today are jobs done in normal television quality, and this resolution is definitely not enough for film archives. Television Archives from this point of view are in a better position today and Television Archives today are already digitizing their analogue collection.
Film archivists are obliged to preserve material with a much higher resolution than TV so film archivists have to wait for the technical possibilities to digitize higher resolution. These are vaguely becoming visible on the technical horizon, High Definition (HD) Technique seems to be a first step into the world of better resolution but still not enough for film archives. First restoration results of new HD software tests are very similar to the results of the today's software for the 625 line television technique.
As a following step film material will be scanned with higher resolutions between 2048 (2K) to 4096 (4K)

pixels. Scanning with 2048 lines is already possible today, in a more or less real-time transfer. The technology for recording these data on tape is making its moves also during the year 2000.
More and more films get produced using the new 'HighDef' Formats, some films even are created inside computers only, look at latest animation movies. This artwork is not using any meter film material anymore even while 'shooting'. Archives are using the same digital technique for restoration purposes. Cinemas are starting to use digital projection, the whole cinema world is about to change, not rapidly but increasingly.
But before Archives are allowed to introduce the digital technique to preserve their film heritage, additional discussions of the new problems coming with the new technique have to be held: like data storage and data compression or the stability of related hard- and software solutions. Different storage systems with or without data reductions for HD systems or 2 K systems are already available, so it may be the right time to start first projects to be able to get first results that can still be compared to the originals, while the originals still exist.
From the point of restoration ethic: is it allowed to use digital carriers for film information instead of film carriers like nitrate, triacetate or polyester? That is a key question and it has to be answered, what is the value of film originals?
Unlike paintings, sculptures or video installations where you can always identify a "real" original, film has always been a duplicated product, aimed to be spread around the country or the world to reach as many people as possible. This is a clear contrast to other fine art products. One exception from film being a mass product can be found in film archives: it is hand coloured nitrate films, they are similar to fine art products, may be stencil coloured material too, therefore both of them should be kept and preserved as film as long as possible.
Film collections stored in film archives are more or less random selections, especially true for the older historical material. The quality of these materials differs from real original negative quality down to junk prints.
Which of these materials now is a valuable one? Which of it deserves the full attention of the archivist? If only an old scratched projection print has survived than that is the last valuable material; if only a 16mm reduction has survived than that is an important original piece of film. Any material which is archived could be a potential valuable original again and which of these has to be stored and protected for eternity?
Many film archivists do think that original negatives and prints of these negatives are the only really important materials and any print thereof is just a compromise. If this is a correct approach other materials and digitizing cannot be a means of processing image and film material at all. Digital technology strips the film- information completely off its original medium, so if the carrier medium is what makes the film precious, you cannot evolve to other technologies at all.
If digital technology is used for restoration purposes, is this already a violation against the "ethics" of restoration?
Actually we do use every day restoration practice being against this strict preserving of the originals: in the early thirties magnetic tape material for sound processing did not exist. Today all archives use this material to improve the sound quality, even for the first films originally made with optical sound –a violation against restoration ethic?
A modern optical sound camera is a digital one, all new sound negatives are exposed in such cameras and the optical sound track is formed or written in a totally different technique than sound tracks in all old cameras –a violation against our ethics?
I think what is really important is to keep the original **information**, the artwork of acting, directing, captured realities in documentary, the art of filmmaking itself during the decades of cinema. Whatever type of medium it is stored upon, be it nitrate film, triacetate film or polyester. The preserved information, the filmed information has to be stored and handed over to the following generations. As I do stress the importance of the film information rather than the medium, I have no fears converting analogue film images into digital data, as long as it's done with respect for the archivists obligation and the film itself.
What is my conclusion? Digital technology is a chance for film archives, first of all for restoration purposes but very careful for other areas of applications too.

My thanks are to the DEFA Stiftung for letting me use the film material for the shown examples a well as to ALPHA-OMEGA for the demonstrated technical restoration work in picture and sound.

Discussion

De la salle

Est-ce que, pour la restitution des couleurs, vous vous fondez sur des archives concernant le tournage des films (photographies prises sur le tournage, costumes portés par les acteurs) ?

Harald BRANDES

Fortunately, when examining faded-colour prints, we had access to a test shot. It was our base for the colouring.

Ed ZWANEVELD

This question and the preceding one shows how much concern there is over this issue. I do not see why we should not define standards and criteria on resolution and colours. This would allow us to have an idea of what source material looked like originally. I know that laboratories use a variety of techniques. Sometimes, the clients send back our work, claiming that a given colour does not look like it should. This is the result of the patch effect. If we had exact numeric guidelines, our work would be much easier. AMIA has established a working group that is looking into this very matter. Any participants who are connected to the Internet are welcome to contact me for information and to join the working group.

Harald BRANDES

We performed our first test on this material using a bad duplicate negative. We compared the white and black patches from the negative with those of the test shot, and used them to make the necessary corrections. When we repeated the experiment without the test shot, the final colours were very different. We are still struggling with restoration of colour.

Bob CURTIS-JOHNSON

When performing high-resolution film transfer, do you feel that you are doing actual restoration or creating a more aesthetically-pleasing way to look at an artifact? How should this new product be described?

Harald BRANDES

Do you believe that using normal laboratory processes for the timing of the colours is a truly different technique? Do you believe that, in using digital techniques to remove scratches, dust or other artefacts, one works with an entirely different philosophy? I do not see what kind of difference there may be. The same problem exists with sound restoration. When sound first entered the realm of cinema, optical techniques were used. Since that time, we have moved to magnetic tape. Yet that does not necessarily mean that we should use magnetic tape to restore the first film archives.

From the floor

Could you please describe the scanners you used?

Harald BRANDES

We used an Oxberry scanner, whose resolution I already listed.

George BROCK-NANNESTAD

There is a major difference between moving toward digital technology and replacing the source material with digital material. Once an archive is digitised, it can no longer be changed. I believe we should keep both formats on hand.

Harald BRANDES

You are correct in saying that. I never said that the original film should be replaced by digital material. I agree that we must keep both formats. That being said, we would not be able to commercially sell the first film ever made since its quality would appear very poor in comparison to today's movies. It is only normal that an archive attempt to draw profits from the material it has on hand.

Jean-Louis BIGOURDAN

George Brock-Nannestad est bien connu de ce groupe car il a contribué aux JTS depuis 1987. George est diplômé de l'Université technique du Danemark en électronique. C'est une autorité en matière de conservation d'éléments sonores. Il travaille aussi comme consultant sur les brevets au niveau européen. Il a participé à plusieurs projets en Europe et aux Etats-Unis (projet " Audio preservation planning study " subventionné par le US National Endowment for the Humanities). Aujourd'hui, il va nous parler des problèmes de conservation des enregistrements mécaniques.

The Calibration of Audio Replay Equipment for Mechanical Records

George Brock-Nannestad
Preservation Tactics, Denmark

Introduction:

Calibration is an activity undertaken for two reasons

1) when it is desired to work to a specific standard of quality, and
2) 2) when it is desired to have repeatability. The standard that one desires to work to may be set by international supragovernmental agreement, by a group of commercial enterprises or by the acting entity itself. This is the simplest, and this is actually our case 2). It is the simplest, because the standard may be fixed without very much discussion and only the compromises that are acceptable to that one entity.

If we look at the electronics field, calibration used to be a regular activity in the analogue days, in particular with valve or electronic tube equipment due to temperature or performance drift. In the digital age calibration is almost forgotten after the manufacturing stage.

The word calibration is an ancient term and is derived from the arabic *qualib* which refers to the former for a shoe. In French, the term *étalonnage* is used, and etymologically this is closer to the activity undertaken, that of comparing to some reference (akin to the English term *template*). The French term *calibrage* seems to indicate the use of force to obtain a particular dimension or measurement. (FR: calibrer, calibrage, étalon, étalonnage, cale-étalon). It is a concept which has been of extreme importance for the development of our modern life which has become dependent on mass production. Its scientific use was very early in connection with thermometer scales and time-keeping (in acoustics Rudolph Koenig, active 1858-1901), and its first commercial use was in US arms manufacture where it was desired that replacement parts should be able to function instantly rather than being individually adjusted during repairs (Eli Whitney ca. 1800). The greatest success in international standards as the basis for calibration has been the metric system (*Bigourdan 1901*). Calibration is a part of the field of metrology. In the following we shall deal with calibration in connection with sound recordings which are on the interface between acoustics and electronics.

Calibration occurs by means of test signals. For acoustic equipment, the test signal is acoustical, i.e. a signal represented by changes in air pressure. Knowing the high quality of the trained ear, acoustical signals may be of two kinds, *qualitative* and *quantitative*. The qualitative signals will quickly permit some kind of adjustment until "it sounds right" - a good example is the tuning pitch emitted by the oboe of the classical symphony orchestra and the manual tuning of the various instruments - by ear. The earliest test signal for sound recordings was *qualitative*: it was the recitation by Thomas A. Edison of the nursery rhyme "Mary had a little lamb". However, this first line is not relevant and does not indicate that Edison was thinking of his invention as a the birth and childhood of a new product. He needed the second line of the rhyme which says "- its fleece was white as snow". This part provides good information on the high frequency behaviour of his system - as it did in telephone research of the time. The reproduction of the fricatives and the formant of the "ee" provided qualitative information of the quality to be expected.

The *quantitative* signals are more similar to calibration in the electrical world: they represent a value which has to be displayed on a piece of measuring equipment which is itself an order of magnitude better than the calibration tolerance. This last term is also very important, because this is what provides realism to the act of calibration.

If we try to make a status as to the requirements for calibration we have seen that we must have a standard, a means for measurement and a definition of tolerance.

A brief definition of mechanical sound recordings.

Mechanical records represent the signal as deflections of a groove on a time axis on the carrier. The carrier may be linear (e.g. Philips-Miller), spiral shape (disc record) or helical (cylinder). On each time axis, the deflection is perpendicular to it, and two main directions at right angles to the time axis are recognised: perpendicular to the surface of the carrier (Edison-type, hill-and-dale) and in the plane of the surface (Berliner-type). These are ideal conditions; in practice there are deviations, and in particular in the Berliner type there may be a time delay between the two flanks of the groove defining the deflection. In 45/45 stereo the two signals are perpendicular to each other and at 45° and 135° to the surface.

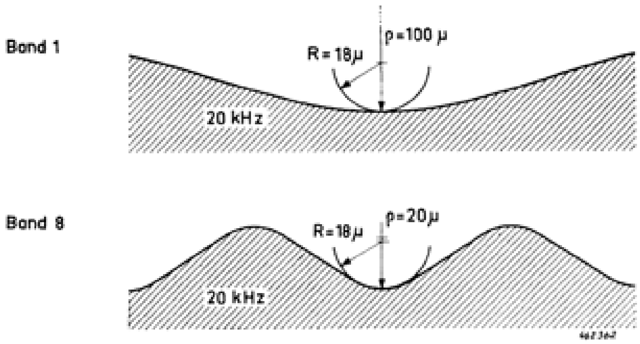


Fig. 1.11. Views in the plane of modulation showing the relative dimensions of the maximum allowed tip radius and the minimum radius of curvature ϱ on the record QR 2009's outer and inner bands presenting a diameter of 28.2 and 12.6 cm respectively at 20 kHz. Note that ϱ is proportional to the square of the diameter D (or of the groove speed). The speed of rotation being 45 r.p.m., i.e. 0.75 r.p.s., the expression for ϱ is

$$\varrho = \frac{\pi (0.75\, D)^2}{2 f v} = 0.88 \frac{D^2}{f v}$$

where f is the frequency and v the peak channel velocity (3.5 cm/s).

Figure 1

The above are all geometrical relations (*Fig. 1*); in the real world the record material (wax, lacquer, celluloid, metal - copper or nickel -, shellac, filled vinyl, unfilled vinyl) has a large influence, dependent on the mechanical "work" that the material has to do during replay.

Fundamental concepts in calibration relating to mechanical sound recordings.

Calibration of a replay system for mechanical records, i.e. a pickup, its cable and its preamplifier is really only measuring the transfer function of the combination and using this measurement for modifying the signal in subsequent stages of amplification and signal processing. However, the normal and practical understanding of the term is to have a transformation from the mechanical to the electrical domain which is transparent, i.e. the total transfer function should be represented by a horizontal line on a graph of amplitude versus frequency. This means that the response of the electrical generator constituted by the pickup and the complex load of the connecting cable should be compensated by inversion of the transfer function in the pre-amplifier (*McProud 1949*). We shall deal with the types of mechanical input to the pickup that are available for use in calibration.

Speed of analogue carrier

The earliest speed reference as such for replay was really a duration reference. This was constituted by two marks on the "back rod" of Edison phonographs, and calibration occurred by adjusting the speed until the time it took for the soundbox assembly to travel between two marks was precisely one minute, indicating that the speed was 160 r.p.m. for two-minute cylinders. *(Frow et al. 1978)*

Tuning pitch or other speed reference in signal

It had been recognised quite early in sound recording that when the sound carrier was rotated at a different speed at reproduction from that at recording, then a transposition of the melody occurred as well as a distortion of the sound, and hence a practice was developed for cylinders that a note from a tuning whistle should be sounded at the start of the recording: a C rather than an A was used. For Gramophone Company disc records only those recorded in Paris 1903-04 used this systematically, well known examples are recordings of la Musique de la Garde Républicaine and of Pablo de Sarasate. The Garde Républicaine are of particular interest, because their tuning pitch was fixed by a decree from their Garde Impériale days to be identical to that of the Opera: a = 870 "Vibrations Doubles" per second (= 435 Hz) (a further brief discussion in section on historical outline). In a brochure giving instruction of the use of vocal records for singing instruction in the home from the Gramophone Company (Deutsche Grammophon?) in 1908 we find the following text: piano adjustment.

Transfer function in the recording-reproducing chain

Transparency means that the chain from electrical input to the record cutting apparatus, via cutting (possibly processing and pressing) and via pick-up and preamplifier must display a transfer function which is a pure constant amplification factor. Obviously the usual limitations in mechanical recording apply, i.e. noise and distortion. However, this requirement means that some specific pre-emphasis in the recording amplifier (the more usual term is "recording characteristic" must be precisely compensated by a de-emphasis in the replay pre-amplifier ("replay characteristic") which is the inverse of the pre-emphasis.

Conversely it means that if we desire to obtain a secondary source in the form of a mechanical record which appears as a replica (physically indistinguishable) of a primary source mechanical record, then the following considerations apply. Even though we do not know anything about the pre-emphasis used when the *primary* source was created, we can still obtain a replica by means of cutting directly from the pick-up output obtained at replay of the primary source. The major requirement will be that the *pre-emphasis* in the cutting amplifier for cutting the secondary source must correspond to the *de-emphasis* in the pre-amplifier for the pick-up (*Brock-Nannestad 1989*).

Splitting the chain

The problems in mechanical reproduction appear because in most cases there is not a direct match between the pre-emphasis and de-emphasis, as commercial recording for reproduction on private gramophones is not conceived as a system. Although standardisation attempted to create a system-like approach to recording and reproduction, it was never completely successful. This is in stark contrast to the in-house standardisation at the British Broadcasting Corporation which permitted them to do things that would be impossible to control in a commercial environment. (*Brock-Nannestad 1997, 1998*). However, this means that in scientific/archival transfer operations, extreme care has to be exercised in spectral correction.

Cutterheads - temperature and ageing dependence

Primitive, non feed-back cutterheads display a transfer function which is dependent on in particular temperature (elastomer used for damping is very temperature dependent). In an acoustic recording set-up in which the horn load on the diaphragm is very important, it is the temperature of the air in the recording room which has the largest influence (apart from the influence of the mechanical impedance of the recording wax). If a feed-back cutterhead is used, the feedback coil feeds back information on the actual velocity that this small coil is subjected to, and this is used for correcting (linearising) the transfer function of the cutterhead itself (*Yenzer 1949*).

Pick-ups - temperature and ageing dependence

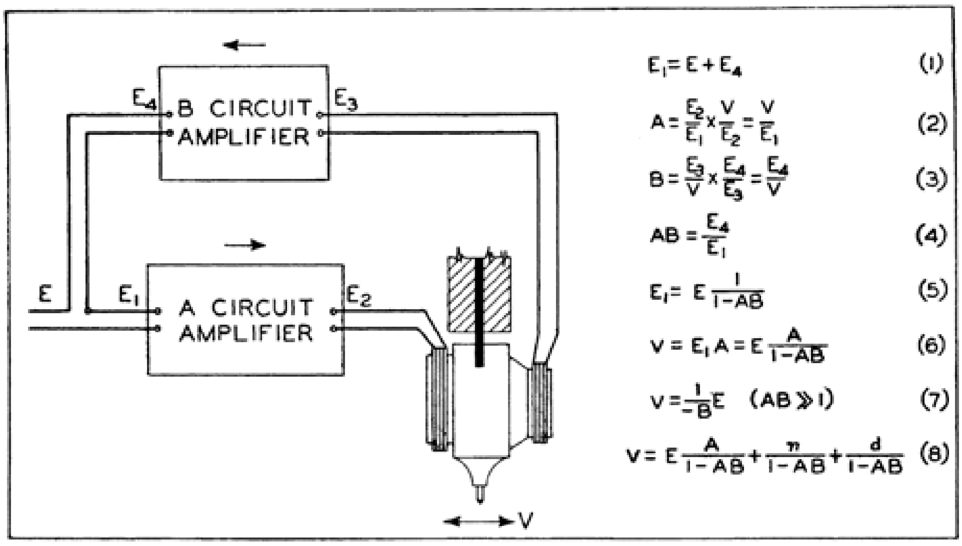
Pick-ups are also very temperature dependent, at least those constructed with an elastomeric bearing. This has the very important implication that any calibration endeavour has to be carried out at the same temperature as the temperature of transfer operation in which this pick-up will be used.

The calibration of the response of a pick-up in dependence of frequency may occur by
using the deflection (amplitude), the velocity, or even the acceleration, since they are easily derivable from each other, provided the frequency considered is known.

Calibration of deflection

The earliest measurements of pick-ups used a vibrator and a variable frequency source to act on the pick-up, and microscope observation of the maximum swing (deflection) of the tip of the stylus enabled an adjustment to a fixed peak-to-peak value of 2x the amplitude determined by means of a graticule in the microscope. This was the desired constant mechanical input over frequency.

Calibration of recorded velocity



Electromechanical feedback system.

Figure 2

If the drive of the pick-up occurs with a vibrator simultaneously driving a coil in a magnetic field, then the output signal of this coil represents the velocity of the vibrator (*Fig. 2*). This velocity may be held constant while the frequency is varied; provided the phasing is correct it may be fed back to the drive amplifier so that the vibrator has velocity feedback (as mentioned above for a cutterhead), i.e. an automatic adjustment for constant velocity. Indeed, using a cutterhead as a drive for pick-up calibration has been performed very efficiently (*Woodward et al. 1953*).

Calibration of acceleration

If the drive of the pick-up occurs with a vibrator simultaneously driving an accelerometer, then the output of this device will provide the instantaneous acceleration of the vibrator. There is really no benefit in calibrating for a constant acceleration with respect to frequency, rather electronic integration is performed in a low pass filter in order to obtain the velocity (*Sørensen 1976*).

Using records as mechanical input signals

Above we have dealt exclusively with vibrators as providing the mechanical driving signal for the pick-up. However, they will not provide a correct response at elevated frequencies, because the mechanical impedance of the drive is very different from the mechanical impedance (a literal construction of the term *driving point impedance*!) that the pick-up will be subjected to when it is used in its correct environment: in contact with a groove on a rotating record. Hence it is imperative that we shall be able to provide the test signals in the form of a mechanical signal from a groove on a record. This is the reason why we need to concern ourselves with calibration discs.

First of all we must realise that the record material (wax, lacquer, metal - copper or nickel- , shellac, filled vinyl, unfilled vinyl) provides the impedance seen by the stylus in the dynamic condition of the relative movement between stylus and record, and only if the elastic limit is not exceeded can we expect it to behave as a complex mechanical impedance. This means that if a pick-up is to be used for the transfer of a record made in a particular material, then the calibration should ideally also occur by means of a calibration record in the same particular material.

Signals on test records, historical outline of test records.

The requirement for test records is obviously related to the use of measuring instruments, because this is the only way that an objective registration of a performance may be made. However, even before the advent of electronic measuring instruments it was possible to apply quality criteria to the record/reproduce process (*Brock-Nannestad 1997a*). The simple unit of measurement was *durability* when sufficient volume and sound quality was obtained at replay. Thus was developed the *qualitative* test record used in conjunction with the quantitative value of the number of replays of sufficient quality. One good example of this is the famed "Melba Distance Test" in which the soprano Nellie Melba who was giving the Gramophone Co. huge problems in reliable recording was enticed to repeat the same phrase a number of times at varying distances from the recording horn (11 May 1910). Other variables were the actual groove profile in combination with the record material and steel needle used: this led to the situation that the Victor Talking Machine Company stated (in July, 1910) that they were recording at 76 rpm but recommended replay at 78 rpm - a true conundrum in source-critical work.

The present writer confesses to not knowing any *early* cylinder recordings made *expressly* for the determination of replay parameters. However, Edison prepared a Diamond Disc dedicated to adjusting the speed of reproduction (Matrix No. 3342-B-7) which was to be used in conjunction with an International Pitch-Pipe - when they sounded the same, the speed was 80 rpm (*Edison*).

The major step forward was taken by the *Reichspostzentralamt* in Berlin who in May, 1929 announced a set of records for use in acoustic and electronic measurement. The intention was not calibration of replay equipment as such, but rather to provide a series of test signals which were useful in the recording of transfer functions of telephones, loudspeakers, transformers, amplifiers, etc., **but** it is stated that the curve for the pick-up must be recorded first in order to obtain a *calibration* curve for the other measurements (*Hilfsmittel*). Hence the awareness was there, although the purpose was not directly aimed at replay equipment. Similar records were made at the Bell Telephone Laboratories and at the major record companies.

Only one known test record has been intended specifically for archive use - again it is a speed calibration record. It is intended for transfer and the obtaining of a secondary source with speed information equally valid to that on the original record, even in transfers to tape. It was developed by the writer in conjunction with the project "Establishment of Objective Criteria For Correct Reproduction of Historical Sound Recordings" (*Brock-Nannestad 1982*).

Qualitative signals

The qualitative signals are meant to be used with the trained ear and are constituted such that errors in reproduction are diagnosable, although not quantifiable. However when, based on experience, the defective part has been identified, it is a simple matter to replace it with a functional part. One example is a "Test for horn rattle" for use in the testing of acoustical gramophones. Important later work has shown that this is a valid approach (*Jacobs et al. 1963*).

Constant frequency

Over the years the reference frequency at which there was no tolerance has developed to be 1000 Hz. For this reason a fixed 1000 Hz tone at the prescribed rpm has been available: a complete side at 78 rpm and a similar time on a side of test tones on an LP record. The early standard DIN 6151 (1943, for commercial 78 rpm records) had prescribed 800 Hz. These frequencies are to be considered as mid-band frequencies, and the performance here gives a first go/non-go indication as well as a possibility to reference all levels to the measurement at 1000 Hz (*Fig. 3*).

Figure 3

Many calibration records were published which had a number of distinct constant frequencies for minimum 20 seconds each, and these were used to obtain fixed points on the transfer function measurement. In a pick-up construction which is not prone to spurious resonances due to ageing or temperature effects this is useful and sufficient time for even manual measurements. Some records have locked grooves, i.e. after a band of constant frequencies has been played, the pickup does not move to the next band but has to be placed manually in it. Other records have a continuous groove with silent intervals or announcements of the frequencies between the signals. Frequently such records both begin and end with bands of 1000 Hz for internal reference purposes (*Fig. 4*).

Figure 4

Sweep frequency

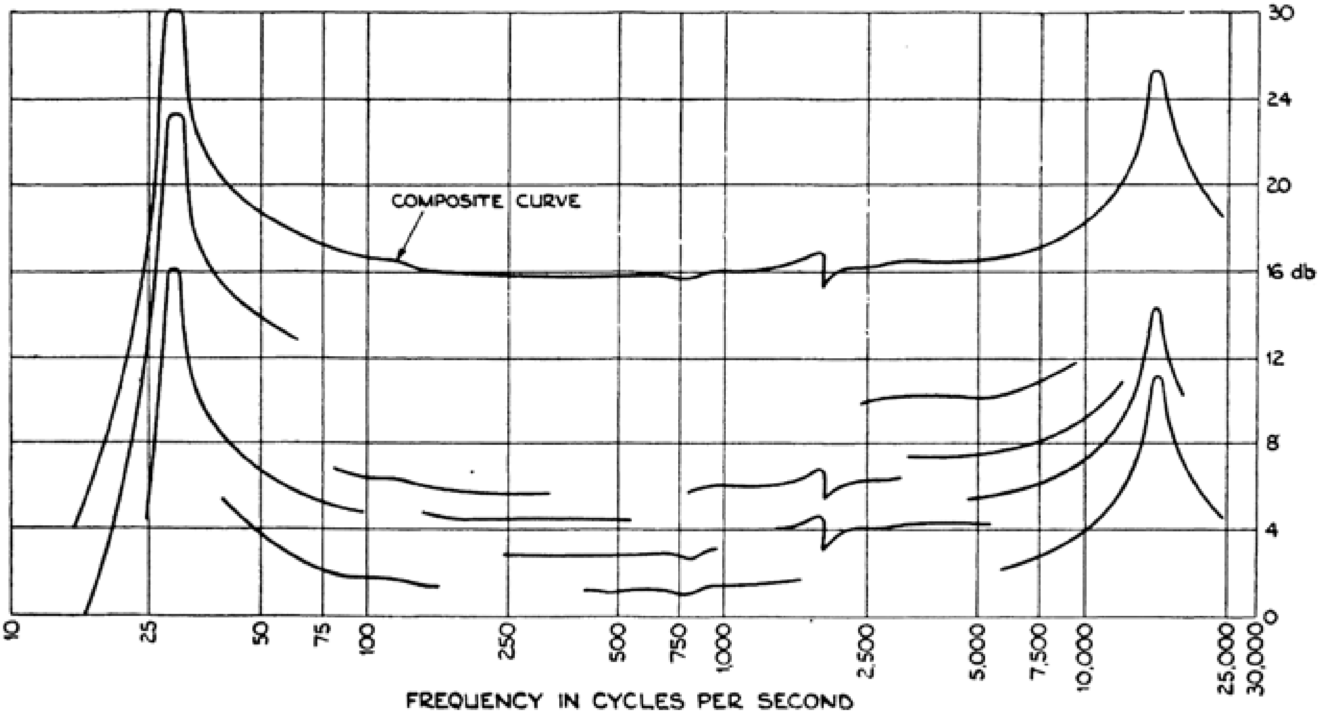
In testing pick-ups for unevennesses in the local frequency response it has become customary to have a sweep of frequencies from the lowest to the highest on a whole or part of a side of a record. This is a continuous and gradual change which - when most practical - follows a logarithmic rule, i.e. the frequency is varying logarithmically with time (*Fig. 5*).

Figure 5

Warble tones

In order to avoid the influence of local resonances in the measurement process and for use with primitive rms measuring instruments there have been available from the earliest times test records with frequency modulated average frequencies - either fixed tone or sweep. The frequency modulation distributes the energy so that local singularities in the frequency response do not get the time to build up a large output at the resonance frequency. This type of signal is mostly used in acoustical measurement because of the danger of having a measurement result obscured by standing waves when using a fixed placement of the measuring microphone.

Extension of the useful range of frequencies



Typical set of pick-up response curves obtained by the variable-disk-speed method

Figure 6

The observation that changing the speed of the record will cause a proportional change in a frequency reproduced from that record has led to a method of testing pick-ups which rely on this phenomenon (*Fig. 6*). The advantage is that a frequency band may be used which does not give any problems with tracing due to short wavelength. The method has the further advantage that the resolution, even with fixed frequency calibration records may be chosen at will, the only need being to compensate for the fact that the apparent recorded velocity at a changed replay speed is proportional to the speed deviation (*Terry 1949*, *Jakobs 1970*).

Modern test records

Alas, there are no such things as modern test records - the technology has been superseded by digital storage, and the last 10 years have seen no new test or calibration record made available to the public. However, with the vast amounts of disc and cylinder recordings worldwide, some of which being in immanent danger of destruction (all instantaneous recordings), there is indeed a need for such records. And it also appears that not only LP (micro-) grooves but also coarse-groove records are needed, because of the need for a good fit between the stylus and the groove.

The Audio Engineering Society has through its Standards Committee taken the initiative to devise a useful set of test records which we expect will mainly be used by archives but potentially also by pick-up manufacturers. The work is undertaken by the Subcommitee numbered SC-03-05 and is two-tiered. At the initiative of Sean Davies of S.W. Davies Ltd. (*Faris 1999*) a mid-1950s test record adhering to IEC-98 will probably be re-issued from original masters, and a new test record containing a useful combination of signals will eventually be cut and processed. Due to the tolerances which have to be below the measuring errors this work is extremely exacting. The other leg has come about at the initiative of the writer (*Brock-Nannestad 1997*), originally conceived in 1989, and is to be a test record with a composite signal containing a mix of frequencies useful for a different approach to transfers in archives.

Multitone signals - the Deliberate Rosetta Tone

A broadband signal is useful as an input to e.g. a pick-up, because it contains energy at a large number of frequencies, and the electrical output of pick-up and pre-amplifier may be spectrum analysed to obtain the transfer function. In this type of measurement, the longer the analyser may average the signals, the better. A granular, non-modulated groove may used as a kind of "white noise" signal which contains all frequencies, however the energy per Hz is low and hence long integration times are necessary (*Brock-Nannestad 1984, 1990*). The writer subsequently realised that it would be possible to generate a composite and repetitive signal with energy at discrete frequencies, and furthermore to distribute the superimposed curve shapes such that the peak-to-average ratio (the crest factor) was sufficiently low to permit tracing of the waveform without undue wear (*Brock-Nannestad 1997*). Such sets of signals have been found (*Boyd 1986, Cabot 1999*). Preliminary mathematical modelling has been performed in order to test for tracking problems. Such problems might appear where the acceleration is maximum (*Fig. 7*).

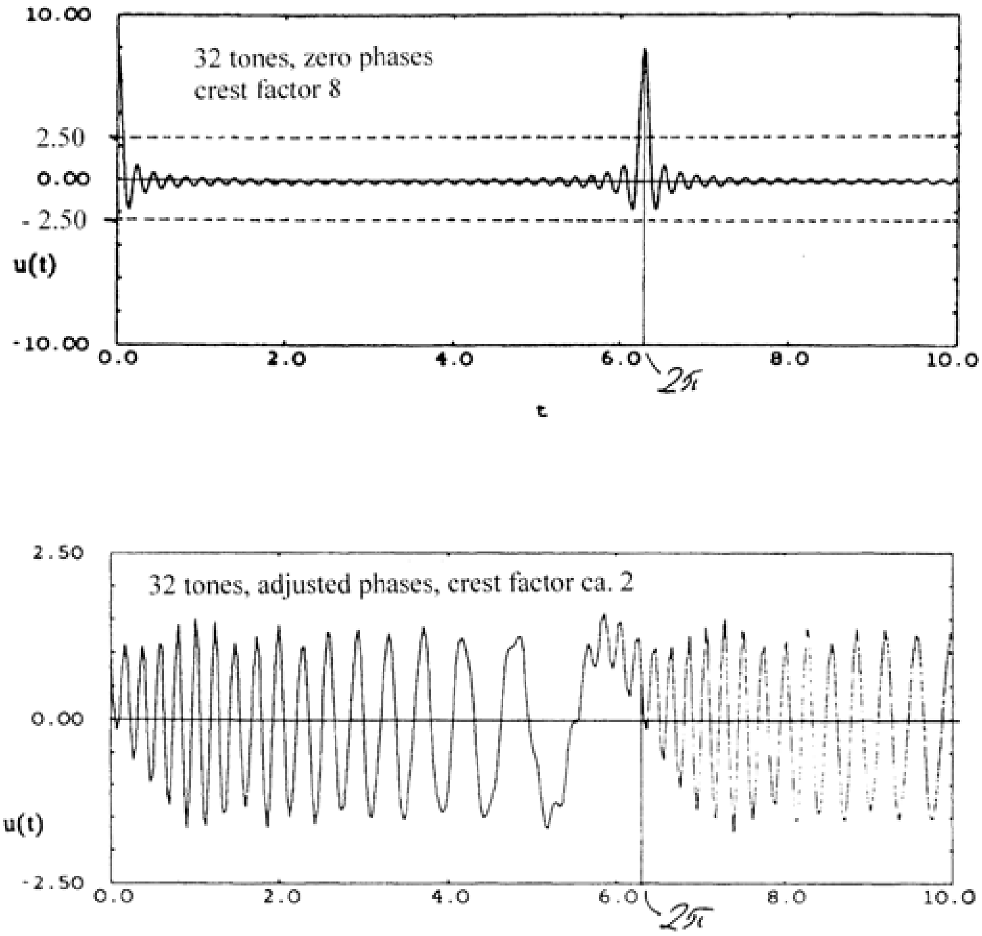
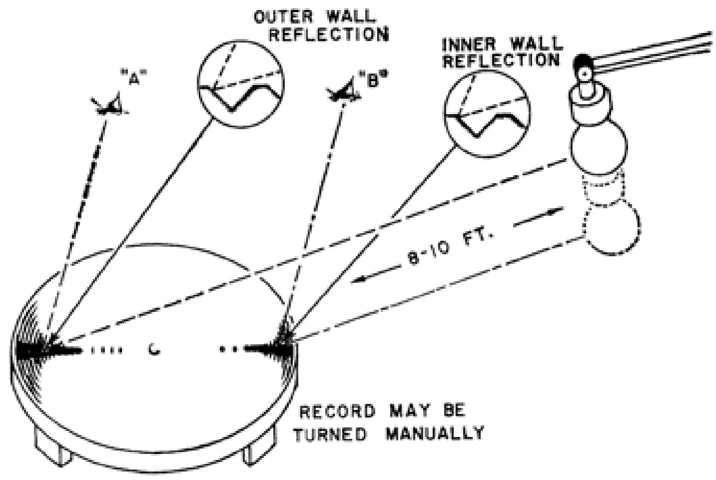


Figure 7

Calibration of the test records themselves (correction curve)

As the test or calibration records are meant to provide a calibration signal, they themselves have to be correct, both as regards stability of frequency and to the recorded level, for instance expressed as a velocity. In the case of banded constant frequency records the stability of frequency and/or speed of rotation may be determined by observing the patterns given to the surface of the record by the regularity of the signal. If both frequency and speed of rotation are constant (as they are meant to be in the case of calibration), then the pattern will display regular, parallel bits of Archimedes' spirals which in some cases degenerate into pure radii. In e.g. a whole record side of 1000 Hz signal the quality will be very apparent.

It was recognized in 1930 by Buchmann and Meyer in Germany that an extremely simple relationship existed between the recorded velocity and a special type of reflection from the surface of the record. This was so simple that it became a standard in the recording industry to measure the recorded velocity or level in terms of the width of the lightband under certain conditions (*Fig. 8*). The method may be refined, and it may provide quite accurate calibration of test records, at least for elevated frequencies. At lower frequencies it may be more expedient to use a measurement microscope (*Standard 1958*). Both procedures are measurements which are performed after the cutting, and if the calibration recording falls outside the tolerances, there is only the possibility to cut another record. This is a fact which makes calibration records more expensive to manufacture than ordinary mechanical records.



Suggested arrangement of apparatus for Light-Pattern Method of calibrating disc records.

Figure 8

Wear of test records

When calibration records become worn, the signal from them also provides energy at frequencies different from the intended - the waveform is distorted. This means that calibration records must be handled with extreme care and that they must be replaced when they cannot perform reliably any longer. This should also be a reminder that whenever experimenting with correct settings of turntable speed and filtering in relation to a mechanical record, it should not occur by a large succession of replays of the record. The responsible archive will make a preliminary and very gentle transfer to another medium and do the experiments on that. It is in connection with this work that the calibration records discussed above will be particularly relevant (*Brock-Nannestad 1982, 1997*).

A note on optical pick-ups

It is relevant to mention the use of optical pick-ups because they are are potentially very useful for archives as they do *not* wear the record during reproduction. Several ingenious devices may be found in the patent literature, most of which have serious drawbacks. In most designs the response is related to the amplitude of the mechanical signal which means that in the case of a constant velocity recording the output falls off proportionally to the frequency. However, even a low upper frequency in the response would at least enable an identification of the recording without wear. Only two systems are currently available. The first is the Japanese ELP Laser Turntable System (*ELP 1995*) which works excellently and with a good high frequency response (due to the geometry of the laser beam) with modern groove profiles (90° between groove walls) and black vinyl or shellac-based records. The other is the Optical Fibre Turntable from École Polytechnique Fédérale de Lausanne (*Poliak et al. 1992*), a design which never had the benefit of moving up from a laboratory prototype. This in effect uses a stylus which is an optical fibre trailing in the groove at ca. 10° to the surface. The advantage is that the fibre is able to bridge the gap in a cracked laquer surface and so will provide a continuous replay.

Use of test records

Label of the QR 2008.

Figure 9

The known sets of calibration records came with extensive instructions for their use, and hence this is not the place to give precise details (*Fig. 9*). It is, however, intended that the documentation for the new AES SC-03-05 development will include such material and instructions.

In general terms, the application of test records means to select a test record which corresponds to the speed, groove dimensions and material of the records to be reproduced. The present brief discussion concerns the most primitive use of a calibration record with bands of fixed frequency, and it relates to techniques which were available from 1929. The groove dimensions determine the dimension of stylus to use, and if a moving-magnet system is used, this means that the front end or stylus assembly must be selected. If a moving-coil system is used, then usually the whole pick-up must be selected. The calibration record is put on the turntable, the level of pre-amplification selected is noted, and the output voltage from the pre-amplifier is noted for each band of frequencies. The values are plotted in dB on graph paper with a logarithmic frequency axis, and when the points are connected, the overall transfer function has been obtained. It must be noted, however, that resonances or anti-resonances which fall between the fixed frequencies are not determined in this way. It is quite feasible to automatise this type of measurement, and obviously modern measuring equipment does just this.

One simple but vital use of test records is a test for malfunction. It must be determined immediately if a pick-up begins to deliver distorted signals, because this compromises any later work with the transferred sound.

A provocative question in conclusion: - do we need calibration?

It depends on the intended use of the transfer. Calibration is essential for the reconstruction of authenticity. If we decide that this will never be an issue, that we do not wish to give this option to future users, then we can omit calibration and just test for outright malfunction. Looking at transfer work generally performed in busy archives we must admit: no, in most cases they do not perform calibration of mechanical replay. This is because it is time-consuming. But we do need checks for malfunction.

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Illustrations:

Fig. 1 An illustration of the geometrical relationship between a spherical stylus and one groove wall representing 20 kHz close to the edge of the record and near the centre, respectively (from *Brüel & Kjær 1965, Fig. 1.11*).

Fig. 2 Obtaining the instantaneous voltage E_3 when calibrating by means of a vibrator (from *Yenzer 1949, Fig. 1*)

Fig. 3 Label of ORTOFON 1 kHz record (ca. 1960). Note that zero level is set at 8 cm/s stylus velocity corresponding to 20mm light-bandwidth at 78 (77.9) r.p.m.

Fig. 4 Label of DECCA Constant Frequency Record No. 1 (ca. 1945). Note information on level at the various constant frequencies at 77.9 r.p.m., indicating the pre-emphasis used and the possibility of indicating how many times the record has been used.

Fig. 5 Label of DECCA ffrr Characteristic Gliding Tone Record No. K.1802 (ca. 1949). Note that the gliding tone is interrupted for every kHz to indicate which frequency is provided at 77.9 r.p.m.

Fig. 6 Calibrating by means of the variable-disk-speed method (from *Terry 1949, Fig. 1*)

Fig. 7 A multitone signal for parallel measurement of several test frequencies by means of spectral analysis. The phase relationship between the tones determines the peakyness of the signal. Zero start phase concentrates the energy in bursts which is not a good waveshape for a mechanical recording. Phase adjustment distributes the energy everywhere in the groove, yet provides all the test frequencies. Note that the lower trace is magnified 4x in the ordinate (From *Boyd 1986, Figs. 1a and 6a*).

Fig. 8 Calibrating by means of the light-bandwidth method (from *Standard 1958, Fig. 3*)

Fig. 9 Label of Brüel & Kjær Type QR2008 Pick-up Test Record (33 1/3 r.p.m.). A highly professional set of test records devised to test stereo pick-ups, including orientation and determination of correct stylus pressure (from *Brüel & Kjær 1965, Fig. 1.6*).

Discussion

Pierre BOUCAN

Nous parlions d'Internet tout à l'heure. Je signale l'existence d'un site de collectionneurs de rouleaux de phonographes. Ces collectionneurs reconstruisent des machines modernes pour pouvoir lire ces rouleaux, y compris des machines complexes avec lecteur optique. Je vous donnerai les références de ce site.

George BROCK-NANNESTAD

Je sais que cela existe. Mais ce que nous voulons, c'est pouvoir étalonner les enregistrements. La lecture des cylindres est très difficile aujourd'hui. Les enregistrements ont tous été acoustiques. Je voudrais poser une question aux représentants des archives qui se trouvent dans la salle. Y a-t-il un marché pour des disques semblables à ceux que nous avons développés dans l'AES et qui ne sont pas trop chers ? Que ceux qui seraient intéressés lèvent la main ? Ce n'est pas mal, et ce n'est rien que pour la France. Manifestement, les professionnels de l'AES ne sont pas les seuls intéressés par ce type de disques, les archivistes aussi.

Jean-Louis BIGOURDAN

Nous allons nous intéresser maintenant aux enregistrements magnétiques. Adam Lee est membre de la commission de documentation de la FIAF et chef de projet d'archives à la BBC. Ce projet est doté d'un important budget. Pouvez-vous nous en donner le montant ?

Adam LEE

Le coût du projet est estimé à 60 millions de livres (90 millions d'euros) sur dix ans.

Jean-Louis BIGOURDAN

Adam Lee sera associé pour cet exposé à Allan King, qui travaille à la BBC depuis trente ans et qui est aussi chef de projet. Adam Lee et Allan King répondront à la question : comment aborder la conservation des 61 000 vidéos format U-Matic que la BBC a produites entre 1980 et 1988 ?

U-Matic Preservation

Adam Lee, Richard Prytherch, Allan King
British Broadcasting Corporation - UK

Background

The BBC has one of the largest audio-visual or multimedia collections in the world. During its 75 year history the BBC has created extensive archives of many different media types. For example, in broad figures the collection consists of:

- 1.5 million items of film & VT: 600,000 hours
- 750,000 audio recordings: 300,000 hours
- 3 million photographs
- 1.2 million commercial recordings
- 4.5 million items of sheet music
- 500,000 phonetic pronunciations
- 22.5 million newspaper cuttings
- 550,000 document files
- 20,000 rolls of microfilm

Most of this material is stored on formats which have a finite life.

The BBC has the typical three way attack on the integrity of its archive.

- Deteriorating physical holdings
- Obsolescent machinery to replay much of it
- Shortage of suitably skilled technicians

Funding preservation projects is the other key issue. The BBC estimates it needs to spend approximately £60 million over ten years to preserve the most important parts of the collection.

Archive Usage

The main driver for the preservation of this material is the very high rate of re-use. For example, for Television material, 25% of the holdings for any given year are used for research or re-use per annum. Across all of the collections, the BBC Archive delivers:

- 1 million transactions per annum
- 0.6 million enquiries per annum

The users of the archive are:

- Programme makers 70%
- News 20%
- Commercial 6%
- Others 4%

This is a working archive which has to be responsive to the changes in demands from customers. These customers want easier access to the material, greater depth in cataloguing and material delivered on formats which can be easily used.

Preservation: Progress

The BBC has begun a number of strands of work relating to Preservation. Specific formats have been identified as requiring urgent attention - because of physical deterioration or vulnerability. The main work strands at the moment are:

- Quad - Transfer of 46,000 tapes completed
- C Format - Transfer underway
- Sep Mag - Transfer underway
- Ekta/Reversal Film - Transfer underway
- Audio: Radio - Transfer underway of 14,000 hours of pop music
- Umatic - Pilot transfer nearing completion

The Umatic preservation work at the BBC is a pilot transfer. Umatic accounts for only 4% of the total television archive but it contains the key news stories for the 1980's.

History

During the 1970's newsgathering in the BBC was on 16 mm reversal colour film. Electronic capture was not viable, the physical size of the equipment required and quality being the main factors. This changed in the 1980's with the introduction of the U-matic format and electronic means of capture replaced film very quickly. Editing of the captured material into news stories for transmission was also carried out on U-matic. The BBC archive currently holds about 61,000 Umatic videotapes which represents the output of BBC News from the end of 1982 to the end of 1988 at which time the format in use quickly changed over to BetaSP. It is these edited transmitted news stories which this preservation project has been examining.

Project Aims

The aim of the project is to transfer material from a number of days, approximately 200, to a digital format which would meet the future requirements of both the Archive and its customers.

The proposal was to produce one DVCPRO tape copy which would be the lending copy for customer use and one compressed digital data copy at 'Broadcast News Quality'.

All the problems encountered during this process would be examined,

this includes:

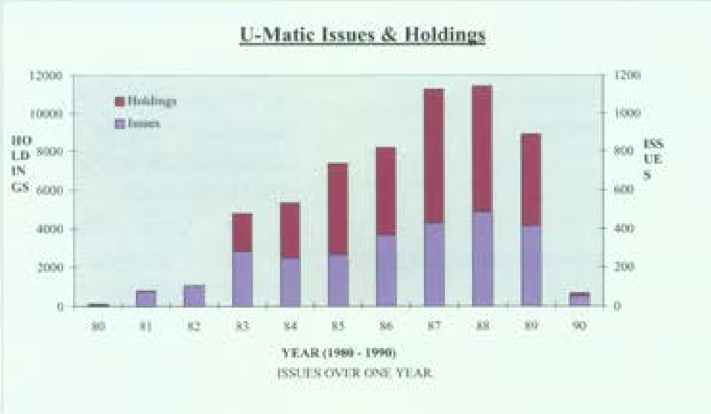
- Analysis of the data held on the Library Database.
- Technical difficulties
- Various methods of transfer i.e. single transfer, compilation or both.

Compression data rates

Usage

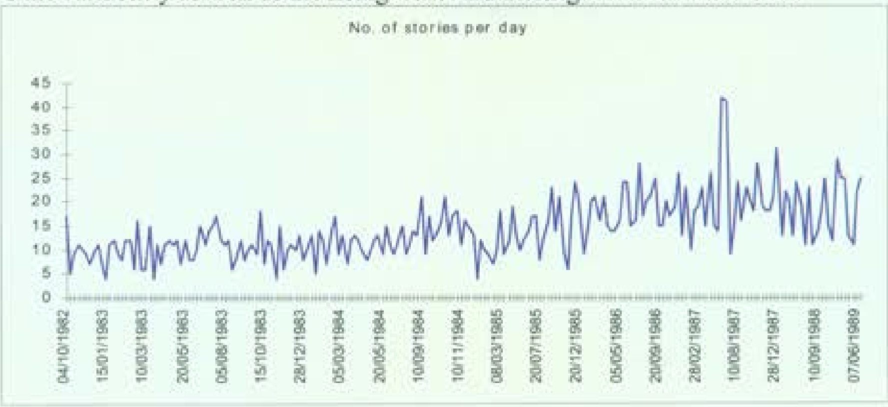
It can be shown that usage of news material is at a maximum during its early life and slowly declines as the weeks and then the years pass. As a result of storage limitations news material was held near the transmission facilities for the first 5 years of its life to allow for rapid access. Storage environmental conditions did not feature highly during this period.

Use of material after this period is as one would expect unpredictable and determined by events. It is also determined by its accessibility. This is of major importance in regional re-use but then accessibility of archive material is not confined to news footage although it may be more easily delivered. Shown below is the U-matic holdings by year of transmission, and the issues over 1998 also by year of transmission.



Current Holdings

The first U-matic recording that the Archive has listed in its holdings occurs on the 4th October 1982. BetaSP recordings begin to take over towards the end of 1989. The number of stories per day varies considerable but in general increases towards the end of its life. The graph below plots the number of recordings per day for the 200 days transferred during the project to date shows the variability as well as the rising trend and the slight fall towards 1989.



The duration of the stories varies enormously, from the 2800 recordings made to date the shortest is 8 secs, the longest 18 mins but most fall between 30 secs and 2 mins. The average duration is 1 min 20 secs
In addition to these single stories detailed above most days have compilation tapes which in addition to other stories may or may not include some of the single stories. These compilation tapes have not been included in this transfer process. A few have been examined but the complications involved without the assistance of a Librarian are considered too time consuming.

Transfer Process

The process involves all Library and technical functions.

LIBRARY FUNCTIONS

Selection/ ordering/ delivery

This involves using a number of the Library database functions. It is at this stage that some of the discrepancies between catalogue entries and actual holdings come to light. Complication arise in the way catalogue entries may refer to another tape when stories are similar but listings may exclude them. Any discrepancy found during the transfer process was noted, even though later detailed examination by a librarian may decide otherwise. Tapes were ordered, taken from the store and delivered to the transfer area.

Intake

Accession numbers were issued for the newly created material which were then added to the holdings screens on the database. All original U-matic material was returned to the stores.

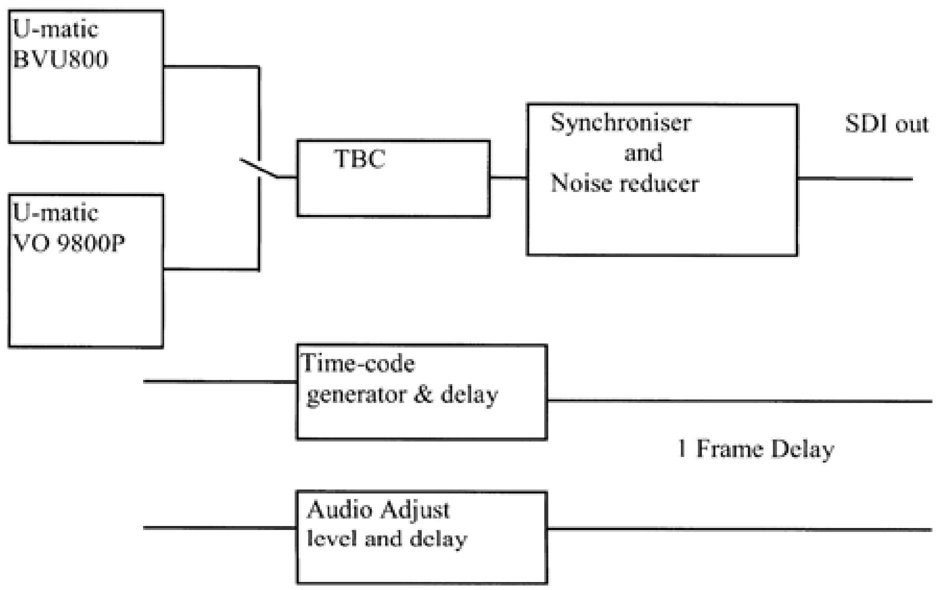
TECHNICAL FUNCTIONS

Assessment of both the replay and recording processes was required.

Replay

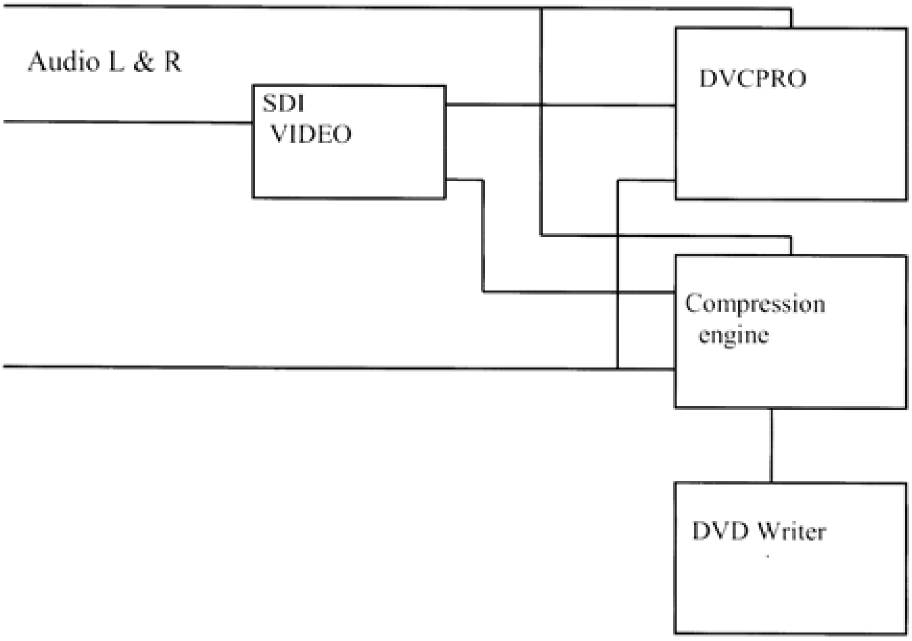
The U-matic tapes as they came out of the box were an unknown quantity.
Where was the recording? It could be anywhere on the tape. The tapes were used many times and it was common practice to use different sections on each occasion.
How dirty was it? Would it clog? Its storage history was unknown.
Was time code present? The compression system requires code to be present.
Was the RF of such a level to recover the signal?
What was the picture quality like? Was noise reduction systems required?
What Audio was present and at what level?

A schematic of the replay system is shown below:-



Recording

Videotape recording principles are well established so few difficulties were expected in making the DVCPRO. Making the MPEG2 data stream needed to be handled with care. These recordings are to be the Archive masters so the quality / storage needed to be established



Replay Analysis

Of the 2800 tapes transferred to date, it was necessary to make technical comments on 1322 of them. The types of comments recorded are:

Recording location: this was not a problem only a small number require a search.

Stories missing: 38 of these are stories listed in the catalogue where we have no holdings.

Stories not transferred: 20 these are stories which were, at this stage, unrecoverable.

Stories without or intermittent timecode: 262 timecode was re-laid.

Audio levels incorrect: Most tapes had high audio levels, a few were low. The range of adjustment was –12dbs t0 +12dbs

Dirty tapes requiring cleaning: surprisingly cleaning was not often required. It was often quicker to clean the video heads following a head clog.

Head clogs: this happened frequently, on a few occasions even cleaning the tapes was ineffective, indeed, some tapes even stalled in the cleaner.

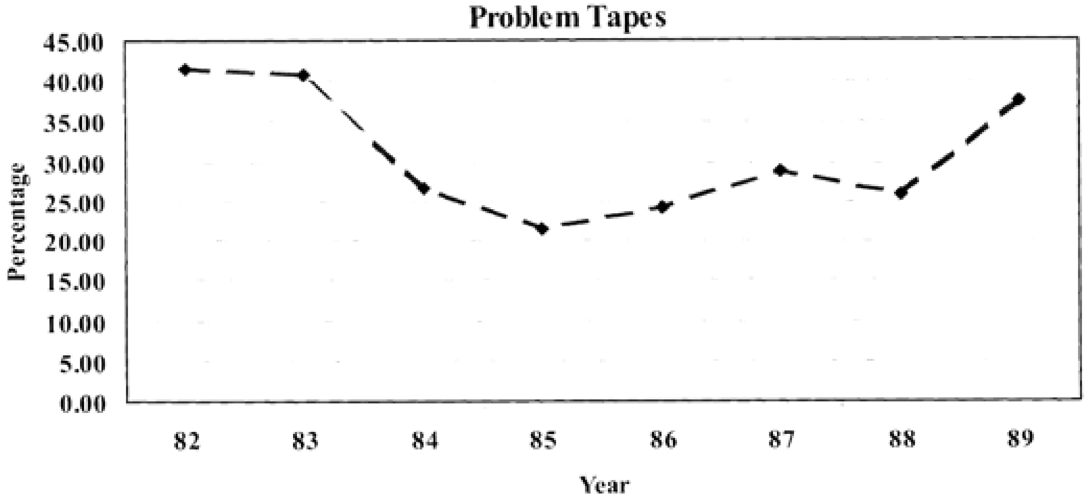
Low rf: this was a common problem which the VO9800P couldn't handle. Fortunately the BVU800 could.

Over deviation: present in varying degrees. A few severe cases.

Tracking errors: a small number required correction.

Noisy/ poor quality pictures: A NRS50 was permanently in circuit with a small amount of recursive noise filtering. On occasions it was necessary to increase the amount of filtering. Often it was a compromise, noise reduction against introducing unwanted artefacts

Catalogue Discrepancies: As stated above some of the discrepancies came to light when selecting the tapes for transfer. However, a few only became apparent during the transfer process, examples are timing differences, stories incorrectly identified, and extra stories existing on the tape which have nothing to do with the catalogued item. From the 2800 recordings transferred to date 358 stories fell into this category, 12.4%. Not all may be a problem but further investigation by a Librarian is likely to be required.



Underlying Data

Total number of tapes transferred 2987

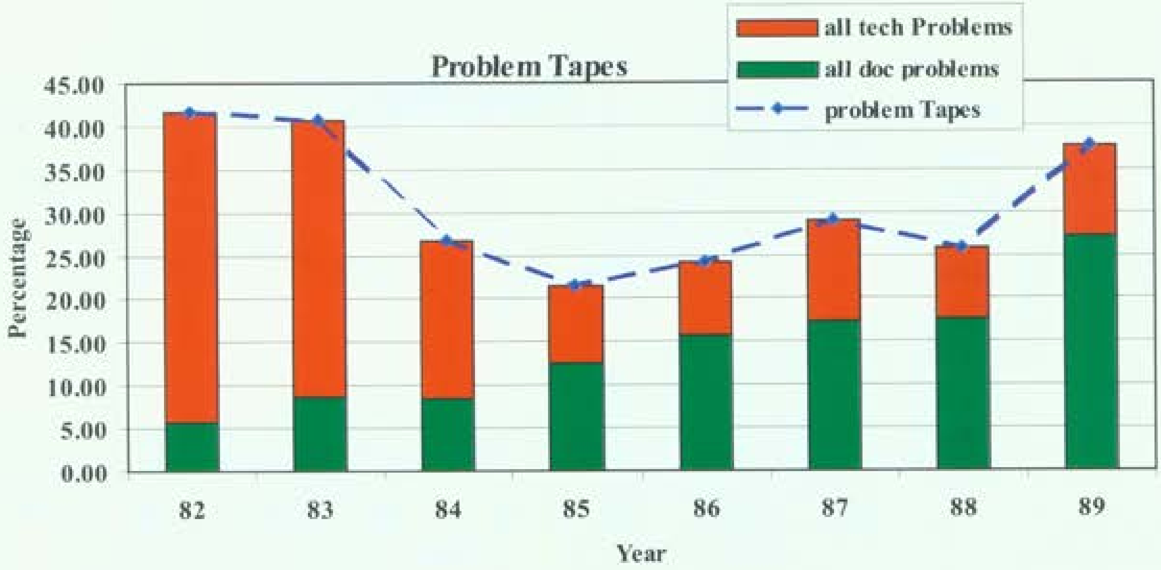
Year	No of days	Total Tapes	Total Problems	% Problems
82	9	89	37	41.57
83	55	533	217	40.71
84	48	595	159	26.72
85	29	397	85	21.41
86	26	462	112	24.24
87	26	519	150	28.9
88	13	228	59	25.88
89	8	162	61	37.65

The project began by transferring the first day that U-matics appeared in our records which is the 4th October 1982. The limit for the end of the period was when BetaSP tapes begin to outnumber U-matics and this occurs about August 1989.

A selection of days within this date range was chosen at random.

A problem is defined as a difficulty, for whatever reason, that prevents the U-matic recording being transferred at the first attempt. It may be as simple as adjusting the audio levels or as difficult as multiple attempts and then aborting the recording because of the tape being so sticky, it stalls the replay machine.

The graph below shows the total number of technical and documentary problems as a percentage of the number of tapes transferred for each year.



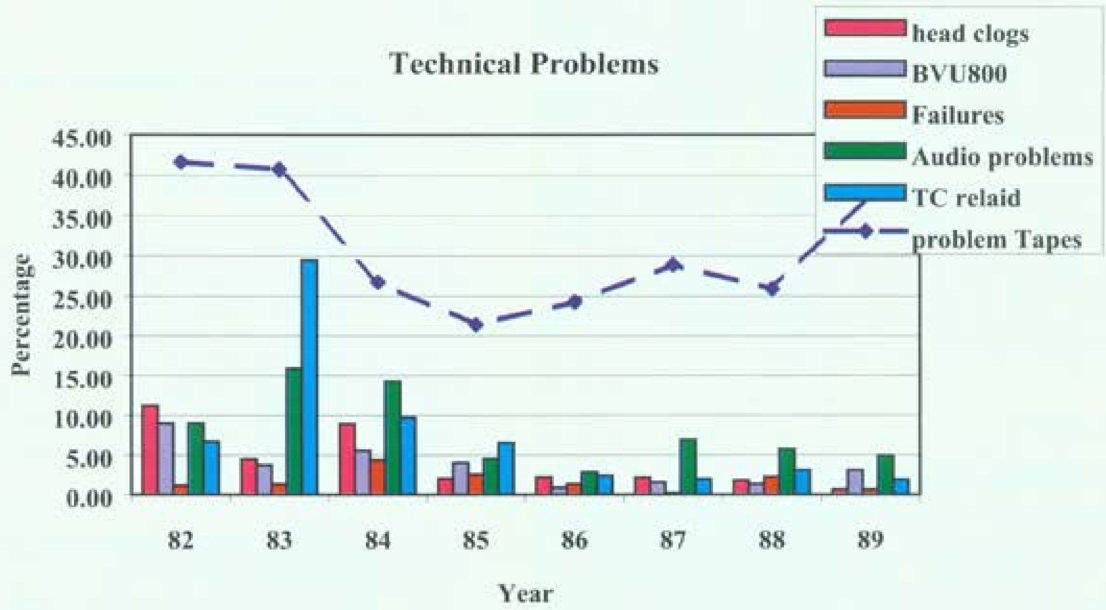
The data associated with the above graph is shown below:

Total number of tapes transferred 2987

Year	No of days	Total Tapes	Total Problems	Documentation Problems	Technical Problems
82	9	89	37	5	32
83	55	533	217	46	171
84	48	595	159	50	109
85	29	397	85	50	35
86	26	462	112	73	39
87	26	519	150	90	60
88	13	228	59	40	19
89	8	162	61	44	17

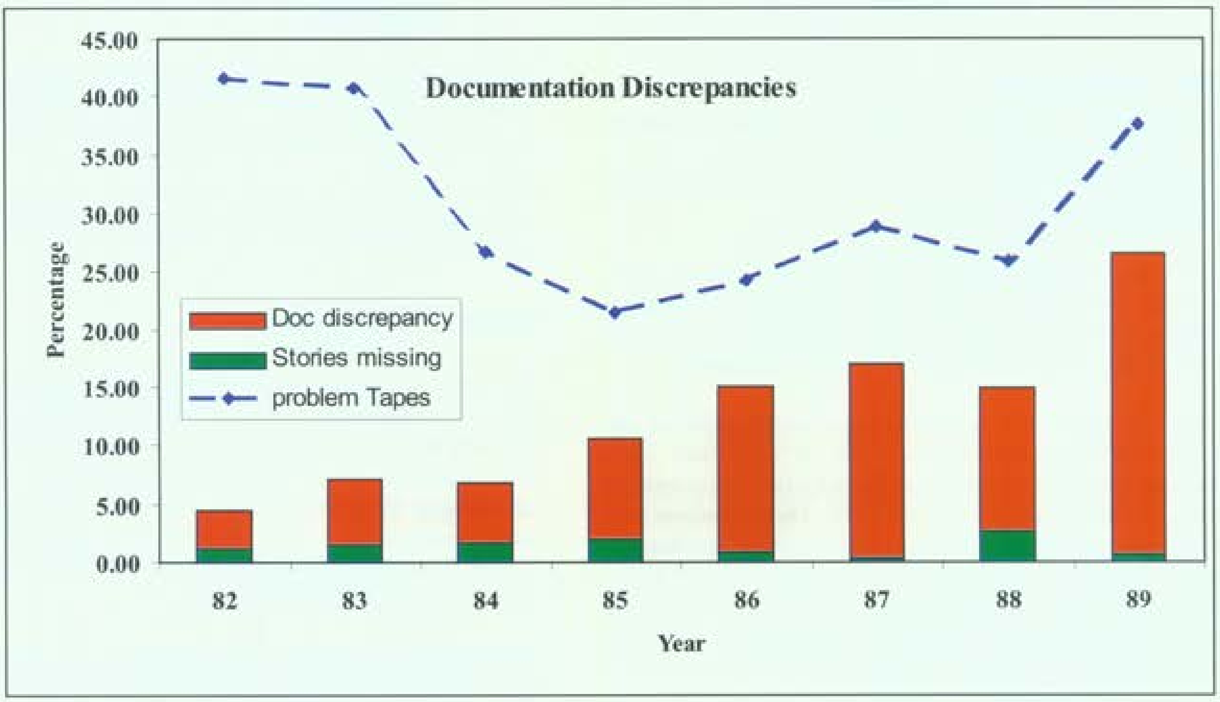
Technical Problems

The technical problems are shown in the graph below. It is interesting to note that the transfer technical difficulties are high for the first 3 years of news coverage and then are fairly constant.



Documentation Problems

The documentation problems are shown in the graph below. The errors increase with time, this may well be down to the sheer volume of tapes being handled.



Observations:
It is quite clear from the results so far that most tapes are recoverable, less than 1% are not. These usually fail catastrophically, so sticky the cassette won't turn or they stall in the machine, often damage to the tape resulting. 47% of all the recordings required attention and many needed multiple attempts before a successful transfer was achieved.
The VO9800P is an easy machine to use. The threading mechanism is simple and the head drum is easily accessible. Its controls are also responsive.
The BVU800 gives better results from some tapes. Its controls are not responsive and the threading mechanism, which occasional fails, is a nightmare.

RECORDING

The Videotape lending copy

It became clear very early in the project that the best way forward was to copy each story to a separate DVCPRO. It was operationally straightforward avoiding the complications of compiling, no time-code or editing problems. One of the most compelling reasons is that it avoided any major changes to the catalogue. Compiling could also introduce difficulties when servicing the needs of our customers. The down side was more tapes than strictly necessary on the shelves.

The Archive Copy

Investigation was carried out before the project began into the systems available
for creating compressed recordings at a quality which was suitable for Archive purposes.

Since the U-Matic material was mainly "news quality" , and the bandwidth of the U-matic Masters is limited to approximately 3.5 MHz, initial thoughts were that the DVD video standard may provide sufficient quality.

Many of the DVD mastering systems available at that time (September 98) were limited in what they could deliver. However the Minerva and Digital Vision systems both offered bit rates up to 15 Mb/s. These systems were evaluated and although there were teething problems, a series of tests using single pass fixed rate MPEG 2 encoding at up to a video bit rate of 12 Mb/s were made. These showed that on "difficult" material the compression artefacts were still clearly visible.

There then followed a search for a compression engine to capable of producing MPEG 2 programme files at higher bit rates. The system chosen for the pilot was made by VELA which enabled MPEG2 files to be created up to 50Mb/s in 4:2:2 mode.

The choice of bit rate was therefore a balance between quality and overall cost taking into account the following factors:

- The visibility of compression artefacts
- Future usage
- Equipment costs
- Storage media costs

The DVD data format permitted delivery of 22Mb/s and this was therefore our maximum desired data rate. Lower rates were tried, in 2Mb/s steps down to 10Mb/s but the macro blocks became objectionable at the lower rates. Recompression of the lower rates was unacceptable.
As a result of these experiments it was concluded that an MPEG 2 program stream of 22Mb/s, 18.5Mb/s vision, 340kb/s audio would be made and recorded on DVD as a data file.

This could be classified as a conservative choice, however two factors influenced the decision:

- The increased cost of 18 Mb/s is negligible compared with the overall transfer cost
- As an archive copy, it is impossible to predict what editing and other compression algorithms the material will be subjected to as part of future programmes.

In the future it may well be regretted that too much compression was used, to the detriment of archive material, to save what in retrospect may seem a paltry sum.
With the hindsight of only 9 months this has shown that the DVD media storage costs have already reduced by 47%.

Future Developments

The Umatic holdings of the BBC have presented a wide range of technical and documentation problems. It seems unlikely that it will be possible to adopt a "production-line" system to maximise possible throughput. This way of working has been possible with Quad, C Format and film soundtracks. The process for transferring and preserving Umatic cassettes is too difficult to allow, for example an automated approach.

If proposals for funding are successful, a second transfer suite will be built, and operated by dedicated staff.

Finally, the BBC also has Umatic collections in its National Regions (Northern Ireland, Wales & Scotland) and in its English Regional Centres. These amount to a total of approximately 17,000 further Umatic tapes. We are considering creating a third transfer.

Discussion

Tony GARDNER, European Commission

I have two or three questions. Firstly, what will happen to BVU tapes? Secondly, you mentioned the transfer toward new formats. Do you intend to carry out that transfer for all of the information that is sent by satellite? Lastly, do you think that DVDs can be used as a long-term preservation method?

Adam LEE

Thus far, whenever we transfer reformat material, we always keep the originals. The BVU tapes, for instance, were turned over to the National Archives. The other transfer projects have not yet reached that stage. In any case, we do not intend to destroy any material whatsoever. As regards DVD, we use it only with U-Matic tapes. When dealing with one-inch tapes, we use the usual formats and, naturally, keep the originals.

Allan KING

I am not worried about the development of DVD. We simply hope to control and limit the deterioration rate. We made our first DVD recordings 18 months ago and perform checks on a regular basis. No variations have been recorded since that time. We are not at all worried; we are simply being prudent. Note that these checks are performed on large sets of cassettes.

Bob CURTIS-JOHNSON

Allan, could you say more on the signal path used for digitisation? Is the TBC digital or analogue?

Allan KING

The TBC used is one of the very early videomatic TBCs made. In fact, we had quite a bit of trouble even finding one. We used YC because it allows for slightly more coverage. Previously, film was cut on one frame. Some people still use that method, despite the fact that the equipment has changed significantly. The 800 allowed them to do that.

Bob CURTIS-JOHNSON

Can you say something about frame delays? I seem to recall having seen a VO 9008…

Allan KING

There is a clear choice to be made between the two machines. The 900 is much more reactive. However, it does not read all types of tape. In the end, both machines are necessary since they both read different types of tape. As regards digital path, we put it through a Wilcox and RX50 noise reducers, so as to limit the noise as much as possible when the machines are used properly.

Bob CURTIS-JOHNSON

Do you use YC or composite?

Allan KING

We used YC.

From the floor

I read in Broadcast magazine that you had begun transferring U-Matic tapes on D3 and Digital Beta. Is that correct?

A Speaker

No.

From the floor

Nonetheless, many of your tapes are still on D3. Do you have any difficulty playing them?

Allan KING

No, we do not expect anything different from what we are already experiencing.

From the floor

I was referring to the problems that are inherent to the D3 machines themselves.

A Speaker

D3 remains our transmission standard. However, we know that we will encounter the usual problems. The equipment is no longer useable after five to ten years and must thus be replaced frequently. This will grow very costly. There does not seem to be any way out of that.

Peter COPELANDDieter KOCHLAND

What is the nature of the sound problems which you encounter?

A Speaker

The sound-related problems on U-Matic tapes seem to have no direct relationship to level. That is the basic problem.

Dietrich SCHÜLLER

What was the target format for your quad collection? How much cost increase would you have to incur if you went to a higher digital standard (Digital-Beta)?

A Speaker

We transferred our quad material to D3 and the one-inch tape to Digital-Beta.

A Speaker

The cost increase would be more significant if we were moving to a new technology entirely and would probably amount to approximately 25%. The margin is rising as the cost of DVDs falls. One of the reasons for which we used DVD is because they are quick to use and can be accessed at any time.

Ouahid BRAHAM, responsable des archives de la télévision tunisienne

Je suis très heureux de participer aux travaux de ce symposium. Notre collègue britannique n'a pas donné les raisons du choix pour les cassettes U-Matic. La télévision tunisienne possède 3 178 heures de cassettes U-Matic, ce qui est très peu par rapport au fonds possédé par la BBC. Nous rencontrons aussi d'importants problèmes parce que les producteurs ne veulent pas utiliser ces cassettes car ce sont des supports de très mauvaise qualité.
Par ailleurs, pourriez-vous parler de l'état des autres anciens supports, les 2 pouces et les 1 pouce ? Quelle est l'expérience de la BBC en matière de transfert de ces anciens supports ? C'est pour nous une occasion de profiter du savoir-faire des grandes télévisions. Je crois que la télévision tunisienne peut constituer un champ d'investigation intéressant pour les chercheurs, universitaires ou industriels.
Vous intéressez-vous uniquement à la production nationale britannique ou également aux autres productions qui vous sont parvenues il y a quelques années ? Je précise que je ne fais pas allusion ici aux problèmes de droits.

A Speaker

I would be more than happy to discuss preservation strategies with you. I hope I understood you properly. We were not responsible for the choice of the current format. That decision was made by the Head of Production in 1980. We never made a formal decision to transfer to U-Matic.

Allan KING

The two-inch tapes are quite satisfactory and do not cause too many problems. The problems we encountered occurred on certain batches (decay, glue on the edges), but were resolved by the manufacturers as time went by. The one-inch material is already proving more difficult to handle than the original product, despite being younger. This is the result of the higher density and friction, in particular. To overcome this, we have used the same techniques. Some one-inch machines play the material much better than others; it is a question of choosing the replay equipment carefully and, if necessary, cleaning it. However, we try to keep cleaning to a minimum since it is a lengthy and costly process.

From the floor

You mentioned that you are using a jukebox for the DVDs, which are in effect operational copies. Do you make only one original and one copy? Can you say any more about your DVD jukebox system? Is it linked automatically to the database?

A Speaker

This is a pilot project and the jukebox DVDs have not yet been marketed. This is planned for the future. Currently, we make only one DVD. Ultimately, we intend to make two: one will be kept under cover while the other will be placed inside the DVD machine. At the moment, the BBC's infrastructure is not ready. Our main delivery format therefore remains DVC-Pro.

Martin JACOBSON, National Archive, Sweden

What is the total timetable on the transfer? To what extent will the project be automated?

A Speaker

Are you referring to the overall preservation process or only the transfer toward U-Matic? We had initially considered automating the process. However, in practise, 35% of the samples showed errors. It was thus very difficult. In the end, the manual system appeared the quickest and most practical method. When the heads become dirty, we clean them one by one.

Restauration de films à partir de formats d'images autres que le 35 mm ou le 16 mm
Eléments de réflexion à partir de l'expérience du service des archives du film et du dépôt légal du Centre national de la cinématographie (Poster)

Philippe Brunetaud
CNC - France

1-Les formats sub-standards

Dans les différentes archives, un certain nombre de films ne subsistent que sur un format différent du 16, du 35 ou du 70mm.
Les archives du film et du dépôt légal du CNC ont essentiellement été confrontées aux cas suivants :

1) FILMS TOURNÉS SUR DES FILMS AU PAS NON STANDARD :
Primitifs 35 mm : la collection des films Lumière, (perforations rondes), des films Edison 35 à petites perforations, des films à perforations Pathé

2)FILMS TOURNÉS SUR DES PETITS FORMATS
Il s 'agit essentiellement de films tournés **en 9,5 mm** par des amateurs ou des secteurs institutionnels, principalement des films documentaires ou de petites fictions.
exemples : collection de films sur « Les croix de feu », films de fiction destinés à l'éducation religieuse.

Le cas se pose également pour des films tournés en 16mm (souvent en inversible) mais dont l'exploitation était prévue en 35 mm.

En matière d'archives, les formats 8mm et super 8 ne sont guère utilisés et peuvent, en tout état de cause être traités par des laboratoires privés.

3) FILMS QUI N'EXISTENT PLUS (EN TOTALITÉ OU EN PARTIE) QUE SOUS FORME DE COPIES DANS UN FORMAT RÉDUIT OU UN FORMAT « EXOTIQUE »:

- Réductions en 9,5 mm (telles les copies Pathé Baby)
exemple : Les dessins animés de la série des O'GALOP

- Réduction en 17,5 mm (film éventuellement sonore, à perforation latérale)
exemple : restauration du film « Le secret des Worontzeff ». Les supports 17,5 étaient détériorés, le report du son très difficile.

- Réduction en 28 mm
Exemple : restaurations en cours à partir d'un dépôt de copies 28mm fait par la Stiftung Deutsche Kinematek :
Parmi ces titres : Le berceau vide, Sang espagnol, Gérone, la Venise espagnole, Tom Pouce suit une femme, Fumée d'ivresse, Rayon de soleil, Un épisode de 1812, Fouquet, L'homme au masque de fer.

- Réduction en 35 mm de tentatives de films sur grand format
Essais Lumière, essais Demeny sur des supports de formats proches du 60 mm

2-La problématique de la restauration de ces éléments

Elle reste identique, que l'on fasse appel à la filière photochimique ou aux techniques numériques

1- L'image

Le choix peut se porter sur le report ou le gonflage de ces images sur un format 16 mm ou 35 mm selon les possibilités et les besoins.
Les contraintes :

- Gonflage des images et homothétie des formats.
- L'instabilité
- Le cadrage(position de l'image par rapport aux perforations)
- Le contraste
- Le grain
- Les rayures
- Les perforations servant à l'entraînement du film original.
- L'incidence du format du support sur la « lecture » de 'image d'origine
- Perforations centrales du 9,5mm et tirage en immersion

2- Les sons
Pour les films sonores, il faut pouvoir lire les sons sur un défileur adapté.

3- Les méthodes de travail pour une restauration traditionnelle faisant appel à la filière photochimique
Pour ces films, il est impératif de dupliquer l'image à l'aide d'une tireuse alternative optique, ce qui permet
- de copier un film 35 mm dont les perforations sont différentes de celles d'un film moderne
- de gonfler (ou de réduire) l'image pour la reporter sur du 35 mm (ou du 16).

Avec une difficulté : Le tirage optique entraîne un accroissement du contraste de l'image d'origine.

3- Quelques solutions théoriques

Le contraste
Utilisation de films intermédiaires à faible contraste (pellicule marron, voire pellicule d'extraction), éventuellement développement spécifique.

Le grain
Le grain d'origine restera visible, mais un traitement doux atténuera sa perception.

Les rayures
Selon les cas
-***Gonflage de gélatine*** dans un bain de carbonate pour les rayures fines côté émulsion
-***Dépolissage et repolissage*** du support pour les films 35 ou 16 dont le coté support est fortement rayé.
-***Recours*** à la technique du ***tirage humide*** (pré-wet) : 17,5 ou à des fenêtres à ***immersion*** (wet gates) (cas des films Lumière)

Dans le cas de films 9,5 mm le recours à des tirages humides ou à l'immersion est rendu extrêmement difficile à cause des perforations centrales.

Le format d'origine et les perforations
Chaque format, chaque type de perforation oblige à confectionner un système d'entraînement spécifique, l'utilisation d'une optique adaptée (longueur focale, différents points focaux) notamment par rapport aux lanternes des tireuses.

L'instabilité
Le cadrage(position de l'image par rapport aux perforations)
L'homothétie des formats

L'utilisation de tireuse alternative optique permet de reporter les images en « calant » chaque image projetée sur le film vierge selon les besoins.
Ainsi :
- la position des images relativement aux perforations peut être corrigée (sauf, bien entendu pour les formats à perforation centrale tels le 9,5mm) Le cadrage peut donc être rectifié
- la taille du grossissement (rapport de projection)peut être adaptée en jouant sur la longueur focale et la position de l'optique dans l'alignement du faisceau lumineux.

On peut ainsi obtenir une image la plus grande possible sans perdre une partie de l'image d'origine qui ne doit pas être tronquée. L'homothétie des formats doit être une règle absolue.
Seule dérogation à cette règle absolue : lorsque l'original est très instable, on peut positionner chaque image à son tour dans la fenêtre et jouer sur une variation de la position relative de l'image d'origine et de la pellicule impressionnée (par exemple à l'aide d'un automate programmable pilotant la position de la platine porte-objectif) en respectant des repères de calage, et retrouver ainsi une image stable.
En tireuse ou en truca, seule les parties communes aux images successives seront conservées. La stabilisation induit le plus souvent une petite perte d'image en bord cadre.
Les trucas permettent, dans le cas de films très abîmés, d'avancer l'image à la main en ouvrant puis fermant le batteur à immersion pour chacune des images.

Les sons : utilisation de mécanismes d'entraînement adaptés.
Si la copie des images présente des difficultés assez évidentes, la restauration des sons semble, dans certains cas, poser au moins autant de problèmes techniques, souvent aggravés par les déformations de la pellicule, liées soir au retrait, soit au syndrome du vinaigre.

Il faut lire en continu, sans distorsion, une piste son sur un support déformé, dont l'entraînement requiert un mécanisme spécialement adapté au format concerné.

4-Les méthodes de travail pour une restauration faisant appel à la filière numérique

1- Rappel des différentes étapes de travail
Numérisation (choix de la finesse de numérisation : 2k,4K…)
Travail de restauration sur station dédiée
Report sur film à l'aide d'un imageur
2- A quel moment introduire l'outil numérique ?
Après une sauvegarde traditionnelle en travaillant à partir d'un support neuf (35 mm)
En numérisant directement l'original, quel que soit son format
Exemple de certains titres de la collection William DAY (société Centrimage)
Exemple de certains films lumière (société ANCOR)
Exemple de certains films DEMENY en grand format (58mm) (société ACME)

La difficulté technique à résoudre reste l'entraînement des éléments souvent très fragiles ou détériorés qui est un des soucis majeurs dans l'utilisation des tireuses ou truca en photochimique.
Comme dans toute restauration, le travail sur ces films doit respecter les règles
d'une documentation précise sur les opérations effectuées.
L'image numérisée au départ doit être conservée intacte sous forme d'un fichier de référence.

5-Quelques cas concrets

Face à ces difficultés, un certain nombre d'essais infructueux ou satisfaisants sont tentés par les restaurateurs et sont illustrés ci-après par cinq problèmes types que nous avons rencontrés :

1 **Structure du support** et effet de granulation sur certains films nitrate (notamment sur des films Lumière)
Cet effet, rare, peut être éliminé en tirant par contact ou en utilisant une source de lumière très diffuse, à l'inverse du faisceau de lumière de la plupart des tireuses optiques.

2 **Augmentation du contraste** liée au tirage optique (à contrôler)
Solution : utilisation de pellicules à plus faible contraste, développement spécifique.

3 **Possibilité de travailler en immersion (ou en tirage humide) réduite** pour certains films : Le cas du 9,5
Solution : Pas de réponse totalement satisfaisante en ce qui concerne le SAFDL
En effet, deux types d'essais ont été réalisés avec un batteur à tirage humide :
Tests avec PF 5060 et avec Fluorinert, peu satisfaisant : propriétés optiques des produits non satisfaisantes.

Tests avec le perchloréthylène.
Tests non satisfaisants en général : La perforation centrale entraîne des effets de traînée au centre de l'image.

4 **La stabilisation des images** :
L'utilisation d'un automate programmable adapté à une tireuse donne un résultat comparable à celui d'une truca.

5 **La lecture et le réenregistrement des sons**

Un exemple de difficulté technique : les sons des films 17,5
Lecture des sons 17,5 mm sur un défileur spécialisé. Normalement, un 17,5 et un 35 comportent le même nombre de perforations pour une longueur identique. Dans le cas du "Secret" le film ne comporte qu'une perforation sur 2 par rapport à un 35 mm standard; il défile donc deux fois plus vite sur un défileur optique 35.
Ce standard semble être un 17,5 du type de ceux qui étaient utilisés pour les projections dans les salles de campagne avant l'avènement du Super 8; le track-son est à l'opposé par rapport à un 35 ou un 17,5 normal.

Pour effectuer les travaux de contretypage et de gonflage image sur une machine de tirage intermittente, il suffit d'effectuer une opération inverse à la réduction d'image d'origine.

Pour le son, deux possibilités s'offrent à nous:
- soit lire sur un défileur à une vitesse définie et constante, mais qui ne sera pas nécessairement la bonne
- soit lire sur un projecteur 17,5 dont la vitesse de défilement peut être aléatoire (certains projecteurs tournant à 27,5 images/s), solution qui ajoute des inconnues.

Le restaurateur du son (dans ce cas :BCAV) a donc choisi la première des possibilités.

Mais ce film étant vétuste, il présente de nombreuses cassures et rétractations, donc en le lisant sur un défileur à vitesse constante, il y avait du pleurage.

Pour effectuer la captation en numérique, la solution a été de faire sauter une dent sur deux au débiteur, et de repiquer en 6,25 bande lisse à la vitesse de 38,1 cm/s et de la relire en 19,05 cm/s.

Les défauts de l'original ont ensuite fait l'objet d'un traitement numérique de restauration.

Sans le numérique, aucune restauration correcte du son n'aurait été possible.

Détection et suppression automatique de rayures dans les films cinématographiques (Poster)

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Introduction

La restauration traditionnelle des documents cinématographiques se fait par des moyens mécaniques et photochimiques, mais ces techniques ne peuvent effacer toutes les épreuves du temps (rayures, poussières,...). L'utilisation des nouvelles technologies numériques, appliquées à la restauration de documents cinématographiques, devrait permettre d'atteindre cet objectif à des cadences plus élevées.

Depuis plus de 20 ans, de nombreux travaux ont été consacrés à la restauration numérique d'images [6]. Toutefois, la restauration de films cinématographiques apporte une spécificité à notre recherche [1,2]:

- Pour préserver la qualité visuelle, une image ne peut être filtrée globalement. Une telle opération est nettement perceptible lors d'une projection, elle est néanmoins utilisée pour des images au format vidéo pour lesquels des filtres passe-bas ou des filtres médian [X,Y] donnent des résultats relativement satisfaisants.
  Nous proposons une technique traitant exclusivement les pixels détériorés. Le principe de base de cette technique, déjà introduit par Kokaram [8], consiste à détecter les détériorations, puis à corriger ces zones détériorées en utilisant les informations intactes du voisinage immédiat de ces défauts.
- La taille des images manipulées (par exemple 2000 x 1500 points par image) et les cadences nécessaires pour viabiliser la restauration numérique nécessitent une quantité de mémoire de masse et une puissance de calcul se situant au delà des besoins classiques du traitement d'images.

Notre technique de détection, déjà utilisée pour la localisation de détériorations ponctuelles [2], est appliquée ici au cas des rayures mais renforcée par un processus de poursuite. En effet, contrairement aux petites altérations qui n'apparaissent qu'une seule fois à un endroit donné, les rayures persistent dans la même zone sur plusieurs images de la séquence. La restauration de ces zones détériorées doit être d'autant plus soignée.

Caractéristiques des rayures

Les rayures proviennent de phénomènes physiques (frottement du film sur lui-même ou sur des pièces dans une caméra ou un projecteur suite à un mauvais chargement,...). Le côté support, mais le plus souvent le côté émulsion de la pellicule est partiellement arraché par ce frottement (donc atténuation de l'intensité ou une perte d'information). Elle se caractérise par sa position au sein d'une image, l'angle qu'elle fait avec la verticale, ainsi que sa largeur. D'intensité plus claire (maximum) ou plus sombre (minimum) que son voisinage, la rayure se manifeste par une ligne plus ou moins verticale traversant souvent la totalité de l'image. Sa durée temporelle est inconnue, parfois périodique. Les rayures persistent dans la même zone sur plusieurs images de la séquence ce qui perturbe l'attention du spectateur durant la projection.

Les techniques utilisées pour détecter les rayures sont le plus souvent statiques [3,9]. Nous présentons ici une méthode exploitant la notion temporelle de la rayure, même non parfaitement verticale (voir fig 1), pour détecter et corriger celle-ci.

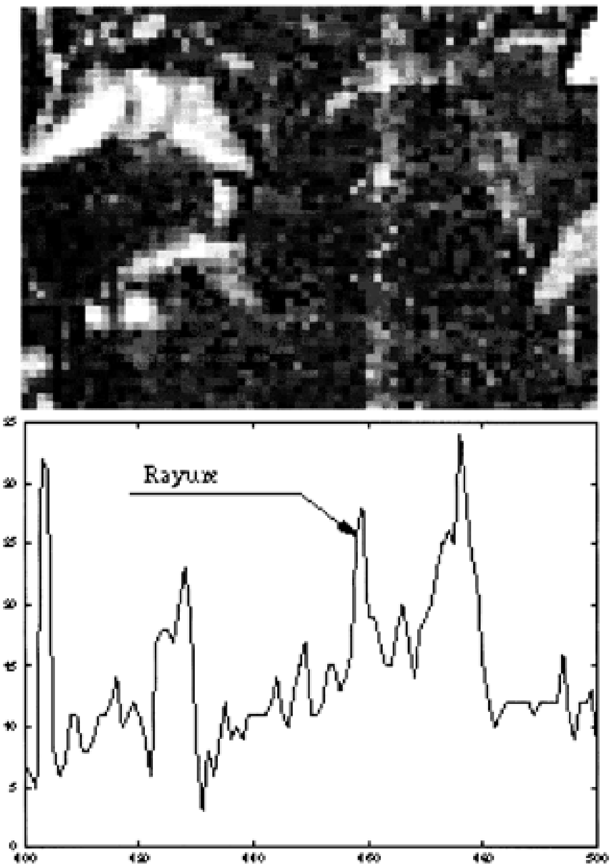

Fig 1 : Partie agrandie d'une image. Le bruit (grain du film, bruit électronique) est visible. En dessous, un profil de cette image

Détection des rayures

La détection des minima locaux (ou maxima) est, dans le cas des images cinématographiques, difficile en raison de la présence de bruit (grain du film, aléas du scanner, poussières, etc.) qui peut être important comme le montre la figure 1.

Projections

Pour minimiser l'influence du bruit, nous utilisons les projections de Radon le long de l'axe des y [11].

Etant donnée une image I en niveaux de gris, nos projections s'expriment par :

$$P_H(x,i) = \sum_{j=0}^{H-1} I(x, j + H.i)$$

La hauteur de projection H est fixée en fonction de l'angle maximal que fait la rayure avec la verticale ainsi que la résolution de l'image.

DÉTECTION SPATIALE DES RAYURES

La détection statique des rayures s'appuie sur une méthode de détection de minima locaux que nous avons précédemment développée [2]. C'est une approche simple qui utilise des transformations morphologiques classiques (ouverture et fermeture) en niveau de gris en se basant sur les propriétés spatiales des défauts [12]. Ce détecteur consiste en une simple différence entre l'image d'origine et sa fermeture :

où M désigne l'élément structurant.

$$D(I(x,y), M) = ((I(x,y) \oplus M) \ominus M) - I(x,y)$$

Comme cette technique a permis de détecter de manière satisfaisante les détériorations ponctuelles telles que les poussières ou les cheveux. nous l'appliquons ici au cas des rayures en utilisant des éléments structurants plus adaptés à ce type de détérioration (largeur en adéquation avec la largeur maximale des rayures, forme allongée). Le principal inconvénient de cette approche réside dans le choix de paramètres appliqués aux éléments structurants et valables pour la séquence complète. Ce choix est loin d'être évident et rend difficile l'automatisation du processus de détection. Cependant, cette méthode peut être utilisée pour initialiser un processus de poursuite. Dans cette optique, de faibles valeurs ont été choisies **pour permettre la détection de toutes les rayures présentes dans la séquence**. Bien évidemment, cela entrainera une augmentation sensible des fausses détections (bords des objets, formes allongées, …) Mais le processus de suivi permettra de les éliminer.

La figure 2 montre le résultat de notre algorithme de détection spatiale des rayures. Le nombre important de fausses détections obtenu était prévisible.

Poursuite des rayures

La seconde phase de la recherche des rayures est la poursuite des rayures détectées le long de la séquence. le résultat final de détection doit être fiable et précis pour focaliser la reconstruction exclusivement sur les régions endommagées.

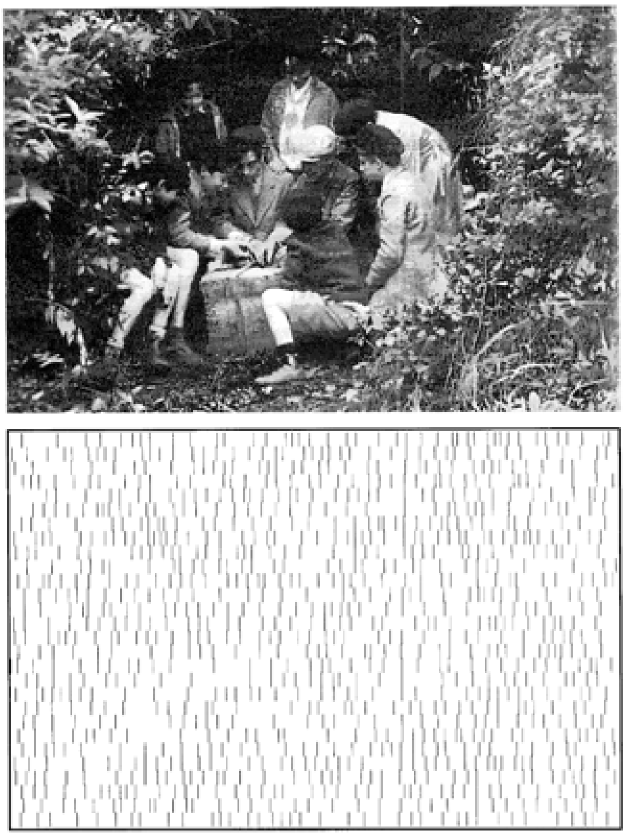

Fig 2 : Exemple au format vidéo 720 x 576 issu d'un télécinė, montrant une petite rayure (en fait, visible uniquement dans le plan bleu) et la détection spatiale correspondante, hauteur de projection 16 pixels.

Une technique puissante et largement pour les processus de poursuite est le filtre de Kalman [5].

LE FILTRE DE KALMAN

Le filtre de Kalman est une technique d'estimation Bayésienne utilisée pour le suivi temporel de processus stochastiques. Ce filtre s'appuie sur deux modèles probabilistes :

- Le modèle du système qui décrit l'évolution au cours du temps du vecteur d'état courant u_k. La transition entre états est décrite par la matrice de transition Φ_k, connue, et la prise en compte d'un bruit Gaussien de matrice de covariance Q_k.
- Le modèle de mesures qui lie le vecteur de mesures d_k au vecteur d'état courant par la matrice de mesures H_k. Le bruit est aussi supposé Gaussien de matrice de covariance R_k.

Le filtre de Kalman opère en deux phases : la prédiction puis la mise à jour. L'étape de prédiction consiste en l'estimation de l'état et de la matrice de covariance de l'erreur d'estimation de l'état. Ensuite, l'état courant et la matrice de covariance courante de l'erreur d'estimation de l'état sont mis à jour en utilisant une matrice de gain K_k calculée à chaque itération.

Détection spatio-temporelle des rayures

La mise en œuvre d'un filtre de Kalman passe d'abord par la définition d'une représentation adéquate pour le vecteur d'état. Dans notre cas, le vecteur d'état est lié à la position $x(t)$ des rayures au cours du temps.

Modélisation à court terme

Les rayures proviennent souvent de frottements contre des pièces mécaniques en rotation. Leur position le long de la séquence devrait donc évoluer de manière sinusoïdale. Une sinusoïde est caractérisée par une équation du type : $x(t) = A \sin(\omega t + \varphi)$. Ce modèle sinusoïdal est tout à fait adéquat pour représenter l'évolution temporelle de la position des rayures. Nous utilisons une approximation linéaire de ce modèle :

$$x(t) = A[b(t+c) - \frac{1}{3!} b^3 (t+c)^3]$$

qui intègre l'approximation bien connue d'une sinusoïde obtenue par un développement de Taylor (au 3ème ordre ici) :

$$\sin(x) \approx x - \frac{x^3}{3!}, x \to 0$$

Le vecteur d'état de notre système de poursuite de rayures est alors : $u_k = (a_0\ a_1\ a_2\ a_3)'$ avec a_0, a_1, a_2, a_3 les coefficients de notre modèle polynomial cubique issu de l'approximation linéaire précédente. L'expression de l'état suivant $x(t+dt)$ en fonction de l'état courant conduit à la matrice de transition suivante :

$$\Phi_k = \begin{pmatrix} 1 & dt & dt^2 & dt^3 \\ 0 & 1 & 2.dt & 3.dt^2 \\ 0 & 0 & 1 & 3.dt \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Le vecteur de mesures est : $d_k = x(k)$ et la matrice de mesures s'exprime par : $H_k = (1\ \ 0\ \ 0\ \ 0)$.

Le processus de poursuite fournit alors les trajectoires des rayures potentielles préalablement détectées. **Les trajectoires incompatibles avec la signature d'une rayure correspondent à de fausses rayures qui sont alors éliminées**. La figure 3 montre, à gauche, la trajectoire d'une rayure et, à droite, celle d'une fausse rayure. Dans ce dernier exemple, aucune condition d'arrêt n'a été prévue. Il est clair que l'incompatibilité de la trajectoire de cette fausse détection avec celle d'une rayure est repérable au bout de quelques itérations. La poursuite de la rayure aberrante est alors interrompue.

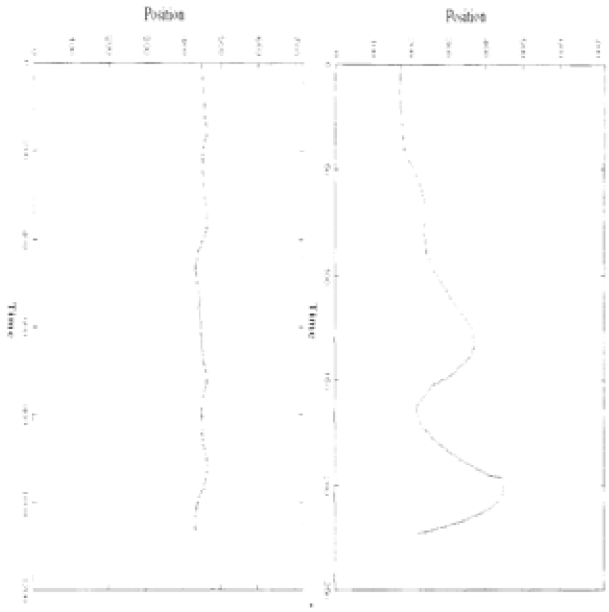

Fig 3 : Poursuite d'une rayure sur 30 images (a gauche). Evolution d'une fausse détection sans condition d'arrêt (à droite)

MODÉLISATION À LONG TERME

Une modélisation à plus long terme permet de piloter avec une plus grande fiabilité et une meilleure convergence la poursuite précédente. En effet, la présence de la rayure peut-être confirmée par la périodicité de la courbe représentative de sa position en fonction du temps qui est visible et relativement stable en considérant un grand nombre d'images de la séquence. La figure 4 montre l'évolution de la position de la rayure le long de la séquence utilisée précédemment. Cette courbe intègre de façon très nette des composantes sinusoïdales avec une période bien déterminée.

La position de la rayure est alors approximée par un modèle à trois sinusoïdes (fondamental plus 2 harmoniques), modèle qui adhère mieux que le modèle précédent aux caractéristiques physiques de la rayure à long terme :

$$x(t) = offset + \sum_{i=1}^{3} A_i \sin(2.\pi.f.i.t + \varphi_i)$$

Avec :

- *offset* la position moyenne de la rayure,
- A_i l'amplitude de la ième sinusoïde,
- φ_i le déphasage de la ième sinusoïde par rapport à l'origine,
- f la fréquence du signal.

Le nombre d'harmoniques est limité à 3 pour restreindre

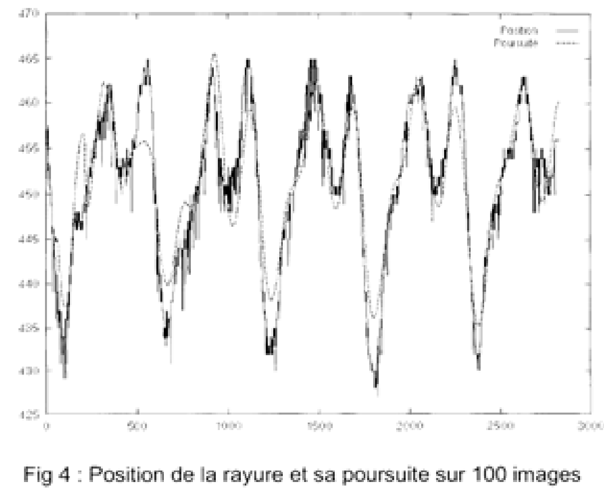

Fig 4 : Position de la rayure et sa poursuite sur 100 images

le nombre de paramètres à estimer qui s'élève à 8 ici, soit deux fois plus que dans le modèle précédent.
La figure 5 montre les résultats de l'estimation de la fréquence f issus des deux différents processus de

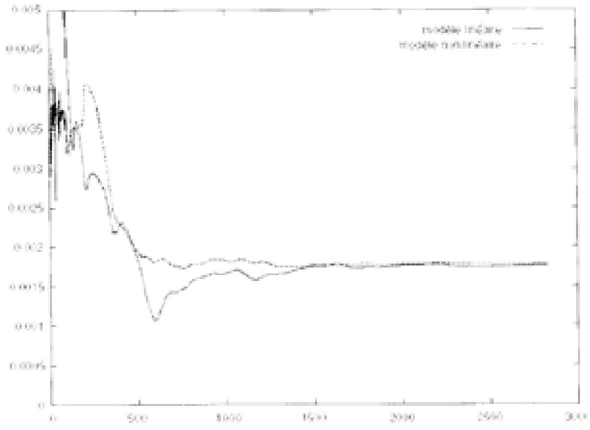

Fig 5 : Evolution de la fréquence de la rayure

poursuite de Kalman, l'un utilisant le modèle polynomial cubique et l'autre le modèle à 3 sinusoïdes.
La figure 4 montre le résultat de la poursuite de la rayure sur une centaine d'images. La courbe obtenue adhère presque parfaitement à la courbe représentative de la position réelle de la rayure le long de la séquence.

Suppression des rayures

Les rayures ayant été détectées, il reste à les supprimer, le but étant d'aboutir à une restauration la plus fidèle possible des régions endommagées. Il est important de souligner ici que la restauration d'images cinématographiques requière une précision de loin plus fine que les images classiques telles que les images vidéo. La localisation préalable des rayures permet de traiter les pixels détériorés en utilisant un voisinage immédiat des pixels à reconstruire. Il est possible d'utiliser deux types de voisinage :

- le voisinage spatial extrait de la même image que la zone à reconstruire,
- le voisinage spatio-temporel extrait aussi bien de l'image courante que des images suivantes et précédentes.

Le voisinage spatio-temporel est complexe à mettre en œuvre. En effet, il doit être utilisé en étroite collaboration avec une technique de compensation de mouvement pour pouvoir retrouver dans les images précédentes et suivantes les informations nécessaires pour reconstruire la zone détériorée. Nous avons dans un premier temps opté pour un voisinage spatial, nettement moins complexe et plus économique que le voisinage spatio-temporel.

La reconstruction d'une détérioration avec un voisinage spatial se décompose en deux étapes :

- la modélisation des motifs formés par les pixels situés dans le voisinage du pixel à reconstruire,
- la prolongation de ces motifs pour effacer la détérioration considérée.

Ce type de techniques est communément appelée interpolation.
Pour supprimer toute trace de rayures des images cinématographiques, nous proposons une reconstruction en deux étapes couvrant toutes les fréquences des signaux. Les basses fréquences sont d'abord reconstruites, ensuite la prise en compte des hautes fréquences complète le traitement. Les rayures persistant sur plusieurs images de la séquence, les zones endommagées par les rayures doivent donc être reconstruites le plus fidèlement possible.

Reconstruction des basses fréquences

Les techniques classiques comme les filtres passe-bas [4] ou les filtres médians se révèlent insuffisantes pour la restauration de films cinématographiques parce qu'elles détériorent les hautes fréquences des images. Pour reconstruire les basses fréquences des images nous utilisons une interpolation polynomiale. La variation basse fréquence de la luminance est modélisée par deux polynômes de degré 3, l'un dans la direction des abscisses et l'autre dans la direction des ordonnées :

$$I_{BF}(x, y) = \sum_{k=0}^{3}\sum_{l=0}^{3} a_{kl} x^k y^l$$

qui est le modèle le plus simple pour représenter les basses fréquences d'une image.
Pour estimer les coefficients a_{kl} du modèle, nous utilisons une technique de régression aux moindres carrés dont les données en entrée sont les coordonnées (x_i, y_i) de pixels non détériorés P_i appartenant à un bloc P autour de la rayure. Les valeurs estimées $\hat{a}_{kl}$ sont alors utilisées pour reconstruire les basses fréquences de la zone rayée :
ou Q désigne l'ensemble des pixels détériorés à

$$R_{BF}(x_j, y_j) = \sum_{k=0}^{3}\sum_{l=0}^{3} \hat{a}_{kl} x_j^k y_j^l \ , \ (x_j, y_j) \in Q$$

reconstruire.
La figure 6 montre, à gauche, une portion d'image à restaurer extraite d'une séquence d'un film des frères Lumière. Sur cette image, qui contient par ailleurs de nombreuses détériorations, nous nous focalisons, pour illustrer notre approche, sur le défaut prédominant, à savoir la rayure. L'image centrale présente le résultat de notre technique de reconstruction basses fréquences sur la rayure détectée. Nous pouvons constater que cette technique est insuffisante pour supprimer complètement cette rayure. La zone interpolée est visible, phénomène qui serait accentué en dynamique.

Reconstruction des hautes fréquences

La majorité des techniques de restauration d'images ne reconstruisent pas ou que partiellement les hautes fréquences des images. Très peu de travaux ont été consacrés à ce problème [13] et concernent principalement le format vidéo [10], [9], [7]. Dans notre cas, le traitement des hautes fréquences est incontournable pour obtenir une qualité de reconstruction propre aux images « cinéma ».

Nous proposons une technique de reconstruction des hautes fréquences des images basée sur les séries de Fourier. Tout d'abord, les hautes fréquences sont isolées de la zone (bloc de pixels P) qui a été utilisée auparavant pour reconstruire les basses fréquences de la région abîmée par la rayure. Cette extraction est réalisée par une simple différence :

$$I_{HF}(x_i, y_i) = I(x_i, y_i) - I_{BF}(x_i, y_i) \;,\; (x_i, y_i) \in P$$

Pour modéliser les signaux hautes fréquences, nous avons choisi les séries de Fourier qui sont tout à fait adaptées pour représenter les textures et les signaux périodiques. Notre modèle d'interpolation des hautes fréquences prend alors la forme suivante :

$$I(x, y) = \sum_{k=0}^{N_{\omega x}} \sum_{l=0}^{N_{\omega x}} \begin{array}{c}[a_{kx} \sin(\omega_{kx} x) + b_{kx} \cos(\omega_{kx} x)] \\ \times [a_{ky} \sin(\omega_{ky} y) + b_{ky} \cos(\omega_{ky} y)]\end{array}$$

où ω_{kx}, ω_{ky} représentent les différentes pulsations du modèle.

Les coefficients a_{kx}, b_{kx}, ω_{kx}, a_{ky}, b_{ky} ω_{ky} sont estimés par un schéma itératif qui s'appuie sur un processus de décomposition du signal [Buis97b]. Les hautes fréquences de la zone rayée peuvent alors être reconstruites.

Le signal reconstruit $R_{HF}(x_i,y_i)$ est alors ajouté à celui issu de la reconstruction basses fréquences $R_{BF}(x,y)$ pour compléter la procédure de reconstruction. La figure 6 montre, à droite, la reconstruction complète de la rayure incluant les hautes fréquences. L'amélioration obtenue par rapport à la reconstruction basses fréquences est flagrante. Toute trace de rayure a complètement disparu. En effet, comme nous l'avons souligné précédemment, la reconstruction hautes fréquences modélise la texture située au voisinage de la rayure ce qui permet de prolonger ce détail tout en effaçant la dégradation.

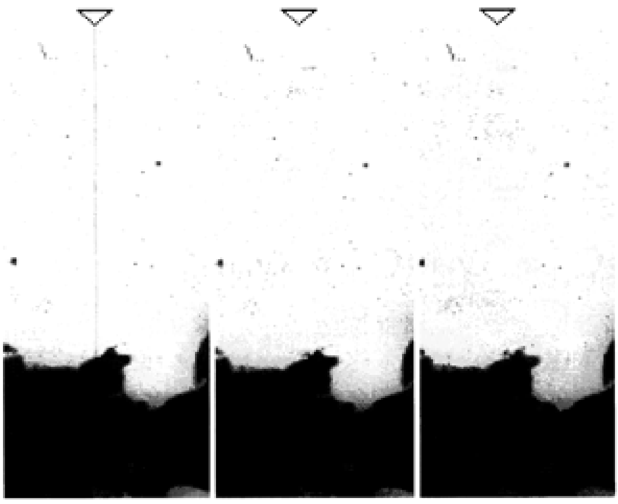

Fig 6 : Image extraite d'un film des frères Lumière. A gauche, l'original, au centre, la reconstruction des BF, à droite, la reconstruction des BF+HF

Conclusion

Nous avons présenté un détecteur efficace de rayures qui comptent parmi les défauts les plus fréquents affectant les films cinématographiques. Ce détecteur spatio-temporel opère en deux étapes : une détection statique, basée sur des opérateurs morphologiques, permet de mettre en évidence toutes les rayures potentielles. La poursuite de celles-ci par un filtre de Kalman permet alors de rejeter les fausses détections. Les rayures sont ainsi détectées avec une grande fiabilité qui permet de ne focaliser le processus de reconstruction que sur les zones détériorées de la séquence. Notre méthode de restauration s'effectue, elle aussi, en deux passes. Les basses fréquences des régions détériorées sont d'abord reconstruites en utilisant une technique simple d'interpolation polynomiale. Ensuite, les hautes fréquences sont reconstruites en s'appuyant sur les séries de Fourier. Cette méthode aboutit à une restauration pratiquement invisible.

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Modérateur/Moderator : Peter DUSEK, FIAT President

I am Head of the Documentation and Archives for the Austrian Radio and Television Institution in Vienna, as well as FIAT President (Television Archives). At my first Joint Technical Symposium in Ottawa (1990), I was a young delegate, still learning about many of the problems that are typical to our work. Films and cylinders were new terms for me. Archivists laughed about sound quality. Today, we realise that those worries were indeed valid.

The material on which we work is changing rapidly (digitisation standards, techniques, copyrights). In order for the future to be bright, we must all move in the same direction. Tomorrow afternoon, our final session will focus on the future of this organisation and this event. Since I will not be able to attend, I would like to take this opportunity to state how valuable this informal meeting between people of different bodies (film, sound, libraries, continental organisations) has become. I thank all of the organisers and the members of the Preparation Committee for their work. With the development of digitisation, we must force better contacts between our various bodies. Alone, we are too small to accomplish any significant progress. The public and the politicians must realise that, despite being technical specialists, we cannot solve all problems. We need to work together.

I would now like to introduce Denis Frambourt, from the Institut national de l'audiovisuel and the Deputy Director of the Archives. He is in charge of the preservation and digitisation plan for the radio and television archives collected from French public broadcasters. He is Head of the FIAT Technical Commission and was on the Preparation Committee for the Joint Technical Symposium. Today, he will address the topic of Strategies for the Digital Migration of Television Programmes Archived on Analogue Video Format.

Stratégies pour la migration vers le numérique des programmes de télévision archivés dans des formats vidéo analogiques

Denis Frambourt
(INA) - France

Les Archives de Télévision disposent de volumes impressionnant de programmes audiovisuels conservés depuis 40 ans dans des formats très variés. Nous arrivons maintenant à une période de transition où les contraintes qui pèsent sur la conservation et l'exploitation de ces fonds sont fortement accentuées : d'une part les menaces de disparition pèsent sur les collections les plus anciennes (obsolescence des formats et dégradation physique et chimique des supports) et d'autre part les contraintes de temps et de coûts d'accès aux contenus audiovisuels sont de moins en moins bien supportées par les utilisateurs au moment où l'accès à des masses d'information est possible par Internet.
Des plans de sauvegarde et numérisation doivent être définis dans l'urgence alors même que les nouveaux supports de stockage de masse permettant une meilleure conservation à long terme ne sont pas encore disponibles et que les formats de stockage et d'échange ne sont pas encore normalisés.

I – Analyse des besoins

Plusieurs critères sont pris en considération pour déterminer les urgences et les méthodes à adopter pour la sauvegarde - numérisation des fonds : les menaces qui pèsent sur la conservation des supports physiques, l'intérêt et la valeur d'usage des programmes d'archives, les modes d'exploitations prévisibles et la qualité requise.
Pour appliquer ces critères il est nécessaire, dans un premier temps, d'établir une grille de classification des programmes en fonction des genres, de leur mode d'enregistrement, des formats d'archivage, …

I – 1 Caractéristiques des fonds d'archives concernés

Les caractéristiques générales des fonds conservés diffèrent peu d'une Archive à une autre si l'on compare des organismes d'égale importance. La répartition entre les deux grandes filières, film et vidéo, si l'on intègre les fonds les plus récents, peut être estimée à 20% film et 80% vidéo pour les organismes les plus importants. Le format film garde donc un poids très important dans la répartition des fonds pour les archives anciennes.

La répartition entre les formats vidéo analogiques à bandes ou cassettes qui ont été utilisés pour l'archivage varie sensiblement d'un organisme à un autre en fonction des choix de formats qui étaient faits pour la production et la diffusion.

Les fonds gérés par l'INA sont estimés à environ :

Télévision : 500 000 heures dont
20 % film
80 % vidéo

Radio : 600 000 heures dont 90% bandes 6,25 mm.

Dans l'exposé qui suit seul le cas des archives de télévision conservées sur supports vidéo sera traité.

I – 2 Critères de sélection et priorités

A l'INA le plan de sauvegarde – migration numérique des contenus à moyen terme est établi sur des critères de première urgence, face à la dégradation physique et l'obsolescence des formats, et de protection des supports uniques d'une part, et sur des priorités liées à l'usage potentiel des contenus d'autre part.

CRITÈRES TECHNIQUES

Le choix des priorités face à la dégradation physique et l'obsolescence des formats est basé sur l'expérience des difficultés rencontrées quotidiennement dans l'exploitation des supports et sur l'analyse des menaces qui pèsent sur les différents formats (raréfaction des lecteurs, des pièces détachées et des compétences techniques d'exploitation et maintenance en particulier)

L'application de critères élaborés est maintenant possible en s'appuyant sur le travail entrepris par le Groupe Projet de l'UER (P - fta) sur les archives numériques de la télévision du futur, qui intègre aussi les problèmes liés à la récupération des fonds existants.

Le groupe a défini quatre niveaux d'obsolescence des formats à bande vidéo du passé abandonnés ou encore exploités :

NEAR EXTINCT (NE) disparition proche
exemple : 2 inch
Les supports et machines ne sont plus fabriquées depuis plusieurs années.
Le format de codage du signal est abandonné en production

ENDANGERED (EN) en danger
exemple : 1 '' B/C, U matic ¾ ''

Les supports sont encore disponibles sur le marché mais les machines ne sont plus fabriquées ou sont en fin de fabrication. Le service après vente sera abandonné dans moins de 10 ans.

VULNERABLE (VU) menacé
exemple : ½ '' D3
Les supports sont encore disponibles sur le marché, les machines sont encore fabriquées mais l'on constate un faible volume de ventes. Le format de codage du signal est en voie d'être abandonné

SAFE (SA) couramment exploité
exemple : ½ '' Digibeta
Les supports sont disponibles avec plusieurs sources sur le marché. Les machines sont encore fabriquées ou les nouvelles machines correspondant à de nouveaux formats assurent la compatibilité en lecture

CRITÈRES DE CONTENUS ET VALEUR D'USAGES

Il s'agit là d'examiner quels sont les types de programmes par genre les plus exploités après un temps de recul assez important (plus de 5 ans) , sous quelle forme et pour quels usages.
La typologie des programmes de télévision établie par les Commissions ''Programme and Cataloging'' de la FIAT, en vue de la collecte et sélection des programmes à archiver, constitue un guide très utile pour la sauvegarde des fonds existants.

Elle permet en effet d'établir une procédure de sauvegarde en tenant compte de plusieurs paramètres :

- Mode de production et supports de production ayant pu être collectés pour archivage (masters de montage, copies de diffusion, éléments de tournage, ...), modes d'enregistrement utilisés pour l'archivage des programmes diffusés en direct ou comportant des éléments de direct.

- Valeur d'usages en fonction des genres et sujets traités (créations, témoignages historiques, ...)

- Modes d'exploitation envisagés (par extraits, sous forme intégrale,...)

A titre d'exemple une grille d'analyse des programmes d'actualités est donnée en annexe

L'INA a défini sur ces bases en 1999 un plan prévisionnel pour la vidéo analogique de 380 000 heures qui devraient être transférées et numérisées sur 10 ans maximum à partir de l'an 2000.
La répartition est donnée ici par types de supports avec une première estimation des coûts :

Nature	Volume en heures	Coût prévisionnel en KF (hors supports de stockage)
- Vidéo 2 pouces (théâtre, dramatiques, variétés, débats, magazines, retransmissions) 1960 à 1980	15 000	12 000
- Vidéo 1 pouce B et C (magazines, documentaires, variétés, débats, retransmissions) 1976 à 1988	35 000	25 000
- Umatic ¾ pouce (journaux d'information, sport, débats, jeux) 1976 à 1990	130 000	53 000
- Beta SP (tous types de programmes) 1988 à aujourd'hui	200 000	50 000
TOTAL	**380 000**	**140 000**

II – Choix des nouveaux formats et procédures de sauvegarde numérisation

Il n'existe pas encore de support pérenne qui s'impose pour la conservation à long terme des programmes de télévision.

De l'avis des experts, la bande magnétique reste encore pour plusieurs années le média le mieux adapté pour la conservation des images de télévision.

Les critères de longévité**, difficiles à établir pour des produits naissant sur un marché fortement concurrentiel,** concernent trois paramètres essentiels **:**

- Les machines d'enregistrement - lecture
  - Existe – t' il une seule ou plusieurs sources ?
  - Combien de machines ont été vendues ?
  - Quelles sont les évolutions prévues ?
  - Assurent-elles la compatibilité pour la lecture des enregistrements antérieurs ?

- Le type de codage du signal enregistré
  - Est-il inscrit dans une norme ?
  - Le format d'enregistrement est-il indépendant du codage du signal enregistré ?

- Le support d'enregistrement
  - Existe –t' il une seule ou plusieurs sources ?
  - Le média est-il utilisé pour différents formats d'enregistrement ?
  - Quels sont les volumes de ventes annuelles ?

Il n'y a pas de choix qui s'impose de façon universelle, l'environnement, le choix de formats de production et diffusion effectué par l'organisme dont dépend le service d'archives constituent des paramètres importants à prendre en compte.

Le seul critère unanimement reconnu maintenant est que le nouveau format d'archivage doit être numérique et d'une qualité compatible avec les usages prévisibles des programmes conservés.

Le groupe projet de l'UER, P-fta travaille sur deux principaux scénarios respectivement adaptés aux migrations à court et moyen termes :

- Transfert dans un format à bande vidéo numérique

C'est la solution utilisée jusqu'à présent qui reste la plus facile à mettre en œuvre à court terme.

Il est recommandé d'utiliser un format qui pourra être automatiquement exploité dans des systèmes robotisés pour faciliter la constitution de copies d'exploitation et la migration future vers de nouveaux formats de conservation.

La création de données d'accompagnement (codes temporels, données d'identification, key frame) est souhaitable pour faciliter l'exploitation et les migrations de sauvegarde future.

- Transfert dans un format de stockage de masse de données informatiques

C'est la solution à moyen terme qui présente le plus d'avantages :

- indépendance entre le format de codage des données et le format d'enregistrement
- exploitation sur plates formes informatiques
- sauvegarde automatique par transferts en temps inférieur au temps réel sans pertes sur de nouveaux supports (clonage).

L'INA a décidé de mettre en œuvre les deux scénarios simultanément sur la base de critères fonctionnels et économiques.

II.1 – Critères fonctionnels et qualitatifs court terme appliqués par l'INA

Les contenus numérisés seront accessibles

- **Par les professionnels : producteurs et diffuseurs**, pour insertion dans de nouveaux programmes (nouvelles productions – rediffusions)
  - ➤ sur la base de traitements additionnels plus ou moins lourds effectués lors des cessions de droits ou lors de l'insert dans de nouveaux programmes :
    - Libération des droits et éventuellement transaction commerciale
    - Restauration amélioration qualitative des images et des sons (rediffusion d'intégrales)

      Dans ce cas, l'accès est indirect et différé.
      Le type et la qualité de l'encodage numérique doivent être compatibles avec le traitement numérique appliqué en restauration.
      Seuls les formats à faible taux de compression sont acceptables : Beta numérique , DVC Pro , MPEG 422

      Le format de sauvegarde actuellement adopté est le ½ pouce Beta numérique

      Principaux genres concernés : fictions – séries – documentaires – sujets montés de magazines.

  - ➤ Sans traitements lourds additionnels au moment des cessions

    Il s'agit le plus souvent d'exploitation d'extraits de courte durée dans des programmes récurrents (information , variétés)

    Pour faciliter cet usage une banque d'extraits prête à l'emploi est en cours de constitution , principalement à partir d'émissions d'information, de sport, de variétés, talk show, retransmissions.

Le type et la qualité de l'encodage numérique doivent être compatibles avec les performances et coûts des systèmes de stockage de masse robotisés et plate-forme informatique d'accès, permettant un accès direct aux contenus au travers de réseaux haut débit.
Les formats à taux de compression plus élevé sont acceptables : MPEG 422, MPEG 2 mp@ml

- **Directement par des publics larges (chercheurs et enseignants),** à des fins d'analyse dans le cadre de recherches sociologiques, historiques, ou à des fins éducatives
La médiation sera nécessairement automatisée au travers de réseaux publics.

La qualité requise ne nécessite pas de traitements additionnels pour améliorer la qualité des images et des sons.

Le type et la qualité de l'encodage résultent du compromis nécessaire entre :

La qualité du visionnage (la plus proche possible de la qualité des visionnages domestiques actuels sur cassettes VHS). Les possibilités des réseaux publics de communication (encore insuffisantes actuellement),
Les coûts de stockage et livraison acceptables.

II – 2. – Critères fonctionnels moyen et long terme

Ils intègrent les probabilités d'obsolescence rapide des formats numériques qui sont ou arrivent aujourd'hui sur le marché.

Aujourd'hui les migrations de contenus audiovisuels de l'analogique vers le numérique sont effectuées en temps réel et avec une intervention importante des opérateurs humains.

Demain, il est impératif, compte tenu des volumes accumulés, qu'elles deviennent automatiques et plus rapides que le temps réel.
A moyen terme, l'objectif est d'utiliser un format numérique de sauvegarde unique pour l'ensemble des collections, compatible avec les techniques de stockage de masse robotisé et exploitable par les procédures et outils informatiques pour les nouvelles migrations qui seront nécessaires pour la conservation.
Différents taux de compression seront éventuellement appliqués en fonction de la nature des contenus et de leur usage potentiel.

II. 3 – Critères économiques

- Coût des transferts de l'analogique vers le numérique

Bandes 2 pouces et 1 pouce

Les opérations sont peu automatisables.
Un enregistrement séquentiel avec réassemblage des programmes transférés peut être nécessaire compte tenu des incidents de lecture rencontrés (encrassement de têtes , centrage têtes – piste défectueux) .

Toutefois les coûts de transfert de masse avec un taux de rejet faible (<5%) sont relativement bas.
2 pouces : 800 FF l'heure de programme
1 pouce B : 500 FF l'heure de programme.

Umatic ¾ de pouce

De mauvaises conditions de restitution (encrassement des têtes, blocages mécaniques) sont rencontrées, toutefois un niveau élevé d'automatisation doit être recherché pour abaisser fortement les coûts compte tenu des volumes et de la valeur d'usage des contenus généralement inférieure à celle des contenus enregistrés sur bandes 2 pouces ou 1 pouce.

Le coût espéré devrait être inférieur à 300 FF l'heure de programme.

- Coût des médias d'enregistrement et conservation

Bande vidéo Béta numérique # 150 FF par heure de programme.

Bande de données # 450 FF pour une capacité de l'ordre de 40 GO
Soit 45 FF par heure de programme encodé en MPEG 2

II 4 – Choix des formats et supports de conservation et d'exploitation

Pour la conservation des programmes élaborés (fictions , théâtre , séries , documentaires , magasines) et de façon générale pour les enregistrements conservés sur supports 2 pouces , 1 pouce et film) :

Le choix à court terme (2 à 3 ans) reste le format Beta Numérique exploité à l'INA depuis 1993.
Il sera remplacé à moyen terme par un format de données numériques plus fortement compressé , avec un stockage probablement sur bandes magnétiques.

Pour la conservation des programmes de flux conservés sur format Umatic ¾ pouce :

Le format MPEG 2 à débit constant de 8 Mbit/s est exploité pour les cessions d'extraits avec satisfaction par l'INA depuis 1996. Des tests sont en cours pour la sauvegarde et son adoption pour la sauvegarde des enregistrements effectués en parallèle antenne sur U matic ¾ pouce est envisagée

Pour l'exploitation professionnelle

Aujourd'hui une copie d'exploitation Beta SP est fabriquée simultanément à l'enregistrement Béta Numérique.

Ce choix tient compte de la facilité d'exploitation du format et du parc important de machines lectrices en exploitation à l'INA.

Dès le début de cette année des copies au format MPEG seront systématiquement réalisées à partir des béta numériques , simultanément aux relectures de contrôle qualité des enregistrements de sauvegarde :

- MPEG 2 CBR 8 Mbit/s pour l'exploitation professionnelle
- MPEG 1 1 Mbit/s pour les visionnages (chercheurs, enseignants)

La copie Beta SP sera abandonnée dès que l'exploitation des fichiers MPEG II sera possible avec les mêmes facilités.

Pour faciliter la navigation dans les contenus les données seront enrichies par la captation d'imagettes représentatives des séquences audiovisuelles.

CARACTERISTIQUES DES FONDS ARCHIVES

CRITERES DE SAUVEGARDE

Genre	Caractéristiques des programmes et matériels les composant	Formats et procédure d'archivage	Caractéristiques des contenus et valeur d'usage	Modes d'exploitation potentielle	Sauvegarde
Actualités : Reportages d'actualité Analyses et commentaires de l'actualité	- Direct du journal télévisé avec commentaires + présentateur - Sujets montés avec son direct international + ambiance - Chutes et éléments non diffusés - EVN avec son international	Enregistrements parallèles antenne Masters de montage et copies Originaux bruts Enregistrements des multilatérales	Factuel non scénarisé Intérêt historique, témoignage de Lieu, objet, phénomène naturel. Interviews d'importance historique, Indicative d'opinions et attitudes de l'époque	- Extraits pour insertion dans de nouveaux programmes d'actualisation programmes à base d'archives. - Intégrale pour chercheurs en sociologie, histoire…	Parallèles antenne et sujets montés au minimum.
Magazines et débats sur tous les Sujets de société : (unitaires de format longue durée et séries avec ou sans présentateur)	- Généralement, enregistrements en studio avec selon le cas, des inserts de sujets de 5 à 15' prémontés - Sujets montés - Chutes et éléments non diffusés	- Support diffusion (PAD) - Master de montage et copies, sujets montés - Parallèles antenne	Débat, interviews pouvant présenter Un intérêt historique ou indicatif d'opinions et attitudes de l'époque	- Extraits - Sujets et reportages intégraux - Intégrale pour chercheur et éducation	Lecture antenne (PAD) Et parallèles antenne pour les semi-directs Sujets montés isolés
Evénements Retransmission de grands Evénements, tels que, cérémonies, commémorations.	- Direct avec commentateurs et insert de documents préenregistrés et montés (séquences d'archives, montage de résumés…)	- Parallèle antenne - Eventuellement, master et PAD des séquences préenregistrés	- Grand intérêt historique - Témoignage du développement de la télévision	- Extraits - Intégrales pour chercheurs	Parallèle antenne

Discussion

From the floor

You chose MPEG 2, at 4-2-0 system, for archiving material. It is distinctive in that it can reduce the vertical chrominance resolution by 50%. This has a major impact on quality. In addition, if one is to re-use the material, one would have to decode the MPEG material to the format that is to be used in the production domain. Future production areas will use compression technology based on DV system (25 to 50 megabytes) as well as MPEG. Future archives, which will be based on massive storage devices, should store the material that comes from the production area so as to avoid degradation in picture quality.

Denis FRAMBOURT

Nous n'avons pas encore choisi le 8-megabytes. Cela étant, il y a une forte probabilité que nous le conservions. L'INA a une double vocation : nous conservons les programmes pour archivage professionnel, tout en les proposant à des publics plus larges. Pour ce faire, la seule voie consiste à réduire les coûts de stockage et d'accès. En l'état actuel des technologies et pour le moyen terme, seule cette solution est envisageable. Nous changerons peut-être d'avis si de nouveaux produits arrivent sur le marché. Il faut comprendre la situation de l'INA aujourd'hui : nous sommes collecteurs pour plusieurs organismes de télévision (services publics, diffuseurs privés). Je ne suis pas sûr que le choix de ces diffuseurs se portera sur le même format.
Aujourd'hui, nous n'envisageons pas que le choix du format puisse être immédiatement compatible avec les salles de montage et les rédactions de toutes les chaînes. France 3 utilise le DVC Pro alors que France 2 utilise le SX. Certains diffuseurs utilisent les deux. Nous n'avons donc pas voulu viser à trouver une interface directe. Les producteurs et les institutionnels, qui font également partie de nos partenaires, auront peut-être fait d'autres choix. Nous avons choisi de référencé les choix des différents acteurs pour faciliter le pré-montage.

Ed ZWANEVELD

The problem here is the need to decode and re-encode our signals. We will have to make DV source material and MP source material migrate together to whatever comes in the future. We have also realised that motion JPEG degrades the signals. My question is as follows: would you take part in a movement designed to pressure today's major manufacturers, so that they realise the need to make migration possible between DV and MPEG?

Denis FRAMBOURT

C'est une action qui est déjà engagée. J'ai cru comprendre que le groupe Pro Mpeg par exemple travaillait avec les partisans du DV pour trouver des ponts entre les deux systèmes. Je rappelle que tous les profils du Mpeg sont pris en compte dans la normalisation des standards d'échanges qui sont actuellement définis par le groupe Pro Mpeg, y compris le Mpeg 2 et mp@ml.

George BROCK-NANNESTAD

Vous avez dit : " Il faut se demander ce que l'on veut garder. " Quels sont les critères de sélection ? Si vous ne pouvez pas le dire ici, vous pouvez faire référence à un texte.

Denis FRAMBOURT

Nous sommes en train d'élaborer une charte d'archivage qui sera signée entre les broadcasters publics, France Télévision et l'INA. Cette charte définira les modalités de sélection et les instances de réponse qui pourront être consultées pour faire cette sélection. On pourrait dire presque la même chose pour la sauvegarde. Aujourd'hui, on n'élimine rien mais on commence à réfléchir à la nécessité de faire une sélection pour la sauvegarde. On procèdera de même pour éliminer des programmes dans nos opérations de sauvegarde : ces instances une fois mises en place seront consultées pour sélectionner les programmes à sauvegarder ou à ne pas sauvegarder. Aujourd'hui, nous ne privilégions aucune approche, ni une approche commerciale ni une approche exhaustive. Nous essayons de rester exhaustifs mais il est évident que nous serons confrontés assez rapidement à des problèmes de choix.

Peter DUSEK

Thank you for your contributions. I would now like to welcome Walter Plaschzug. Born in the mid-1960s, he is part of the new generation of dynamic young technicians who grew up with computers. He studied at the Technical University in Graz and quickly moved on to the Johanneum Research Group, where he developed projects such as Limelight. He now works in a small firm that deals specially in the restoration of film. He will speak about User Controlled Affordable Film Manipulation and Restoration through Support of High Performance Computing.

User Controlled, affordable Film Manipulation and Restoration by support of High Performance Computing

Walter Plaschzug
HS-ART Digital Service GmbH - Austria

Introduction

Digital restoration as an application to preserve and improve quality of film and video-material is now successfully established and has its place in film and video treatment. This is due to the strong growing IT-market and increasing performance-to-price-ratio of the processing-hardware experienced during the past 20 years.

Up to now only hardware based solutions have been capable to deal with real-time. Whereas real-time restoration devices started with simple noise suppression (e.g.: MNR) some 10 years ago, we can today make use of very sophisticated devices. But the variety and diversity of film imposes restrictions to such automated devices, therefore software based solutions on standard platforms still have room. Be it as extension and enhancement of automated devices or for special purposes (high resolution, shooting incidents, etc.).

Approaches

One main criteria to classify different restoration technologies are the access-capabilities to the frames of the moving image sequence:

- Single image access

  This is a rather simple approach, which results in single image manipulation. Only one frame at a time can be accessed and manipulated. There is no flow of information between the frames implemented in the system. This has to be done by the operator using the system. This method is today more or less obsolete.

- Sliding Window access

  This architectures allows to keep several frames in memory. For processing the current frame the information from all frames currently in the window can be used. As an example for this architecture we can see a typical dust-removal routine, which takes the motion compensated neighbouring frames in order to detect and eliminate dust. This is a typical approach for hardware and real-time solutions, but also most of the software solutions are based on that technique.

- Random access

  This is certainly the most sophisticated architecture. It allows full access at any frame of the moving image sequence. Due to the nature of this approach there is need for a central storage media, which allows random access to the frames. Due to restrictions of computing-power and disk-capacity this approach is only practically possible since a very few years. Increasing hardware-performance brought us today down to a level, where this sophisticated approach becomes reasonable for large scale film and video restoration. As an example you may consider image stabilisation, where the stabilisation-routine works best after having analysed all frames of a cut. Re-arrangement of cuts, according to functional necessities are another example, which can be managed optimal in this architecture.

Restoration Process

Considering the Random Access Architecture as optimal we will work on more details on that option.

The digital restoration process includes all steps from the scanning of the film, image sequence processing, up to the printing of the restored image sequence (see **Figure 1**).

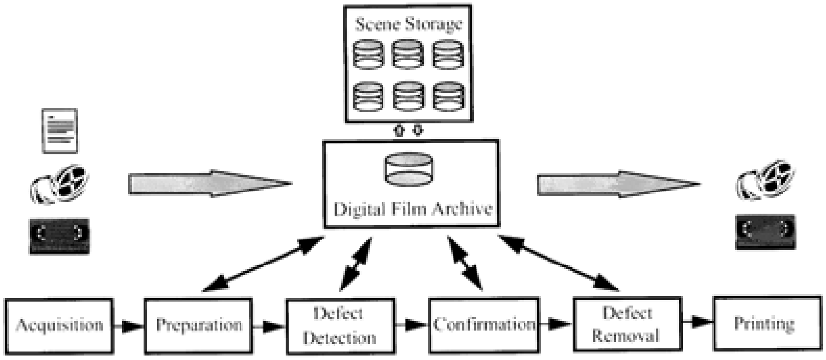

Figure 1 : **Digital Restoration System**

In the acquisition process information is transformed from the analogue to the digital domain. The acquired data consists of the image sequence itself, technical attributes of the scanned film (e.g. scanning parameter, calibration data) and art-historical annotations (background information like director, copyright owner, the place where the film has been found, etc.). All this data is stored in a repository, called Digital Film Archive. Every step of the restoration process is recorded in a log, which is also stored in the repository, in order to provide a transparent processing history for the operator.

In the preparation phase a first analysis of the image sequence is made semi-automatically. It may include motion detection, image partitioning and generation of annotation-data like scene cuts, camera movement etc. Completely destroyed frames shall also be discovered and logged. Scenes are the units for all further analysis steps. An expert is supported by the hints of the analysis software to decide, which classes of defects are analysed for a distinct scene.

The detection of defects is the central step in the restoration process. Each scene is investigated with respect to the pre-processed data and the desired defects like dust, dirt and image vibrations. The results of this analysis are stored in the repository and are suggested to the expert. He can follow the suggestions of the system or can do corrections on the analysis data before the removal of defects is done. Defect removal depends on the defect class. The restored film can then be stored permanently (printed back to film, video or digital tapes).

DIAMANT

The development of a common platform supporting the manipulation of moving image sequences in an easy (from the user's point of view) and fast way (consider the million of meters of film stored by the film archives) on the one hand supports the immediate needs of the audio-visual archives and media companies in Europe, on the other hand using the basic functionality of this platform new applications manipulating digital film will be developed and implemented.

DIAMANT's objective is to build up a scalable digital film manipulation system by means of commercial off-the-shelf computation hardware (PCs) and high-speed interconnect hardware (SCI). The system is based on inexpensive hardware equipped with an intuitive and easy to use software system for the manipulation of moving image sequences. Open interfaces will allow technology providers (e.g.: hardware-devices, annotation-software and restoration-software), to prepare their own components within the DIAMANT system.

Repository for media objects

DIAMANT will develop a very large scale co-operative repository for media objects (film and video). This system integrates a high performance file system, a media database and a distributed object model for media and I/O objects.

A repository has only value if it contains content. Content in our case does usually come from external sources (e.g.: film reels, video tapes,..). Devices which deal with that external content are widely used. Therefore a standardised, open interface will be developed which allows full integration of such devices into the repository. As a consequence the operator can manage all devices from one access-point.

Beside the pilot of digital restoration, further applications dealing with large media objects will benefit from the system features:

- Very high bandwidth (200 MB/s)

The network software development inside DIAMANT enables to set up a high performance shared file system for distributed computers based on standard operating system interfaces. All distributed storage environment applications with the requirement of handling large amount of data can benefit from this application of SCI (Scaleable Coherent Interface) interconnect technology. The targeted system throughput exceeds significantly today's solutions in the domain of Storage Area Networks. This bandwidth is demanded for the case of high resolution film restoration.

- Optimally distributed

Multimedia objects will be automatically distributed among resources inside the system. The optimisation software to be developed will allow automatic load balancing, which takes all system resources (storage, network, computation, I/O) into account. The optimisation algorithms will be implemented as a learning system. The available hardware resources will be used optimal by implementation of a discrete optimisation approach or a neural network model.

- Extended object set

Objects which are handled by the system are based on standard file system objects (file, directory, ..). This set is extended by an image sequence (uncompressed film and video) object with application specific semantics. The concept takes care of further media objects (large images, audio ...). Further application areas of the distributed media object manipulation system can be seen in the domain of special effects, medical imaging and remote sensing.

- Unique resource names

To avoid confusion by using file names and file systems located on different machines unique resource names (URN) in conjunction with a name broker will be used.

- Object persistence

Objects will be administrated in a hierarchical file system with a strong historical aspect; e.g. if an object is recorded to 35 mm film or a backup was prepared and if afterwards the data are freed the object still can be seen and manipulated on the DIAMANT desktop although the original data have been deleted.

- Autonomous object servers

The knowledge about objects is available through object servers. If an application (e.g.: restoration) requests an object or storage space, it starts to negotiate with the autonomous object servers in the system. That means that no central database holds all the knowledge about objects, so scaling of the system is easily possible. Additionally the risk for a failure of the whole system is minimised by this approach.

Automatic Restoration Agent (ARA)

The Automatic Restoration Agent is considered as a pilot application, which will make use of the repository for media objects. It deals with the implementation and integration of digital film restoration methods and tools on top of the media object repository.

Basic restoration routines are being defined as general as possible. The publication of the interface will allow any restoration routine provider to make use of the underlying structure. For each defect-class, which is defined an appropriate routine may be implemented.

The concept of restoration jobs will allow to bundle several basic restoration routines into one job, which can then be applied on a digital moving image sequence.

The user-interface will be strongly application-oriented and not technical at all. The operator does not have to care about underlying hardware or software structures. He simply does his job, which is dealing with film, not with the technical configuration of the equipment.

Co-operation of developers and end-users

The DIAMANT project starts January, 2000 and will be a 24 month effort.

The consortium consists of representatives from research institutions from Austria (expertise in image sequence analysis and manipulation) and UK (expertise in distributed and high performance computing).

The user partners (film laboratory and film museum) contribute with their knowledge and background. Practical experiences in film and video post-production, traditional and digital film restoration and archiving issues, contribute to the specification of the user requirements and evaluation of the prototype system.

The industry partners come from different domains. High speed networking equipment, solutions for image manipulation and restoration and marketing experts in information access from archives shall help to turn the project into a success.

One of the main intention of DIAMANT is to establish a new way of co-operation between end-users and developers. DIAMANT will produce a framework and standards which shall attract industry-suppliers and end-users to find a common platform for film manipulation methods.

The partners forming the consortium are ready to extend the user-partner group by some additional structure. A proposal for an accompanying measure is being prepared, which shall be the framework for extensive user integration and the ambitious goal to early involve interested parties throughout Europe. Beside the technical effort, especially during the first and last 6 months, extensive contacts to potential user-groups are being initiated. Within DIAMANT a strong relationship to several initiatives is planned. Information exchange with international projects like EBU´s MetaData project "P/Meta" and FIAT´s "Cataloguing and Restoration of Endangered Material" initiative is a must in order to build-up on a strong basis.

For further information and possibilities to engage in the accompanying measures project please contact the author of this article.

Discussion

Jim LINDNER

In describing the storage repository, you mentioned a 200 megabit band-width. That is at least twice the amount currently available on the SCSI drives available on the consumer market. Yet, you stated that the system was designed for "standard platforms". Similarly, the system on standard PCs (in the US) is only equipped for 150-megabits. Are you planning ahead for the arrival of new hardware?

Walter PLASCHZUG

It is important to make the distinction between SCSI technology, which is already available at a reasonable price, and future machines, whose capacity will most certainly exceed 200 megabits.

Peter DUSEK

Our next lecturer is Jean-Hugues Chenot. His career is similar to that of his Austrian counterpart. After having completed Ecole Polytechnique in France, he moved on to INA (EDP Department), where he specialises in video restoration techniques. He will discuss Recent Tools for Making Broadcast Programmes Ooing ut of Archives.

Le Projet Aurora: Outils pour la création de programmes de qualité 'broadcast' à base d'archives

Jean-Hugues Chenot
Institut National de l'Audiovisuel - France

1. Introduction

L'explosion récente du nombre de canaux de diffusion hertzienne, satellite, et câblée, l'édition vidéo et DVD, et l'apparition des services de vidéo à la demande et de services multimédia, génèrent une demande croissante de programmes audiovisuels. Cette demande fait des archives des télévisions les gardiens d'une immense fortune faite de documents d'archives. Mais l'exploitation des ces documents est rendue difficile par les coûts et délais importants de restauration de ces documents, pour atteindre le niveau de qualité attendu. L'exploitation à grande échelle des archives de télévision dépend donc de la possibilité de les restaurer efficacement et économiquement. Les bénéfices tiré de l'exploitation commerciale de ces documents restaurés permettront d'aider les archivistes à obtenir les moyens de préserver notre héritage audiovisuel.

Au sein des archives des diffuseurs, la plupart des formats de stockage (principalement les enregistrements vidéo comme le 2 pouces, le 1 pouce B et C, les 3/4 U-matic et BVU) sont gagnées par l'obsolescence. Pour certains formats, il est quasiment impossible de trouver des machines pour la relecture. Même si les machines de lecture sont disponibles, il est coûteux de les maintenir en état de fonctionnement, et les pièces de rechange sont difficile à trouver. En ce qui concerne les documents stockés sur film, les principales difficultés proviennent des conditions de stockage, des manipulations, et du vieillissement naturel des supports. L'ensemble de ces facteurs fait que les programmes d'archives sont souvent affectés par des défauts de relecture. La relecture dans des conditions optimale de documents anciens mérite des développements qui ne seront pas adressés ici. Cependant il est possible de traiter certains défauts dans le domaine vidéo après relecture.

2. Contraintes sur les outils pour la restauration des archives de télévision

Lorsqu'on doit restaurer un programme d'archives, la contrainte principale est celle d'une qualité suffisante pour la diffusion. On doit éviter au maximum les dégradations à tous les niveaux de la chaîne de transfert. La compression doit être autant que possible évitée, car certains des défauts les plus communs, tels que le bruit et le grain, en limitent considérablement l'efficacité, et affectent de manière irréversible la qualité après restauration. L'œil est un très mauvais juge sur ce point : des marges de sécurité considérables doivent être prises.

La plupart des initiatives pour restaurer des programmes de télévision viennent d'une demande commerciale externe ou interne. L'objectif de la restauration est habituellement vendre ou exploiter le programme pour deux principaux cas d'utilisation :

- *Rediffusion ou distribution vidéo de documents complets.*
- *Utilisation d'extraits dans la création de nouveaux programmes, documentaires par exemple. Dans ce dernier cas, le tarif à la minute utilisée sera plus élevé.*

En outre, il convient de noter qu'il y a une variation importante entre les coûts supportables pour la restauration , en fonction de l'utilisation du programme (par exemple, on ne s'attend pas à ce que des chaînes hertziennes et les chaînes câblées payent le même prix pour le même programme). Dans la pratique, les contraintes de qualité, aussi bien que des contraintes économiques, viennent des clients : producteurs, qui tireront profit des extraits d'archives pour développer de nouveaux programmes, et diffuseurs et éditeurs, qui réutiliseront les documents complets d'archives. Une conséquence immédiate est que la restauration doit être assez flexible et assez bon marché pour fournir le niveau désiré de qualité à un prix raisonnable. Les coûts associés doivent être compatibles avec les tarif pratiqués, qui sont inférieurs de plusieurs ordres de grandeur aux coûts d'une production nouvelle.

Les coûts de restauration sont principalement constitués des coûts de main-d'œuvre. Le rapport de temps, c.-à-d. le temps consommé pour restaurer une heure de programme, est en général largement supérieur à 10 pour 1. En conséquence, tout ce qui peut favoriser l'efficacité de la restauration sans affecter la qualité aidera les archivistes, les producteurs, et les diffuseurs à exploiter les archives.

Une autre contrainte est le temps de restauration : les archives, qui détiennent des programmes déjà existants, peuvent facilement concurrencer de nouvelles productions en termes de livraison à court terme. Cependant, la restauration consomme un temps non négligeable qui doit être limité autant que possible : si une ou deux semaines peuvent encore être acceptables, un mois pourrait excessivement réduire les opportunités d'exploitation d'un programme.

La répétabilité est souvent une contrainte sous-estimée. Les outils utilisés aujourd'hui pour restaurer des émissions télévisées présentent un grand nombre d'interfaces différentes et incompatibles. L'opérateur est contraint d'agir sur les différents sous-ensembles dans une ordre spécifique. Même lorsque les outils permettent d'enregistrer des listes de montage ou des instructions timecodées, l'absence d'un outil centralisé commun empêche le stockage, dans un simple fichier, de toutes les instructions nécessaires pour répéter le travail de restauration. En conséquence, un changement de dernière minute, par exemple requis pendant le contrôle final, peut mener à re-éditer une séquence entière, entraînant de nombreuses manipulations manuelles et des risques d'erreur.

3. Outils existants

La restauration des documents de télévision est actuellement principalement exécutée en utilisant des réducteurs de bruit : ces dispositifs sont raisonnablement performants sur un niveau limité de bruit aléatoire et de bruit impulsif. Une restauration meilleure et plus fiable exige une estimation et une compensation de mouvement au niveau du pixel. La plupart de ces dispositifs permettent de la correction d'ouverture, et de la correction de couleur, mais leur limitation principale est due au fait que ce sont les outils en temps réel, et qu'ils ne sont pas conçus pour la restauration des programmes particulièrement endommagés. Quand il n'est pas possible de corriger les défauts, on utilise souvent des outils de montage pour supprimer les séquences affectés. Même dans ce cas, le manque de flexibilité, et parfois la complexité des outils, demande à l'utilisateur de passer un temps considérable à préparer des suites complexes d'opérations.

Certains outils utilisant des disques pour le stockage, destinés aux effets spéciaux et l'édition non linéaire sont parfois utilisées pour la restauration de séquences. Dans ce cadre, ces systèmes sont généralement utilisés en tant qu'outils de rotoscopage, pour la correction semi-interactive de salissures et de rayures, et pour la stabilisation d'image. La plupart de ces dispositifs demandent une implication considérable de l'opérateur pour donner un résultat acceptable. Dans certains cas, des filtres peuvent être appliqués aux images, avec des temps très longs de traitement, et permettent de réduire le bruit et le grain. L'inconvénient principal de ces outils est le temps très long passé par image, même en utilisant des systèmes multiprocesseurs. Un taux de plusieurs images par minute est inacceptable dans le contexte de la réutilisation de programme pour la diffusion. Un deuxième inconvénient est le manque de filtres spécifiquement conçus pour la restauration.

4. Les besoins de l'utilisateur

Le projet d'Aurora qui a démarré fin 1995, avait comme objectif principal la construction d'un prototype d'outil de restauration d'archives télévision et film, opérant sur de la vidéo numérique. L'analyse des contraintes, et des outils existants, récapitulé ci-dessus, a mené aux principes suivantes pour le futur système de restauration d'archives de télévision :

- Le système travaillerait en temps réel, bande à bande, pour la plus grande partie des programmes. Le traitement en différé, trop long, serait réservé autant que possible pour des effets complexes sur de très courtes séquences.
- Le système serait entièrement intégré : l'opérateur donnerait simplement les instructions au système sur les défauts à traiter, sans nécessairement préciser comment y arriver. Par exemple,
    - "Ici il y a une salissure à corriger"
    - "L'image est correcte dans cette zone"
    - "Appliquer telle filtre à partir de maintenant/pour ce plan"
    - "Appliquer tel traitement pour cette image"

- Toutes les opérations seraient enregistrées dans un "Plan de Restauration", qui serait modifiable jusqu'à la dernière minute, il serait possible de conformer le résultat à la demande (par exemple quand le magnétoscope enregistreur est disponible). Pour cela, l'intégration devait être assez complète pour que l'opérateur ne soit pas tenté d'utiliser manuellement les différents outils, ce qui aurait rendu le Plan de Restauration sans objet.
- Le système utiliserait de l'estimation et de la compensation de mouvement, pixel par pixel. C'était la seule voie pour automatiser une correction efficace de salissures et de drop-outs, et améliorer la réduction de bruit et de grain. Pour le moment, et pendant plusieurs années encore, un tel traitement en temps réel exigera une puissance de calcul largement supérieure à celles des calculateurs. Ceci entraînait donc le développement d'équipements électroniques temps-réel.
- Des outils de montage seraient intégrés, pour permettre une correction locale ou supprimer des sections endommagées.
- Il y aurait une intégration complète entre le mode bande-à-bande en temps réel, où le traitement se poursuit sans interruption, et le mode off-line, où l'utilisateur pourrait intervenir au niveau de l'image ou de la zone. Les retards associés aux preroll des magnétoscopes seraient supprimés. Ces conditions demandaient un stockage temporaire (cache) sur disque des images et des sons. La durée du cache n'est plus une limitation : les enregistreurs vidéo à disque contiennent actuellement sans problème une heure de vidéo non comprimée. Mais le chargement

et le déchargement du cache devaient fonctionner en tâche de fond sans affecter la partie interactive du travail.

Ce scénario suppose que les supports source et résultat sont les cassettes vidéo numériques non comprimées. Naturellement, des adaptations peuvent être trouvées pour un environnement où les programmes sont enregistrés sur un serveur vidéo. Cependant, des précautions doivent être prises :

- On ne doit pas utiliser de compression, ou limiter celle-ci au strict minimum . En-dessous de 25 Mbps il y a un risque d'endommager le document source, gaspillant ainsi l'effort de restauration.
- Les résultats (Plan de Restauration, programme restauré) devraient être archivés, en utilisant un format stable et de qualité 'broadcast'. Garder seulement une copie de distribution (2 à 12 Mbps) peut ne pas être suffisant pour re-exploiter plus tard le programme restauré, et peut demander une nouvelle exécution du plan de restauration, qui peut s'avérer difficile plusieurs années après.

5. Développement du système

La nature ambitieuse du projet a exigé des avancées significatives dans le domaine des algorithmes de traitement de vidéo en temps réel. La recherche a été conduite par les universités de Cambridge, de Delft et de Tampere, ainsi que par BBC R&D et l'INA. Snell&Wilcox a développé le système de traitement vidéo temps réel. L'INA a développé le logiciel et SGT le contrôleur temps réel.

Le système développé fournit en temps-réel les fonctionnalités suivantes :

- Détection, et correction de salissures et éclats de gélatine, et de drop-outs,
- Détection et correction de rayures film,
- Réduction de grain et de bruit,
- Correction de pompage,
- Stabilisation,
- Correction de contour,
- Correction colorimétrique.

L'interface offre l'accès aux fonctions suivantes :

- Multiples modes opératoires : temps-réel pur, avec ou sans interventions de l'opérateur, possibilité de passes multiples.
- Contrôle temps-réel de l'ensemble des équipements.
- Contrôle fin de paramètres sur une séquence courte tournant en boucle.
- Réglages particuliers dans des zones désignées à un timecode donné ('rustines').
- Reconstruction d'images ou de trames manquantes.
- Préparation, sauvegarde, et rappel de Plans de Restauration, avec stockage complet dans un fichier texte de l'ensemble des opérations effectuées au cours de la restauration d'un document spécifique.

6. Résultats

Le système a été intensivement testé par les trois partenaires utilisateurs, BBC, RTP, et INA. Des centaines d'heures de programmes ont été traités en utilisant les prototypes développés.

L'évaluation du système a donné lieu aux commentaires suivants :

- Le fait de pouvoir spécifier des corrections à appliquer à un timecode particulier est très utile.
- Le réglage fin d'un paramètre sur une séquence jouée en boucle a été apprécié.
- Le débruitage récursif avec compensation de mouvement est très efficace.
- La correction de défauts impulsifs (salissures, éclats de gélatine, drop-outs) est puissante, son absence d'effets sur les textures est particulièrement appréciée. Ceci est considéré comme un point fort par rapport aux débruiteurs existants.
- La correction d'instabilité et de pompage dépasse tout autre système, et ceci sans effet visible sur les textures. Auparavant, le seul moyen pour tenter de corriger ce type de défauts, était de pousser au maximum les filtres récursifs, avec des résultats limites, et des artefacts sur les textures.
- D'une façon générale, les défauts sont bien corrigés, chacun indépendamment par un filtre spécifique sans affecter les textures.

L'impression globale était bonne. Le système offre clairement des possibilités intéressantes de faciliter et d'accélérer le travail de restauration. A l'INA, après une nécessaire période d'accoutumance, les opérateurs ont atteint un rapport de temps de 6 à 1 (6 heures d'exécution pour 1 heure restaurée). Sur les mêmes programmes, ce rapport aurait été de 30 pour 1 sur les anciennes chaînes de restauration. Le temps gagné se trouve surtout dans la correction automatique d'instabilité et de pompage, et dans la puissance de la correction de salissures film. Un nombre très élevé de points de montage aurait été nécessaire en utilisant des outils traditionnels, avec un résultat inférieur.

7. Conclusion et développements futurs

Le projet est maintenant terminé. Pendant ces trois années, des progrès considérables ont été réalisés, dans le domaine du traitement en temps réel, apportant dans la plupart des cas des progrès significatifs sur les réducteurs de bruit existants. En même temps, l'approche intégrée pour la restauration a prouvé son efficacité en réduisant le temps passé à restaurer des documents d'archives. Le prototype est en service depuis plus d'une année maintenant, et les développements supplémentaires sont en cours pour étendre les fonctionnalités et progresser vers une commercialisation. Des systèmes basés sur les résultat du projet seront commercialisés pendant l'année 2000.

Les développements sont maintenant orientés vers un niveau plus élevé d'automatisation : parmi les décisions actuelles prises par l'opérateur, la plus grande part est prévisible. L'objectif est de limiter les interventions de l'opérateur aux décisions de haut niveau, comme le choix des stratégies de restauration et les corrections de décisions prises par le système. De plus, on veut élargir la gamme des défauts corrigés, pour pouvoir traiter en temps-réel un ensemble de plus en plus étendu de programmes d'archives.

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Discussion

George BROCK-NANNESTAD

In one of your slides, you mentioned the need to develop concrete requirements. What parameters do you use to measure quality?

Jean-Hugues CHENOT

When we launch a specific programme, a quality assessment test is carried out by an experienced engineer. The person states what might be achieved in a variety of situations and indicates what kind of quality can be expected within a given timeframe. For example, they might state that Level I could be reached in three hours. They base their judgements on prior experience.

From the floor

I saw this system at the IBC and was very impressed by what you have managed to achieve. In particular, I was impressed to see that you had eliminated typical defects, such as flicker, scratches and jumping. Why do you not continue to work on film resolution? You have performed such effective work. Why limit yourselves to broadcast resolution? We often restore old films for TV and are faced with problems that you may be able to solve within the next year or two years. It is very frustrating to work only on television resolution. Why do you not work on higher resolutions? Other companies may win the race, despite being intrinsically less qualified than you are. Real-time is not a necessity in this situation.

Jean-Hugues CHENOT

We did not even try to compute the processing power necessary to perform the same work in real time. It is probably 1 000 to 10 000 higher. It is incredible. Our users wanted real-time and our partners were able to develop it. At some point, one must choose between real-time and software-based systems. Disk-based and software-based systems allow one the possibility of running on octane. However, the processing time is much longer. We did not want to go over 10 hours of processing time per hour of recording. It is impossible to achieve this without using the SDI-in/SDI-out method. We decided that our priority was real-time.
Now that the equipment can offer broadcast-quality results from archives, we have begun considering using the same machine for HD. However, the hardware unit required for HD work is four times larger than that required by the current system. That gives you some idea of the type of equipment needed for performing HD. Software computing and HD might be developed at another time. I was very interested to hear the previous speaker broach on that topic. Ours is a totally different way of thinking, based principally on economical requirements.

Sean DAVIS

You showed some accidental interventions that produced unexpected results. This would mean that, when working with processed programmes, one would have to be very careful if high levels of concentration were encountered. Would it be possible to develop some kind of parallel display indicating where some of the interventions have occurred? That would allow us to view only the part of the picture that is most important.

Jean-Hugues CHENOT

Yes, that is possible. By activating the de-bug mode, we would be able to see where the correction was applied. We could run two passes, the first in de-bug mode and the second in a normal mode. We do not yet do that.

Michael FRIEND, FIAF Technical Commission

I have two suggestions regarding the future development of your system. Firstly, when we perform telecine transfer, marking all of the changes and laying down the transfer, we can interpose those changes any number of times on the same element. Would it not be appropriate to make a software log of the changes you create, so as to use it when working on super-high definition (1920 x 1080, or higher). Your work could be re-performed at a much higher level of resolution, using exactly the same changes and corrections.
Secondly, when we restore high-definition digital video, we have great problems tracking the work we perform and the changes we have made. Workflow software for high-definition correction will prove to be an important tool in the future for both automated and non-automated processing. These two elements, which I have discovered over the course of my work, will be essential in the future.

Jean-Hugues CHENOT

Our processing methods include a restoration module. It remembers all of the actions that are linked to a certain process. The system was obviously designed to prevent any oversight in the transfer process. Your point is well-taken. We intended to archive our restoration plans in any case. I do not know if we will be able to apply your suggestion since the systems may not be compatible.
As far as tracking HD work, it is necessary, but not always easy. The situation is much more complicated when many devices are involved. We have not managed to integrate everything into one machine, but have at least tried to keep all of the information in a central location.

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III

LES SYSTÈMES DE GESTION DE L'INFORMATION ET LES STRATÉGIES DE MIGRATION

DATA MANAGEMENT SYSTEMS AND MIGRATION STRATEGIES

—— ——

Modérateur/Moderator : Peter Dusek, FIAT President and ORF Head of Documentation and Archives

Peter DUSEK

We will now discuss Data Management Systems and Migration Strategy. Werner Deutsch is Head of the Austrian Research Institute (Austrian Academy of Science, Vienna). His special research topics include Speech, Music and Digital Signal Processing since 1986. He is one of the pioneers of this field, having undertaken his research when no one realised the importance of the matter. He is currently leading a Work Group network on digitisation, known as Harmonica. He will share his ideas on Segmentation of Sound for Content Description.

The concept of stratification is a relatively new concept in advanced documentation of audio and video material, or, more generally speaking, time-based media. Stratification is based on multiple levels of descriptions, with each level being segmented by in-points and out-points and referring to different aspects of the essence to be described. Figure 6 shows an example for this, where three copies of the essence exist in different qualities and on different carriers (preview, hi-res, tape), and where various strata refer to different attributes of the essence (persons, background, objects, subtitles, IPR, image content). Both the essence and the strata are time-based and linked to each other via timestamps. This concept allows for a very flexible documentation of time-based media, taking into consideration that depending on the purpose, different aspects of the essence are relevant for the librarians. It also allows for a fine granularity of documentation with the annotations referring to specified time segments within the time-based media.

A Generic Hardware Architecture

Digital television production is a very demanding task for information technology equipment. This becomes clear by taking a look at the storage requirements and the data throughput requirements which are associated with handling production quality audio and video in an IT-based environment. The highest audio quality level, which is uncompressed waveform, requires a data transfer rate of 1.5 Mbit/sec, which results in a storage requirement of about 680 MByte/h, which translates into 60 TByte for 100,000 hours. In the video world, the same kind of transfer rate and storage requirement applies to preview quality video in MPEG-1 format. Production quality video in which each single frame is accessible, as it is used in production video servers and non-linear editing suites, typically comes with the transfer rate of about 50 Mbit/sec, which results in a storage requirement of 23 GByte/h or 2.3 PBytes per 100,000 hours.

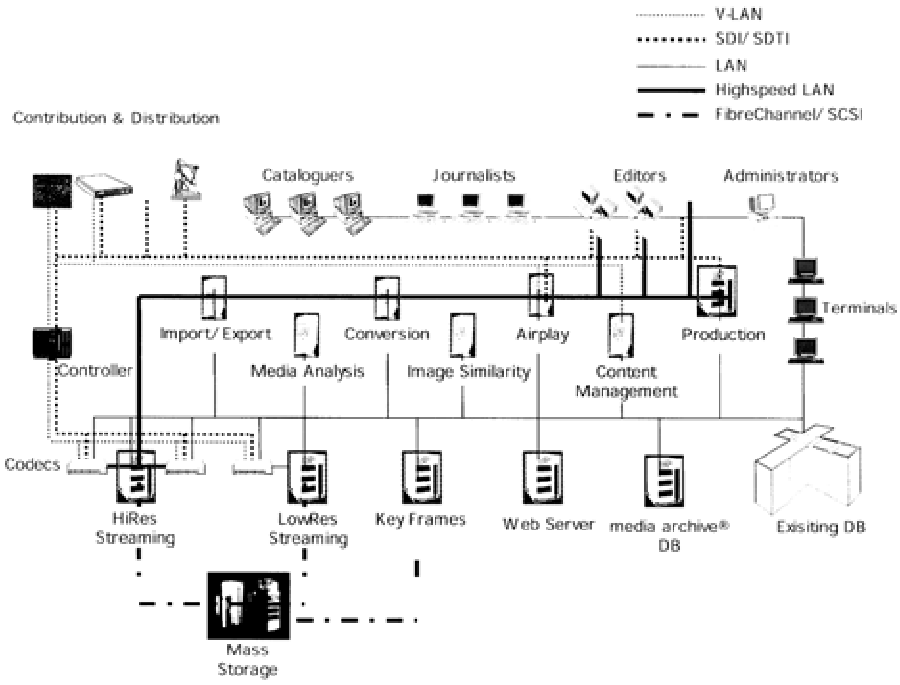


Fig. 7: A Generic Hardware Architecture for Content Management Systems

Due to these extreme I/O and storage requirements, the hardware architecture underlying content management systems in broadcasting today typically are hybrid architectures including both IT and audio/video hardware components. Along with a high speed network, they typically include a central matrix switch (SDI/SDTI), IT and audio/video servers and workstations.

Incoming feeds and footage are recorded to high resolution and low resolution streaming servers via browse quality and production quality codecs (Fig. 7). These servers are connected to a mass storage system, typically a tape library using either data cartridges or video cassettes for mass storage. Numerous servers provide different services like play-out of production quality and browse quality, audio and video material, video analysis, full-text retrieval, image similarity based search, format conversion services and database management. From the desktop PCs, the journalists can access the content management systems database, can retrieve the items they are looking for and playback the browse audio and video on their desktop PCs. After selecting the required material and putting together an

EDL, they transfer it to the post-production area where cutters put together the item on non-linear editing suites. These non-linear editing suites are connected to the hi-res streaming server either by a central matrix switch or by a high-speed network. The finished items then are transferred to a play-out server from which they are played to air.

In this architecture, the hi-res and the low-res streaming servers and the mass storage system form a storage hierarchy which is managed by a hierarchical storage management system (HSM). The HSM system takes care of automatic migration of essence between the online and near-line storage levels.

A Commercial Perspective

- Cost Reduction
  by...
  - improved process efficiency
  - reduced costs for content perservation
  - reduced production costs
  - rapid cost decreases in standard IT equipment
- Profit Increases
  by ...
  - improved quality of programmes
  - optimal reuse of content
  - sales of archive content

Fig. 8: A Commercial Perspective

Integrated content management systems in broadcast production and archiving induce a number of benefits. They improve workflows and process efficiency, thus reducing costs for content preservation and production. Since they make use of standard IT components, rapid cost decreases and performance increases can be expected for the future. On the revenue side, integrated content management systems can contribute to an improved quality of programs by making access to content easier and more efficient, and by stimulating the editors' and journalists' creativity. They also make re-use of content much easier, thus contributing to generating the maximum revenue of content once produced. Last but not least, they provide the option of selling archive stock via new sales channels like the Internet.

Discussion

Albrecht HÄFNER

Thank you for this impressive presentation, which gave us an idea of how video contents and archives can be designed and managed.

Bob CURTIS-JOHNSON

I would like to touch on a few points. In the 1980s, when I was in the field of post-production, CMX was in the process of testing a voice-controlled editing system. It was rejected by the editors, who did not want to talk all day long.
You also mentioned stratifying resolution for input, especially on video media. When you stored four different resolutions, at what point did you reach the saturation point? It might have been easier to maintain a high-resolution for the input and a low-resolution system for the various types of output.

Rainer KELLERHALS

That is indeed a second option: creating only high-resolution copy and deriving low-resolution material from that. However, each of the encoding processes must take place in real-time. We are therefore forced to wait for the low-resolution copy to be created.

Albrecht HÄFNER

Our third speaker will explain how to transfer large collections from the analogue domain into the digital mastering system. Joerg Houpert studied Electrical Engineering at the University of Bremen. Since 1994, he is the President of Spectral Design Signal Processing, an organisation that performs research on the digitisation of audio archives.

Transfer of Large Collections from the Analogue Domain into Digital Mass Storage Systems - Challenge and Response.

Jörg Houpert
(Houpert Digital Audio) - Allemagne

Most broadcasting companies hold very large sound archives where preservation and handling needs a lot of manpower and money. The stock of a middle range German radio station's sound archive consists of about 20 to 30 years continuous audio material, e. g. 500,000 1/4» magnetic tapes, 150,000 vinyl records and shellacs, 100,000 CD's and CD-R's and 10,000 DAT cassettes. And yearly the archives are growing by large amounts.

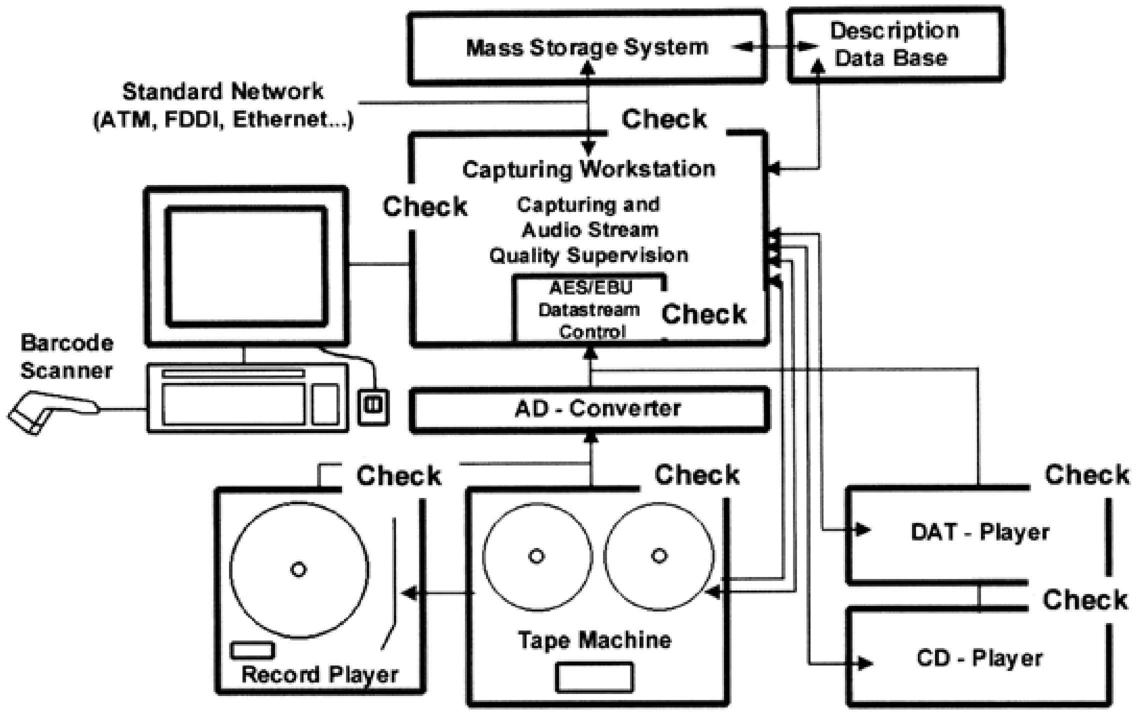
The question which special digital sound carrier is most qualified for archival purposes will be of decreasing importance, due to the lossless copying of digital sound recordings, a process which can be easily automated. Considerations concerning the long term stability of analogue sound carriers do no longer focus on what life time could be expected and how ageing processes could effect the technical quality. Instead, the question arises how to guarantee the reliable safeguarding of those data representing the sound recording by use of any storage media in a totally automated way. Nowadays, methods used in computer processing which offer extreme high protection against loss of data, are applicable. The copying process needed requires only a small part of that time expense which corresponds to the run of the audio information. The change of paradigm from the 'eternal sound carrier' into the 'eternal audio data' allows audio files which represent the sound recordings in its original technical quality and can be considered as being independent from any storage medium.

Transfer Errors from Analogue to Digital – Safety First

An optimal quality controlled transfer from the analogue to the digital domain is required. For safeguarding historical sound recordings, the Digital Audio Workstation (DAW) presented here supports the human-ear monitoring of the sound operator with effective controlling of the copying process from the analogue sound carrier to the digital BWF file by monitoring and protocolling the relevant quality parameters. The copying process can be disturbed by defects of the storage medium, malfunction of the playback machine or other errors in the transmission chain. In order to guarantee optimal digital audio data stored in the BWF file, the DAW shall be able to detect all re-recording errors. Provided that all components of the playback system operate perfectly, nearly all detected errors are caused by medium defects. Some of the errors, e. g. on magnetic tape recordings, are drop-outs, analogue and digital clippings, clicks, print-through, azimuth, bad splice and wow and flutter. All audio data defects and system errors have to be documented in the quality protocol stored in the quality chunk of the BWF file. To relieve the operator from detecting audio errors and to minimize the time and costs for digitization and restoration, a computer aided quality monitoring process is necessary. The analysis of the audio signal, transmission chain quality characteristics, archive requirements, as well as the demands for an ergonomic re-recording station, determine important requirements for the workstation. In principle the following error classes may occur during safeguarding:

1. Errors caused by the recording and/or re-recording equipment,
2. Errors caused by the medium, e. g. magnetic tape or record,
3. Errors caused by the operator.

Because of sometimes boring situations and to eliminate human errors, the DAW has to supervise the sound operator. But as the last authority the sound engineer has to decide whether errors are tolerable or not.



The whole Migration Chain

The transfer process has to be analyzed for the necessity of each step with an optimized guidance of the user. All potential error sources have to be ruled out by supervising methods and fail-safe routines. Signals from analogue sources such as magnetic tape recorders and record players will be digitized by sophisticated AD converters, while CD- and DAT- players (juke boxes) will be connected by AES/EBU interfaces. All devices should be remotely controlled by the capturing workstation and the playback equipment should be monitored at all times. The AES/EBU status information and the digital audio signal should be monitored each in a different but parallel process.
During the capturing of the audio, all events can be verified without stopping the transfer process. The audio data will be stored in a BWF file and thus can be stored in the input buffer of mass storage systems via LAN connection. Alternatively, the BWF file can be stored on a single carrier, while copies of the file will be available in MPEG or RealAudio format for online access.

Now the three areas of supervision will be explained in detail: 1. AES/EBU data stream; 2. Player – analog magnetic tape machine; 3. Real-time audio stream.

AES/EBU DataStream Check

The digital audio input is supervised continuously by the DataStream Checker. Error types and information such as 'No Lock Error', 'Biphase Coding Error', 'Parity Error', 'CRC-Error', 'Validity-Flag-Error', 'Emphasis Mode', 'Non Audio Mode' will be detected. The user bit stream and the channel status bit stream are permanently analysed and all relevant information extracted and displayed in a REPORT window, together with all other detected errors.

Supervision of the Magnetic tape Machine

The remote control of all transport functions such as magnetic tape speed, locator, zero locator, tape loaded, etc., should be integrated as well as the supervision of bad splices, tape transparency (with optical sensor), time code of start and end of leader & separation tape. The automatic recognition of related data, e. g. Telcom noise reduction by leader tape, is obligatory.

Automatic Single Error Detection

Automatic pattern recognition algorithms will automatically detect clicks, crackles, hum & buzz, drop-outs, analog overload (distortion), digital overload (clipping), or groove jumping of records. All this errors will appear with the exact time code information in the

REPORT and will be stored in the quality chunk of the BWF.

Extraction of Audio Quality

To get a description of the overall quality of the captured BWF file, it is good to have knowledge about the average signal-to-noise ratio, average azimuth error, average bandwidth, average stereo correlation, average dynamics, maximum peak, mean Level and DC-offset. All this measurements should be done automatically without extra human resources and must be shown while audio is captured.**Collecting useful Information**

The automatic recognition of the start and end of the audio modulation will be a big time-saver. It will no longer be necessary to cut start and end of the audio modulation manually. Event marks should be automatically set at this points and they can easily be checked aurally or visually. The noise before and after the modulation can be stored in a private chunk in the BWF file, so it will be hidden for every standard wave player, but will be available if needed (for restoration purpose or if the marker was not perfectly set). Pauses (start an end) will be found automatically; this will help to organize the contents. There should be also a device that detects the start and end of speech, music and ambiance.

Manual Error Detection

Visualising tools such as a PPM (according to EBU-R68 and IEC-268)and a stereo master display (goniometer with integrated compatibility meter) are integral parts of the user interface. During capturing and analysis of the audio material, the operator has to be free to go through the REPORT and listen to the automatically detected errors with player remote control for quick A-B comparison between player and file playback. A scrubbing tool with jog and shuttle mode, as known from analogue magnetic tape machines, enables the operator to precisely monitor each detected error and thus easily to determine the causes.

Additional Safety Features

Analogue to the ´read after write´ monitoring function used with magnetic tape machines, the workstation can provide the sound operator and sound engineer with the same security during listening to the audio material stored to the hard disk. Beyond that, the operator must be able to click on already detected errors in the REPORT and check them by listening from the hard disk without interrupting the ongoing re-recording process. A special BWF security code will guarantee the authenticity of the sound signal stored in the WAVE chunk and of the accompanying metadata in the BWF file. This means even years later we can verify that the BWF is in the same condition it appeared when it was cleared as archive file. For additional safety the DAW must perform self tests of hardware and software on each power-up, to assure a faultless working system for each session.

So, if there were a workstation being already available which would be optimized for converting large single media libraries to BWF files, what will the future bring?

OUTLOOK

There is no doubt, there will be further improvements in digital signal processing. The quality of the error detection algorithms will further increase (learning curve in the research and faster processors will allow more advanced and complex algorithms). From the technical side, it is quite possible that there will be improvements with better analogue players which will give better audio quality and offer the possibility to create additional quality describing data (For this please refer to the article from Michael Gerzon [18]).

But there are also warnings against waiting with the digitisation of single carriers held in archives.

- The quality of analogue media is decreasing year by year.
- Unavailability of analogue players such as high quality magnetic tape machines and record players due to obsolescence.
- Specialists, knowing how the old media was produced, will be rare in future.

The decision to use technological progress to preserve the cultural heritage better than it has been done so far will be influenced by the executive's assessment of the value of the content of the archive.

Aside from the exclusivity of the content, the assessment will depend upon:

- the availability of the archive content,
- the usability of archive content,
- the quality and the variety of metadata,
- the accessibility of the metadata.

So, there is a need to achieve this in a most cost-effective way. Let's look at some cost aspect of the capturing process.

Economic View - Some Cost Aspects

The time factor how much time one minute of audio material needs to be captured depends upon a lot of things:

- Is there a need for documentation of the contents?
- Should simple errors be corrected?
- Should the metadata be aligned?

The average length of the audio documents and the audio quality of the analogue media has a tremendous influence on the time needed. A time factor of 1:3 up to 1:5 is an acceptable value for material in good shape.

Now, let's assume that you intend to convert a collections of 20 years continuous audio material on analogue ¼ inch magnetic tapes into a digital mass storage system. If you plan to capture 50 percent of this size in a five year period, you have to transfer two years of continuous audio; this means 17,520 hours every year. If you do the capturing 7 hours a day, with 250 days a year, you will need 30 technicians for the capturing process (with a time factor of 1:3). The cost for this manpower is 1,500,000 €uro per year (30 technicians, each for 50,000 €uro per year) and for the workplaces 500,000 €uro per year. The cost for equipment is 120,000 €uro (30 units for 20,000 €uro each, divided into 5 years). In sum that amounts to 2.12 Mio €uro per year.

If specialized equipment allows reducing the time factor to 1:1.5, the calculation looks something like this: only half of the technicians and workplaces are required; cost for man-power (15 technicians) is 750,000 €uro per year, cost for working place 250,000 €uro per year; the cost for equipment rises to 258,000 €uro. In sum that amounts to 1.258 Mio €uro per year. This means a saving of 41 percent.In this calculation a possible change of qualification of the human resources and the quality of the work, meaning the satisfaction of the technicians, is not taken into account. Imagine your job for the next five years is to listen every day for seven hours to errors on old magnetic tapes. It is most likely that the assumption of this calculation will differ from each personal situation. But the heart of the matter will not be changed by that. The crucial factor are the costs for human resources. The costs of technical equipment are very low compared to the potential saving.

Conclusion

The new concept presented here comprises the whole migration chain from analogue sound carriers to Broadcast Wave Format files. Linear sound quality saves the original audio information for 'eternity'. If necessary, useful interim DAT and CD archives are possible for continuation within broadcasting companies. But the great thing about it is that the digitized sound signal, together with all the interesting additional information as quality protocol, cue sheet, coding history, etc., is stored in the BWF file. The platform-independent Broadcast Wave Format guarantees easy integration of the workstation; and each personal computer is able to play back the wave sound of the BWF. If editors, producers, etc., are connected online by PC or DAW via network to the robotic mass storage sound archives, they are thus able to use these new information centres for effective work.

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Discussion

Albrecht HÄFNER

Thank you for this very interesting presentation.

Sean DAVIES

It is extremely gratifying to see that Michael Gerzon's research is remembered in this way. Considering the automation that must be used, detailed attention cannot be given to the transfer process when moving from the earlier formats (shellac and LP discs) to present day material. The equalisation curves may be very different according to the period of production. To a lesser extent, analogue tape may also show either different equalisations or loosely-controlled calibrations. In such cases, would it be possible use a standard calibration rate that could be incorporated into the file structure so as to allow for alternative equalisations at a later time? We would have the option to improve the medium when we want to play just one recording.

Joerg HOUPERT

That is a very good point. I focused mainly on large archives, where quality is still satisfactory. I agree that, when working with older material, it is worth taking more time. We can perform equalisation and correct speed later if we know how to go about it.

Dietrich SCHÜLLER

Naturally, this installation only works if the tapes were produced under controlled conditions. This is indeed the case for almost all radio broadcast material. They had an excellent lining up of tapes. However, most of the world's audio history (ethnological archives, etc.) was recorded on machines that were not properly aligned. They are even problems in track alignment. When working with such material, we are forced to guess at the proper equalisation level. All of these automatisation measures are of no use unless one can be certain that the material was produced under regular circumstances. When working on old stocks, one must invest far more time (one day for one hour) and money. It has become customary to perform only flat transfer when dealing with old shellac discs. Equalisation is left to a later time.

Segmentation of Sound for Content Description

Werner A. Deutsch
(Österreichische Akademie der Wissenschaften) - Autriche

Paper not submitted

Texte non reçu

****

Peter DUSEK

Asset Management, the next topic, simultaneously involves content, assets and rights. The latter is a particularly important topic, since we must find agreement between all of the stakeholders. FIAT has begun working with a number of bodies, including a Working Group that brings together people from the Radio, Archives, Digitisation and Television industries. In order to further foster his overlapping co-operation, it has organised a number of joint workshops at its next International Convention. If you are interested, please contact us or any of our member organisations. We must forge ahead to develop co-operation and to give rise to better understanding.

Our next speaker, Mrs. Andrea Kalas La Vere, began her career in a film and television archive. She now works in Los Angeles and is a former Vice President and President of AMIA. Whereas FIAT, IASA, ICA, etc. are all international, AMIA is the global organisation. It does not specialise in film or sound alone, but has decided to take up a multi-media challenge. She will present a report on the Digital Asset Management Demonstration at AMIA's November 1999 Conference.

Report on Digital Asset Management Demonstration 1999 AMIA Conference

Andrea Kalas La Vere
(AMIA Digital Archive Interest Group) - USA

The question of digital archiving of entertainment industry assets is one that is challenging technologists, archivists, and professionals in all aspects of making, selling and distributing digital content.

Deciding how to manage this content is a decision many are facing. There are a number of vendors offering a variety of solutions.

For this reason, the Digital Archive Interest Group of the Association of Moving Image Archivists sponsored a DIGITAL ASSET MANAGEMENT DEMONSTRATION

The following vendors were given the same content to demonstrate the varied functionalities of their software:

AT&T
Bulldog
Cinebase
Excalibur
Informix
Mate
PNI
Teams/Artesia

Each had 15 minutes to present their system using sample data that was provided to them in advance of the conference.

The data was a series of broadcast news clips from NBC, and animation data (images, wireframe models, etc) from DreamWorks. Only two vendors used the animation data in their demonstrations, whereas the rest focused on the broadcast footage exclusively.

* Bulldog

Bulldog emphasized customizable workflow engine and GUI. Their demonstration consisted of three different GUIs: (1) a visual effects clip library with custom UI for Sony Imageworks, (2) a web client browser using video footage captured with the Virage video logger, and (3) a Java client with browsing, searching, versioning, and grouping capability. Bulldog claimed their flexible API and database independence makes these sorts of customizations possible.

* PNI / Cinebase

Cinebase and PNI have announced plans to merge and form a new company. The PNI side of the venture will bring expertise in web commerce and hosting services as well as natural language search. Folks in the audience seemed confused as to what Cinebase would bring to the table.

Picture Networks International is a Kodak Company. Their product is entirely web based, including browsing and searching capabilities. There are web based forms to customize metadata fields, setup user accounts, and grant/deny access to the archive. Video is streamed to the client via Real Networks. PNI has a sophisticated natural language search engine with a semantic net to handle word associations like "auto is a synonym for car" or aggregations like "Los Angeles implies California". There's a "shopping cart" capability for folks wishing to sell assets out of their archive. Database is Oracle, server runs on NT or Solaris, client can be any web browser.

Cinebase demonstrated their Java client and the usual host of browsing and search tools.

* Excalibur / AT&T

Excalibur has a product for capturing and cataloging video. They have announced a partnership with AT&T/Lucent to develop advanced technology for indexing and logging video automatically.

Excalibur demonstrated their Screening Room product, which is primarily a browsing and search engine for video assets. As video is captured into the system, it is analyzed for scene cuts and dissolves, significant scene motion is tracked, and closed caption text is parsed and stored. The result is a series of thumbnails that represent the individual scenes with "in" and "out" timecodes and associated caption text as metadata. You can search the archive based on the text transcription, or based on other manually attached text files or metadata. "Concept" searches, booleans of keyword searches, fuzzy pattern searches for hard to spell names like "Chechnya", or image based searches to retrieve "things that look like this."

AT&T demonstrated current research in "multi-modal" analysis of video streams. They combine simultaneous analysis of closed caption text, speech, and video scene cut detection to achieve more accurate "story segmentation". Speech analysis is not yet in real time, of course, but the rest runs at faster than frame rates. The point is, the closed caption text is often incorrectly transcribed and speech recognition is always error prone, but to combine the two sources gives you a much more accurate transcription of the broadcast. Analysis of the video gives hints to when one news story ends and the next one begins.

* Informix

Informix has appeared, seemingly out of nowhere, with something called Media360. At the core is, of course, Informix as the database search and storage engine. At the periphery are a wide array of partnerships with vendors who provide capture, logging, content creation, editing, and other specialty tools. They demonstrated a simple web interface that was dynamically generated by the database itself with a HTML "blade" of some sort. Assets were stored in the database with a default set of metadata tags, all customizable. The workflow engine was simple check-in/out. All this was essentially "demoware" and serious clients would need to work with Informix to develop a workable solution based on their specific needs.

* Mate

Mate is an Israeli company founded in 1997. They specialize in technology for video indexing and search. Their product incorporates the usual scene-cut detection and closed caption text analysis with other more sophisticated searches. For instance: face detection and recognition (show me everything with Bill Clinton's face), text recognition (show me images that have the word "Dodgers" in an overlay), voice and sound pattern recognition (find clips with Barbara Walters speaking), logo detection (find clips with the FOX sports logo in the corner), motion and sound "event" searching (ie. show me all the explosions). Not a true asset management system per se, but a technology to be incorporated into one of the other systems. Nice demo, but I noticed they used their own data instead of the data that was provided by NBC and DreamWorks.

* Artesia

Artesia's product "te@ms" is used by the Library of Congress, the Washington Post, Jane's Information Group, and others. The demo of the Java client focused on search and browse capabilities, and the user-defined asset relationships or links. Like the others, te@ms has a variety of search engines including image-based search, text search via Oracle's ConText, boolean/keyword searches on metadata fields, and so on. Import is done using 3rd party video capture and logging tools from companies such as Virage. Other data such as rendered images and clips, or text files, can be imported directly as well.

The demonstration was a hybrid of the vendor's slick marketing presentations and a more traditional "shootout" where software vendors are required to follow strict guidelines.

The audience members felt comfortable in challenging the marketing and future-ware assertions that they felt the vendors made. Questions on metadata and encoding standards were posed to the vendors. The vendors responded as candidly as they could, explaining that responding to, rather then setting standards was in their best interest.

The rapid-fire comparison gave the audience a real look at what the software companies are currently offering, and a look at the kind of research that is on-going. The vendors offered similar functionalities in the video intake and logging capabilities, and all addressed issues of vocabulary control on some level. It was easy to compare these basic functions vendor to vendor. Research-oriented participants like AT&T and MATE showed developments in face and pattern recognition. Accuracies are still low and processing time is still longer than manual cataloging, so these types of auto-logging tools are still not adding value to software products.

At this point in history, vendors have cut their teeth on a number of different business processes -- pre-press; newspaper publishing; stock photo sales. The functions that the vendors built into their software often reflect the business processes they've worked most closely with -- no surprise.

This was the natural evolution in data-mining softwares. It seems that when workflow is an obvious part of the data and metadata gathering process, then vendors often struggle to determine that functions which may be unique to one business are essential to a software product.

The overall goal of the event was to create a forum between asset management vendors and users. And although a lot was said, the conversation has only begun.

Discussion

Peter DUSEK

Thank you for this presentation. Our aims are similar: to devise solutions and a similar workflow so as to bring new material together with the older technology. We want to move in the direction.

From the floor

Were there subtle differences between the results obtained by the vendors?

Andrea KALAS LA VERE

The differences were extremely distinct in many cases.

From the floor

Does AMIA see itself as a steering group? If three very successful vendors were to produce equally effective products with slight technical differences, would AMIA feel a duty to inform the archivists and curators of the differences between these? Would it attempt to provide a temporary substitute for the standards that we all await?

Andrea KALAS LA VERE

The vendors were very responsive to our presentations and showed real interest in our work as archivists. In a way, they did not understand that their software would be relevant to what we did. Their sales force has devoted most of its attention to traditional information technology groups or production-oriented players. The fact that archivists existed was somewhat of a revelation to them. Nonetheless, they quickly realised that our accomplishments in the field of access, cataloguing, preservation, etc. was related to the functionalities they are trying to put in their software. They were interested in returning and finding out more. However, it is important to remain realistic. The entertainment industry, whether film or archives, is but one part of the market for these vendors. The functionalities they are trying to develop have been designed for people all over the world. We do not enjoy the same leverage.

George BROCK-NANNESTAD

How much space does an index of 15 to 30 minutes require? The answer must depend on whether the information is properly organised by a thesaurus or whether users must perform text searches.

Andrea KALAS LA VERE

That question did not arise. I do not think that the size is problem, especially considering that video and data storage required so much more effort. Text is quite simple to handle in comparison.

George BROCK-NANNESTAD

That is certainly true. You could put it in front of every file, though.

Andrea KALAS LA VERE

Many systems have some form of text database server in which information about the asset is stored. That is the general process. I do not think the storage of the text has any effect on the requirements relating to media- or video- based storage.

George BROCK-NANNESTAD

I had imagined a system with headers. That is apparently not the case.

Andrea KALAS LA VERE

No.

From the floor

It is hard in such a short time to cover all of the bugs that hamper our work daily. I would like to know your opinion on a more specific matter: the difference between transferring from disc-storing stills (new clips or music) to real-time audio or video 3D objects. What do you think must be done in this context?

Andrea KALAS LA VERE

Vendors focus on their software offering, giving less attention to their partnerships with hardware companies. They are not strongly integrated. Naturally, the problem lies in understanding how the different levels of software and hardware blend and match and encouraging vendors to take that into account. Every day, tens of hours of material are digitised. How will this connect with the top-level software? This issue is not being addressed sufficiently.

Bob CURTIS-JOHNSON

These are clearly very expensive systems. How are the manufacturers structuring their product offerings to suit the varying needs of archives of different sizes? Will these products only be used by the largest and better-funded archives?

Andrea KALAS LA VERE

The vendors see themselves as serving enterprises and consequently sell rather expensive material. However, smaller software for desktop or workgroup use has been designed (Cumulus, etc.) to handle archives with 1 000 to 2 000 assets. One vendor has even devised a rental plan to accommodate lower budgets. That being said, basic installation still costs USD 500 000.

Modérateur/Moderator : Dietrich Schüller
(Phonogrammarchiv, Austrian Academy of Sciences - Chairman IASA Technical Committee)

Klaus Heinz is currently undertaking transfer for several German radio stations, from analogue tapes into digital domains. He will tell us about Two Distinctive Ways from the Analogue Audio Heritage to the Audio File of the Future—R-DAT and DLT as Target Formats.

Two distinctive ways from the analogue audio heritage to the audio file of the future R-DAT and DLT as target formats.

Klaus Heinz
AudioFile Musikproduktions GmbH, Allemagne

A Archiving Studio Tapes in the digital format

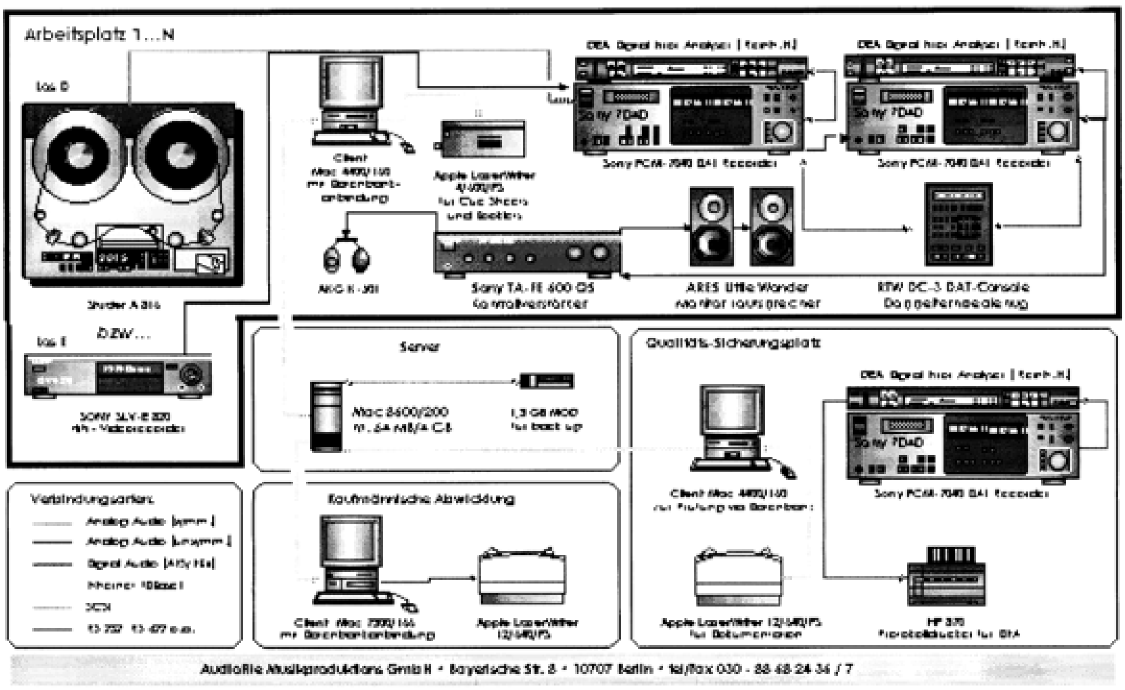
To transfer large amounts of studio tapes into the digital domain is a task that contains different aspects. All of them can be combined to either

1: find dedicated operators who use appropriate technical equipment, or

2: prepare to organise thousands of incoming studio tapes, their handling, plus the conversion to the digital domain, i.e. handling thousands of DAT cassettes and transfer of documentation and archive numbers, all errorfree and effective.

Errors concerning archive numbers lead to perturbations that may become evident much later only, at a time when the corresponding DAT is to be used, and there are little chances to correct such errors after all these years and find the music originally selected. The machine set-up we used for the task looks as follows:

Block Diagram for tape-to-DAT conversion



Whereas the first group of problems can be handled by typical engineering efforts and usual management care, the second one asks for a new approach. The answer is a data base application that handles and controls the various steps during the digitising process. Some of the guidelines and details of the application developed by AudioFile - the company - are discussed in part A of this paper.

1 THE DATA BASE

First we have made special cases, where the tapes remain during transportation and workflow.

Studio tape case

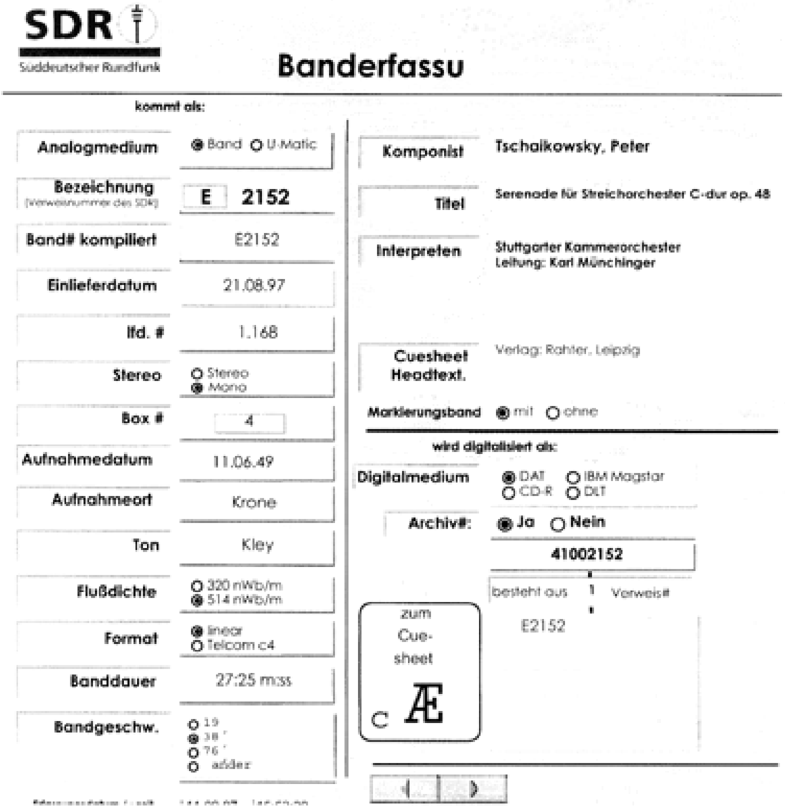
This simple idea proves to be very useful, because it enables us to control status and location of every tape anytime by documenting number and location of the cases within the database. For example, the moment the broadcaster needs a tape for transmission we have it on the desktop within a minute.

Organising and controlling all the steps while capturing audio and archive data demands a data base application that:

- on the input side takes into account the grown structure of the tape numbers under consideration, (area codes, range and structure of possible numbers),
- controls all input data on a logical basis as far as possible: no double numbers, no missing numbers or details, conditions for numbers to appear and similar considerations,
- automatically generates the archive numbers from the existent analogue tape numbers - very useful to avoid errors in this most critical moment,
- generates barcodes if desired to enable later automatical transfer to large archive systems,
- inputs and validates measured values of error corrections and their location for effective quality control of every DAT cassette to be delivered,
- generates appropriate documentation like cue sheets and booklets from the data captured by the operators,
- generates various listings to allow systematic controlling,
- stops work in progress as soon as any data are missing or found to be illogical in one or another way,
- after finishing the DAT, enables a separate quality control to be executed to ensure the correct relation between original music, attached documentation and finished DAT cassette. To demonstrate the functionality of the software we follow an incoming studio tape on its way to become a well documented DAT cassette

2. REGISTRATION

First every case and every tape entering the company is registered with all the information that is given on the cardboard box. When all tapes have been keyed in, the operator calls for somebody else and all data are re-read by a different person and controlled on the screen to avoid input data error.



SDR
Süddeutscher Rundfunk

Banderfassu

kommt als:

Analogmedium	◉ Band ○ U-Matic	Komponist	Tschaikowsky, Peter
Bezeichnung (Verweisnummer des SDR)	E 2152	Titel	Serenade für Streichorchester C-dur op. 48
Band# kompiliert	E2152	Interpreten	Stuttgarter Kammerorchester Leitung: Karl Münchinger
Einlieferdatum	21.08.97		
lfd. #	1.168	Cuesheet Headtext.	Verlag: Rahter, Leipzig
Stereo	○ Stereo ◉ Mono	Markierungsband	◉ mit ○ ohne
Box #	4		wird digitalisiert als:
Aufnahmedatum	11.06.49	Digitalmedium	◉ DAT ○ IBM Magstar ○ CD-R ○ DLT
Aufnahmeort	Krone	Archiv#:	◉ Ja ○ Nein
Ton	Kley		41002152
Flußdichte	○ 320 nWb/m ◉ 514 nWb/m		besteht aus 1 Verweis#
Format	◉ linear ○ Telcom c4	zum Cue-sheet	E2152
Banddauer	27:25 m:ss		
Bandgeschw.	○ 19 ◉ 38 ○ 76 ○ andere		

3. CASE LIST

The following list accompanies every case to be sure about the tapes that have been delivered and the number of DAT's that are to be produced. If more than one tape is compiled to a DAT, this structure is set here and can be recognised from now on.

Together with the list the software creates the 8-Digit archive number automatically. So errofree operation is guaranteed at that very crucial point within the process.

Liste eingegangener Bänder:

lfd. Nr.	Box	Einl.dat.	Dauer	Band#	Archiv#			Verweis# 1	2	3	4	5	6	7
50	1	31.05.97	21:00	E1377	Ja	Nein	**41001377**	E1377						
51	1	31.05.97	22:15	E1387	Ja	Nein	**41001387**	E1387						
52	1	31.05.97	32:00	E1388	Ja	Nein	**41001388**	E1388						
53	1	31.05.97	29:30	E1397	Ja	Nein	**41001397**	E1397						
54	1	31.05.97	15:40	E1398	Ja	Nein	**41001398**	E1398						
55	1	31.05.97	27:50	E1399	Ja	Nein	**41001399**	E1399						
56	1	31.05.97	75:15	E1403	Ja	Nein	**41001403**	E1403	E1404	E1405	E1406			
57	1	31.05.97		E1404	Ja	Nein	•	E1404						
58	1	31.05.97		E1405	Ja	Nein	•	E1405						
59	1	31.05.97		E1406	Ja	Nein	•	E1406						
60	1	31.05.97	26:20	E1413	Ja	Nein	**41001413**	E1413						
61	1	31.05.97	46:00	E1415	Ja	Nein	**41001415**	E1415	E1416					
62	1	31.05.97		E1416	Ja	Nein	•	E1416						
63	1	31.05.97	17:45	E1417	Ja	Nein	**41001417**	E1417						
64	1	31.05.97	49:00	E1474	Ja	Nein	**41001474**	E1474	E1475					
65	1	31.05.97		E1475	Ja	Nein	•	E1475						
66	1	31.05.97	26:10	E1476	Ja	Nein	**41001476**	E1476						
67	1	31.05.97	31:15	E1477	Ja	Nein	**41001477**	E1477						
68	1	31.05.97	24:35	E1495	Ja	Nein	**41001495**	E1495						
69	1	31.05.97	26:45	E1500	Ja	Nein	**41001500**	E1500						
70	1	31.05.97	24:25	E1523	Ja	Nein	**41001523**	E1523						
71	1	31.05.97	16:20	E1537	Ja	Nein	**41001537**	E1537						
72	1	31.05.97	15:00	E1550	Ja	Nein	**41001550**	E1550						
75	1	31.05.97	66:50	E1553	Ja	Nein	**41001553**	E1553	E1554	E1555				

Dauer	593:55 m:ss = 9:53 hh:mm	**min lfd.#**	50	**DAT34**	26	**DAT94**	4
Zahl der Bd. = 24 St.	ø = 24:44 mm:ss	**max lfd.#**	75	**DAT64**	8	**DAT124**	0

Seite 1

4. BARCODE LABELS

To prepare the DAT cassettes for identification and later machine based transfer into large archive systems, barcode labels representing the archive number are printed for the A and B samples.

The labels are applied the moment the DAT´s are made ready for recording. The same number goes into the User Bit section of the Sony PCM 7040 DAT machines we have in use. As in this section 8 digits are allowed only, the „Interleave 2 of 5" format is recommended:

!L#Eg"

5. CUE SHEET - THE AUDIO PROTOCOL

A detailed cue sheet contains archive data, monitored ID times and durations, left headroom (margin) and cue comments. A number of „classical" problems like drop outs, band saturation or audible distortion can be chosen from pop up menues. Thus the later operator, knowing description and location of the problems can examine the DAT and decide whether it is still suitable for transmission or not. Furthermore, more general comments like „Modulation starts 11 sec later" can be made in another box, so that the status of the digitised studio tape becomes quite clear.

Cue Sheet

SDR

Verdi,

Requiem - für 4 Solostimmen, Chor und

Archiv-Nr. 410018

Daten Analogband:

Stereo / Mono

Aufnahmeort

Medium: DAT / CD-R

Sampling: 48 kHz / 44.1 kHz

Maria Stader, Sopran - Marga Höffgen, Alt - Fritz Wunderlich, Tenor

Gottlob Frick, Bass

Der Südfunk-Chor und Der Stuttgarter

Digitale Arch.

Operator

Umschnittsdat.

Margin

Südfunk-Sinfonie-

Verlag:

Peters

ID Nr.	ID Text	Start ID hh:mm:ss	Mod.ende hh:mm:ss	Zeit/ID hh:mm:ss	Werkzeit hh:mm:ss	Margin p.Werk
1	Requiem	00:59	09:08	08:09	84:07	
2	Dies irae (1. Teil)	09:17	31:44	22:27		
3	Dies irae (2. Teil)	31:44	47:03	15:19		
4	Offertorium	46:11	57:04	10:53		
5	Sanctus	57:22	60:13	02:51		
6	Agnus Dei	60:21	65:44	05:23		
7	Lux aeterna	65:56	72:21	06:25		

Irgendeine ID Zeit | Margin fehlt | ID Start vor letztem ID Ende: eher

Cue-Kommentare

Werkzeit Summe

DAT Gesamtlaufzeit

• Knackgeräusche

Verweiser

E1863

E1864

E1865

E1866

E1867

• Nutz-Modulationsbeginn ab 01:11

In the case of the WDR the Cue Sheet looks like:

Various logical tests make sure, that no ID time is forgotten or in an unlogic range. In the following sample ID 4 starts before the end of ID 3, and the margin has been forgotten as you can see from the red remarks on the cue sheet.

6. DEA - The Digital Error Analyser

One of the foremost aspects in the whole process is safety. To be sure about the technical quality of the produced DAT cassettes and to meet the specification by the broadcaster it is necessary to monitor and register the control activities of the DAT recorder

Observed parameters are BLER (Block error Rate) per minute, upper limit 10 ‰, the averaged BLER per measurement period, upper limit 2 ‰, and the maximum error per track with its location, upper limit 25.

Additionally the freedom from averages and mutes is confirmed; consistence and correctness of the Time Code (TC) are indicated.

The behaviour of DAT cassettes can be quite different, as can be seen from the following 3 protocols:

(HP500) *** DAT-Fehlerprotokoll ***

Betrieb /Anstalt:

Name des Prüfers:

Datum: 02.08.1997

Titel: Druckner 8. 1. Band

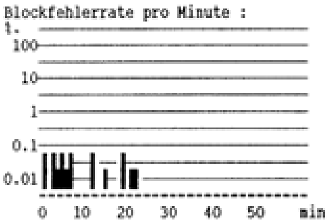
Band Nr.: 41001403

Kassettentyp: 124

Rekorder: PCM-7030 Nr.:

Abtastfrequenz	48kHz
Gen Timecodeformat	25F EBU
Tape Timecodeformat	30F SMPTE NDF
Emphase	Off
Copy Mode	Permit
START-Timecode	00:00:00:13
STOP-Timecode	00:21:56:23
Blockfehlerrate KopfA	0.021%.
Blockfehlerrate KopfB	0.017%.
Durchschnitt A/B	0.019%.
Max Error pro Spur	8
Aves	0
Mutes	0
Timecode Fehler	0

Blockfehlerrate pro Minute :



(HP500) *** DAT-Fehlerprotokoll ***

Betrieb /Anstalt:

Name des Prüfers:

Datum: 05.07.1997

Titel:

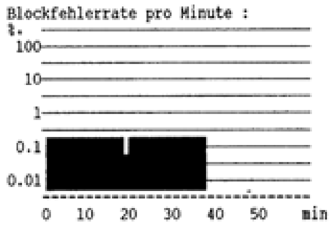
Band Nr.: A000E972

Kassettentyp: 64

Rekorder: PCM-7030 Nr.:

Abtastfrequenz	48kHz
Gen Timecodeformat	25F EBU
Tape Timecodeformat	30F SMPTE NDF
Emphase	Off
Copy Mode	Permit
START-Timecode	00:00:00:14
STOP-Timecode	00:36:45:14
Blockfehlerrate KopfA	0.18 %.
Blockfehlerrate KopfB	0.17 %.
Durchschnitt A/B	0.17 %.
Max Error pro Spur	8
Aves	0
Mutes	0
Timecode Fehler	0

Blockfehlerrate pro Minute :



(HP500) *** DAT-Fehlerprotokoll ***

Betrieb /Anstalt:

Name des Prüfers:

Datum: __.__.19__

Titel:

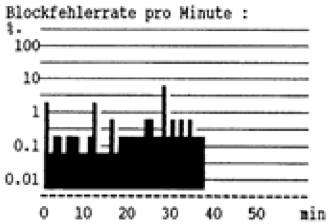
Band Nr.: 41002116

Kassettentyp: 64

Rekorder: PCM-7030 Nr.:

Abtastfrequenz	48kHz
Gen Timecodeformat	25F EBU
Tape Timecodeformat	30F SMPTE NDF
Emphase	Off
Copy Mode	Permit
START-Timecode	00:00:00:13
STOP-Timecode	00:37:17:11
Blockfehlerrate KopfA	0.53 %.
Blockfehlerrate KopfB	0.43 %.
Durchschnitt A/B	0.48 %.
Max Error pro Spur	30
Aves	28
Mutes	0
Timecode Fehler	0

Blockfehlerrate pro Minute :



-----AVERAGE-----

Anfang	Anzahl	Ende
00:27:55:03	25	00:27:56:02
00:33:30:16	3	00:33:30:17

The results are transferred to the database and compared to the limits. In the following sample 5 tapes go into the DAT cassette and have been measured separately. The averages of the single correction activities related to the completed DAT cassette are calculated and used to generate the „passed" logo if everything is ok.

Eingabe der vom DEA gemessenen

DAT 4100186-A

	Mittelwert	Bl.korr/Min	Location hh:mm	Max. Fehler /Sp.
1	0.062 ‰	0.140 ‰	00:08	8
2	0.032 ‰	0.110 ‰	00:16	8
3	0.034 ‰	0.120 ‰	00:31	6
4	0.024 ‰	0.130 ‰	00:47	7
5	0.032 ‰	0.420 ‰	01:05	9
6	‰	‰		
7	‰	‰		
8	‰	‰		
9	‰	‰		
10	‰	‰		

DEA Messungen: OK

DAT A controlled

£

Mittelwert_A ok? (80)	OK
Blöcke_DAT_A korr/min ok? (810)	OK
Max. Fehler_A pro Spur ok? (825)	OK
Mittelwert A gesamt	0.037 ‰
Blöcke_DAT_A korr pro min	0.420 bei 01:05
Maximaler Maxfehler	9
Averages / bei	Ja . Nein
Average Details A	
Average A Kommentar	

DAT 4100186-B

	Mittelwert	Bl.korr/Min	Location hh:mm	Max. Fehler /Sp.
1	0.034 ‰	0.080 ‰	00:07	9
2	0.045 ‰	0.130 ‰	00:12	8
3	0.026 ‰	0.100 ‰	00:39	8
4	0.026 ‰	0.098 ‰	00:57	10
5	0.036 ‰	0.140 ‰	01:05	8
6	‰	‰		
7	‰	‰		
8	‰	‰		
9	‰	‰		
10	‰	‰		

OP Kontrollliste

zum Booklet

C Æ

DEA Messungen:

DAT B controlled

£

Mittelwert_B check	
Blöcke_DAT_B korr/min	
Max. Fehler_B pro Spur	
Mittelwert B gesamt	‰
Blöcke_DAT_B korr pro min	bei
Maximaler Maxfehler	
Averages / bei	Ja . Nein
Average Details B	
Average B Kommentar	UZ-Bit Wackler bei 38:18 - :28

Again it looks different in the case of the WDR to have the many DAT´s per VHS Tape together and to have a second chance if one of the tapes has to be repeated:

Eingabe der vom DEA gemessenen Werte:

OP Kontrolliste | zum Booklet c Æ

Sitzung Nr. 220 996 - #

DAT	Mittelwert ‰	Bl.k./Min ‰	Location mm:ss	MFE	DEA	Averages Ja/Nein Loc Comments
1	0.044	0.190	00:46	10	ok	
2	0.073	0.220	01:28	12	ok	
3	0.130	0.260	00:18	11	ok	
	0.091	0.400	00:42	10		
4	0.065	0.230	00:48	8	ok	
	0.058	0.130	01:17	8		
5	0.110	0.240	01:10	10	ok	
6	0.046	0.110	01:38	9	ok	
7	0.051	0.090	00:15	8	ok	
	0.061	0.260	00:16	7		

Safe

DAT	Mittelwert ‰	Bl.k./Min ‰	Location mm:ss	MFE	DEA	Averages Ja/Nein Loc Comments
1	0.037	0.110	01:25	10	ok	
2	0.066	0.140	01:41	21	ok	
3	0.042	0.130	00:03	10	ok	
	0.038	0.330	00:41	10		
4	0.066	0.360	00:25	10	ok	
	0.040	0.260	01:01	11		
5	0.086	0.330	00:25	14	ok	
6	0.019	0.120	00:37	10	ok	
7	0.024	0.078	00:00	9	ok	
	0.033	0.110	00:16	9		

7. BOOKLETS

From the acquired archive descriptions plus the numbers obtained in the cue sheet and the DEA measurements, the following DAT booklet is compiled:

1	1. Sinfonia (Ouverture)	02:11
2	2. Serenata	03:41
3	3. a) Scherzino ,b) Allegro	04:30
4	4. Tarantella	02:10
5	5. Toccata	01:23
6	6. Gavotta con due variazioni	02:19
7	7. Vivo	01:36
8	8. a) Minuetto, b) Finale	04:40

Strawinsky, Igor **A**

Pulcinella - Suite für kleines Orchester nach G.B. Pergolesi

Das Südfunk Sinfonieorchester
Leitung: Hans Müller-Kray

Verlag: Boosey & Hawkes

Mittelwert 0,051 **Max/S** 8 | **Laufz./Werkzeit** 23:44/ 22:43
Bl.korr/Min 0,110 **Roc.** 00:16 | **Margin** 4 dB **Aufn.:** 21.06.61

41002107 !L#8*" A

Strawinsky, Igor | **Pulcinella - Suite für kleines Orchester nach**

1	1. Sinfonia (Ouverture)	02:11
2	2. Serenata	03:41
3	3. a) Scherzino ,b) Allegro	04:30
4	4. Tarantella	02:10
5	5. Toccata	01:23
6	6. Gavotta con due variazioni	02:19
7	7. Vivo	01:36
8	8. a) Minuetto, b) Finale	04:40

Strawinsky, Igor **B**

Pulcinella - Suite für kleines Orchester nach G.B. Pergolesi

Das Südfunk Sinfonieorchester
Leitung: Hans Müller-Kray

Verlag: Boosey & Hawkes

Mittelwert 0,140 **Max/Sp** 19 | **Laufz./Werkzeit** 23:44 /22:43
Bl.korr/Min 0,600 **Loc.** 00:21 | **Margin** 4 dB **Aufn.:** 21.06.61

41002107 !L#8*" B

Strawinsky, Igor | **Pulcinella - Suite für kleines Orchester nach**

As every booklet has complete information about the technical quality of the cassette, the long-term behaviour of these parameters can be studied easily.
It will be interesting to look at these numbers in a statistical approach in two or three years to confirm whether there are unexpected changes or not, and how life expectancy of DAT cassettes may be affected.

7. FINAL QC (QUALITY CONTROL)

Each pair of cassettes is individually controlled for correctness of

- Continuos User Bit,
- Continuos Time Code and
- Correct ID settings.

The result, after inserting control operator and control date, is the final ok for the cassette to be delivered:

Typical DAT with attached documentation

9. CHECK LIST

The moment all tapes within a case are digitised, the following list permits an overview whether something went wrong with one of the DAT cassettes:

OP Kontrolliste

				DAT A						DAT B											
Bd.#	Box	Einliefer.	Archiv#	DEA					fertig	DEA					fertig	#	DAT Lz	Marg.	Umrechn.	Operator	Int.
98	2	31.05 97	**41001779**	OK	0.100	0.250	10	00:00	£	OK	0.100	0.750	11	00:01	£	£	19:10	6dB	11.07.97	Voigt	
99	2	31.05 97	**41001774**	OK	0.200	0.500	9	00:14	£	OK	0.067	0.130	10	00:18	£	£	26:06	4dB	11.07.97	Voigt	
100	2	31.05 97	**41001760**	OK	0.028	0.090	9	00:11	£	OK	0.056	0.160	9	00:12	£		20:53	4dB	11.07.97	Voigt	2
101	2	31.05 97	**41001758**	OK	0.047	0.150	9	00:10	£	OK	0.140	0.390	10	00:00	£	£	18:31	6dB	11.07.97	Voigt	
102	2	31.05 97	**41001756**	OK	0.096	0.310	10	00:00	£	OK	0.130	0.230	9	00:01	£	£	18:25	5dB	10.07.97	Brandenbu	
103	2	31.05 97	**41001754**	OK	0.047	0.160	9	00:03	£	OK	0.150	0.230	10	00:00	£	£	30:31	7dB	11.07.97	Voigt	
104	2	31.05 97	**41001750**	OK	0.091	0.160	10	00:17	£	OK	0.083	0.190	10	00:02	£	£	26:07	10dB	10.07.97	Brandenbu	
105	2	31.05 97	**41001749**	OK	0.130	0.440	10	00:00	£	OK	0.170	0.260	9	00:01	£	£	20:37	8dB	10.07.97	Brandenbu	
107	2	31.05 97	**41001745**	OK	0.335	0.480	10	00:01	£	OK	0.210	0.420	9	00:00	£	£	45:44	6dB	10.07.97	Brandenbu	
108	2	31.05 97	**41001742**	OK	0.180	0.490	10	00:00	£	OK	0.096	0.230	8	00:17	£	£	19:40	6dB	10.07.97	Brandenbu	
109	2	31.05 97	**41001741**	OK	0.150	0.300	9	00:09	£	OK	0.076	0.150	10	00:01	£	£	26:45	8dB	10.07.97	Brandenbu	
110	2	31.05 97	**41001740**	OK	0.180	0.350	9	00:13	£	OK	0.076	0.210	10	00:01	£	£	21:05	6dB	10.07.97	Voigt	
111	2	31.05 97	**41001719**	OK	0.095	0.170	9	00:16	£	OK	0.190	1.200	12	00:03	£	£	27:37	5dB	10.07.97	Brandenbu	
112	2	31.05 97	**41001716**	OK	0.110	0.220	10	00:02	£	OK	0.072	0.210	10	00:00	£	£	20:49	3dB	10.07.97	Brandenbu	
113	2	31.05 97	**41001715**	OK	0.035	0.110	9	00:08	£	OK	0.100	0.190	7	00:11	£	£	16:45	6dB	10.07.97	Voigt	
114	2	31.05 97	**41001697**	OK	0.069	0.230	10	00:03	£	OK	0.048	0.170	10	00:08	£	£	22:13	5dB	10.07.97	Voigt	
115	2	31.05 97	**41001688**	OK	0.120	0.360	10	00:22	£	OK	0.100	0.210	10	00:02	£	£	23:36	5dB	10.07.97	Voigt	
116	2	31.05 97	**41001687**	OK	0.490	2.100	19	00:06	£	OK	0.130	0.880	11	00:01	£	£	34:11	1dB	10.07.97	Voigt	
117	2	31.05 97	**41001680**	OK	0.100	0.340	10	00:20	£	OK	0.069	0.170	10	00:14	£	£	25:27	7dB	09.07.97	Brandenbu	
118	2	31.05 97	**41001667**	OK	0.071	0.130	9	00:17	£	OK	0.086	0.250	9	00:17	£	£	22:22	5dB	09.07.97	Brandenbu	
119	2	31.05 97	**41001635**	OK	0.210	0.480	9	00:26	£	OK	0.140	0.440	9	00:00	£	£	27:23	4dB	09.07.97	Brandenbu	
138	2	31.05 97	**41001611**	OK	0.045	0.210	9	00:15	£	OK	0.086	0.180	9	00:01	£	£	18:17	5dB	08.07.97	Voigt	

DAT Laufzeit = 8:52:14 = 532:14 **Zahl der Bd.** = 22 St. = 23:08 min

DAT number 41001760 for example has a problem, although the measurements are ok. An internal comment asks for a new label, because the old one has been damaged.
To control whether all DAT's belonging to one VHS are ok a different list layout is necessary to get the right overview:

Liste eingegangener Bänder mit Archiv# : in Bearbeitung Lief

lfd.	Box	Einliefer.	Archiv#	1	2								#	Job Dauer	Fak.	DAT Lz	Int.	Schuber	Lieferdatum		
7	26	15.10.97	**2202968-#**	€ €	€ €								€	05:00	1.3	03:50		1	24.09.1998	1	10:00:05
366	31	16.10.97	**2202996-#**	€ €	€ €	€ €	€ €	€ €	€ €	€ €			€	16:44	1.3	12:55		3	24.09.1995	1	09:00:05
364	31	16.10.97	**2202999-#**	€ €	€ €	€ €	€ €						€	07:43	1.2	06:27		2	24.09.1995	1	08:00:00
356	31	16.10.97	**2203006-#**	€ €	€ €								€	03:41	1.3	02:49		1	24.09.1998	1	10:00:20
342	31	16.10.97	**2203011-#**	€ €	€ €	€ €	€ €	€ €	€ €	€ €			€	17:46	1.3	13:37		3	24.09.1995	1	09:00:05
335	31	16.10.97	**2203014-#**	€ €	€ €	€ €	€ €	€ €	€ €				€	14:35	1.2	12:15		2	24.09.1995	1	09:00:20
620	29	16.10.97	**2203023-#**	€ €	€ €								€	03:50	1.1	03:35		1	24.09.1998	1	09:00:05
630	29	16.10.97	**2203031-#**	€ €	€ €	€ €	€ €						€	09:38	1.3	07:11		2	24.09.1998	1	14:00:05
631	29	16.10.97	**2203032-#**	€ €	€ €	€ €							€	06:25	1.4	04:36		1	24.09.1998	1	09:00:05
652	26	16.10.97	**2203167-#**	€ €	€ €	€ €	€ €	€ €	€ €				€	12:58	1.1	11:39		2	24.09.1999	1	09:00:25
121	24	07.11.97	**2203257-#**	€ €	€ €	€ €							€	06:49	1.2	05:49		1	24.09.1998	1	09:00:00
122	24	07.11.97	**2203258-#**	€ €	€ €								€	03:25	1.1	03:05		1	24.09.1998	1	12:09:55
130	24	07.11.97	**2203264-#**	€ €									€	00:31	1.5	00:21		1	24.09.1998	1	14:01:00
72	24	07.11.97	**2203269-#**	€ €	€ €	€ €	€ €	€ €	€ €	€ €			€	17:24	1.2	14:22		3	24.09.1998	1	09:00:55
75	24	07.11.97	**2203270-#**	€ €	€ €	€ €	€ €	€ €	€ €	€ €			€	18:00	1.4	12:26		3	24.09.1998	1	09:00:00
77	24	07.11.97	**2203271-#**	€ €	€ €	€ €							€	07:02	1.7	04:15		1	24.09.1999	1	09:00:00
231	32	16.11.97	**2203287-#**	€ €	€ €	€ €	€ €	€ €					€	13:01	1.4	09:37		2	24.09.1998	1	10:00:00

DAT Laufzeit = 128:54 = 7734 mm **Jobfaktor insgesamt** 1,29 30

Zahl der Bd. = 17 St. ø 465:28 ms 25.911

When the list is clean, the case is closed and the DAT A samples are sent to the Broadcast station. For safety reasons the B samples are sent separately.

10. DELIVERY NOTE

The detailed delivery notes contain every DAT including its history and duration.

udioFile GmbH • Friedrichstraße 95 • 10117 Berlin

An den SWR
FB Dokumentation u.
Herrn Humbert / Herrn Dr. Polster / Herrn Dr.
Neckarstr.
70190 Stuttgart

Lieferschein DLT A Cartridge 236/99 Seite 1 vom 02.12.99

ox	Einl.dat.	Archivnr.	Verweis Nr. 1	2	3	4	5	6	7	File Dauer	ok.	DLT Nr.	gel. am:
3	24.11.99	60002255	602255-1	602255-2						1:09:46	£	26	02.12.99
3	24.11.99	60002295	602295-1							0:28:01	£	26	02.12.99
3	24.11.99	60002989	602989-1	602989-2						0:38:12	£	26	02.12.99
3	24.11.99	60007155	607155-1	607155-2						0:57:47	£	26	02.12.99
3	24.11.99	60012867	6012867-1	6012867-2						1:18:07	£	26	02.12.99
3	24.11.99	60019221	6019221-1	6019221-2						0:57:41	£	26	02.12.99
3	24.11.99	60020695	6020695-1	6020695-2	6020695-3					1:25:44	£	26	02.12.99
3	24.11.99	60020686	6020686-1	6020686-2						0:53:38	£	26	02.12.99
8	04.10.99	60020688	6020688-1	6020688-2						1:03:00	£	26	02.12.99
3	24.11.99	60020689	6020689-1	6020689-2						0:56:32	£	26	02.12.99
3	24.11.99	60020690	6020690-1	6020690-2						0:40:26	£	26	02.12.99
8	04.10.99	60020691	6020691-1	6020691-2						1:05:18	£	26	02.12.99
3	24.11.99	60020692	6020692-1	6020692-2						0:51:57	£	26	02.12.99
3	24.11.99	60020694	6020694-1	6020694-2						1:01:29	£	26	02.12.99
20	24.11.99	60020706	6020706-1	6020706-2						0:49:43	£	26	02.12.99
8	04.10.99	60023858	6023858-1	6023858-2	6023858-3	6023858-4				1:16:01	£	26	02.12.99
8	04.10.99	60023991	6023991-1	6023991-2						0:52:28	£	26	02.12.99
8	04.10.99	60023997	6023997-1	6023997-2						0:57:09	£	26	02.12.99
8	04.10.99	60024033	6024033-1	6024033-2	6024033-3					1:18:38	£	26	02.12.99
8	04.10.99	60024034	6024034-1	6024034-2	6024034-3					1:26:11	£	26	02.12.99
3	24.11.99	60024038	6024038-1	6024038-2						0:49:12	£	26	02.12.99
8	04.10.99	60024099	6024099-1	6024099-2						0:58:52	£	26	02.12.99
8	04.10.99	60024233	6024233-1	6024233-2						0:58:43	£	26	02.12.99
8	04.10.99	69001796	691796-1							0:14:42	£	26	02.12.99

Gesamtzahl der audio files: 24 **DLT Gesamtlaufzeit:** 23:09:17 = 1389 min

Furthermore the final control status is ensured and correct samples only reach the customer. Invoicing on a correct price per minute basis is achieved.
So, in the end, we are quite sure to send error free DAT cassettes to the Broadcast Corporation and help to develop the archives of the future.

B Statistics: Inspecting the error behaviour of the DAT recorders and cassettes

One of the nice things with databases is the fact, that acquired data can be exported and analysed elsewhere to learn more about their statistical behaviour.
If we want to look at the frequency of events or measurement data related to a complete examination of a process or experiment histograms are the diagrams of choice. Thus you find histograms for most of the parameters of interest.
Analysis of distributed measured values typically is described by a Gaussian distribution that generally is written:

$$y = e^{-\lambda x^2}$$

The according graph grows from 0 to 1, the defined maximum, and decreases to 0 again. The bigger the coefficient, the narrower this so called bell curve is distributed around its maximum. It is that kind of curve, that describes „friendly“ statistical behaviour, the widely used normal distributions. To have a measure of the degree of deviations the so-called Variance is calculated as

$$s^2 = \frac{\sum x^2}{n}$$

More popular and descriptive is the already mentioned standard deviation, that is the average of the individual deviations S of the average of the distribution we look at.

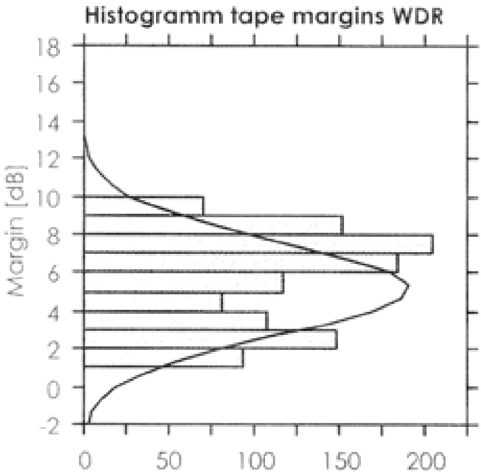
$$\sigma = \sqrt{\frac{\sum x^2}{n}}$$

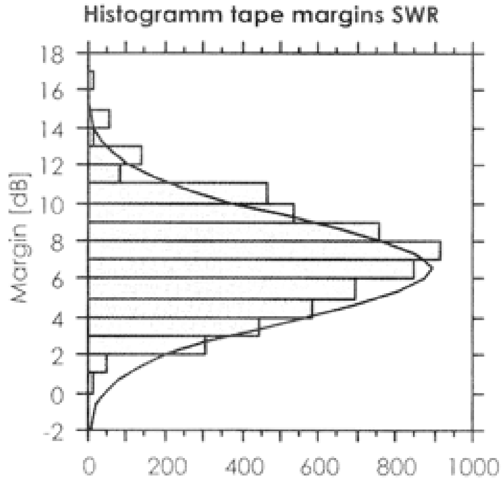
To give a complete picture of the examined cassettes, we show both diagrams and complete numbers for every parameter we look at.
A total of 2060 DAT Cassettes is the basis of the following statistical report. To give an impression of the technical quality achieved, we look at the behaviour of the following parameters:

1. MARGIN

Following the ARD[1] guidelines a 0 dB analogue VU meter value is translated into a -9 dB reading on the DAT meters. So even encouraged use of the saturation area of the former studio tape machines should leave some headroom for the digital recording. As you can see in the following histogram, these reserves are well needed, because in some cases we found 0 dB readings, and in 3 cases we even had to attenuate the analogue input to get proper results. As we carefully calibrate our Studer A 816´s, the question arises how engineers in the late 50´s could achieve these astounding recording levels. All following histograms are given separately for the SWR and WDR DAT´s:

[1] *ARD = Arbeitsgemeinschaft der öffentlich-rechtlichen Rundfunkanstalten der Bundesrepublik Deutschland = German Broadcast Corporations.*





Deskriptive Statistiken

	Margin [dB]
Mittelw.	5,183
Std.abw.	2,428
Std.fehler	,071
Anzahl	1159
Minimum	1,000
Maximum	10,000
# fehlend	27

Deskriptive Statistiken

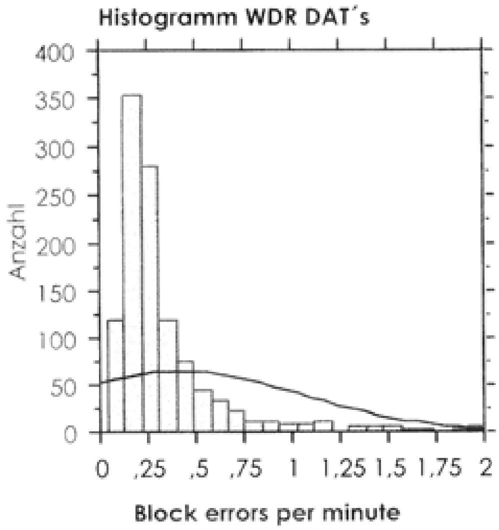
	Margin [dB]
Mittelw.	6,530
Std.abw.	2,637
Std.fehler	,034
Anzahl	5920
Minimum	,000
Maximum	18,000
# fehlend	6

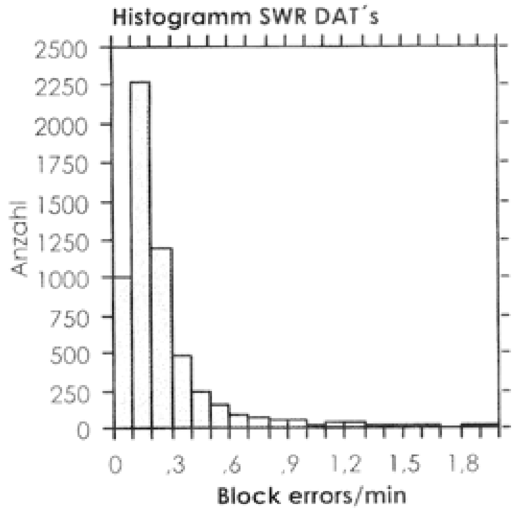
2 ERROR CORRECTIONS

2 a BLER (Block Error Rates) per minute

First we take a look at the BLER per minute, that should be less than 10 ‰ following the guidelines of the SDR. As the measured values concentrate around 2 the upper limit in the graph is set to 2 only.

The frequency of a total of 50 groups of values is shown in the following histograms:





The exact numbers o f these diagrams are as follows:

Deskriptive Statistiken

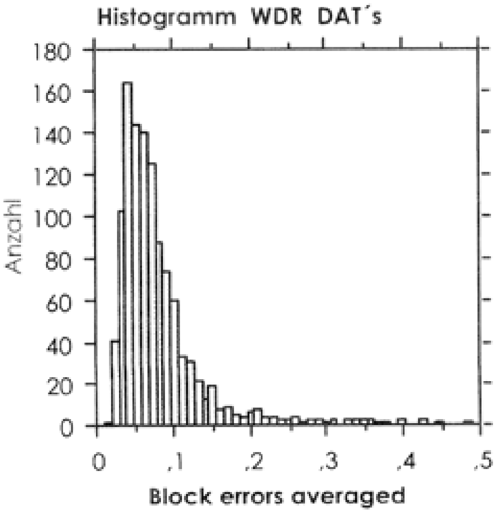
	Block errors per minute
Mittelw.	,415
Std.abw.	,642
Std.fehler	,019
Anzahl	1157
Minimum	,040
Maximum	9,000
# fehlend	29

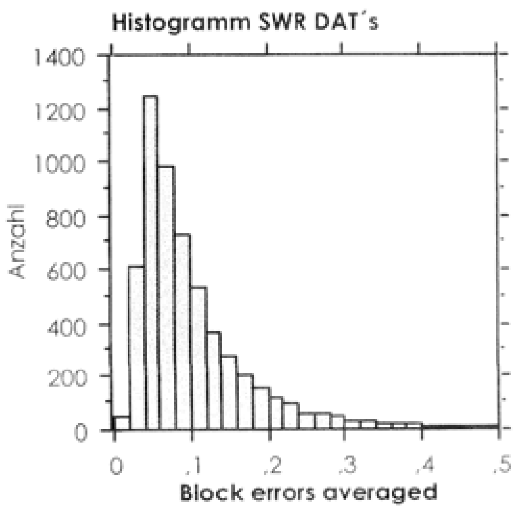
Deskriptive Statistiken

	DAT Laufzeit [min]
Mittelw.	15,798
Std.abw.	11,477
Std.fehler	,149
Anzahl	5919
Minimum	1,550
Maximum	135,600
# fehlend	7

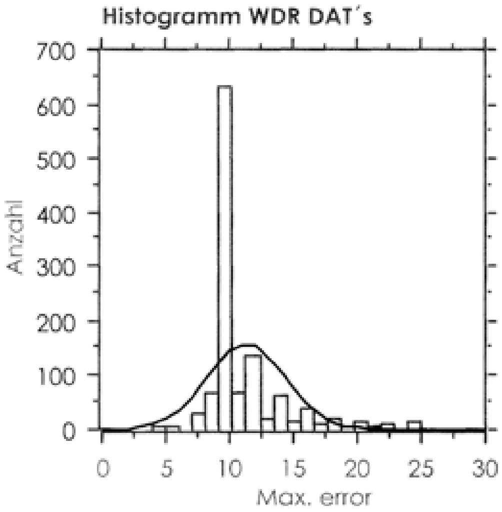
2 b BLER - averaged values for the measured DAT

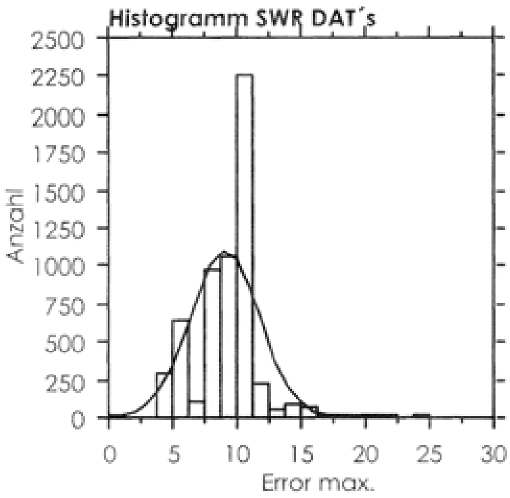
The following diagrams for the averaged values for the complete measurement periods show the values on an upper limit of .5 instead of the permitted 2 to increase visibility:





In both cases error behaviour shows to be „friendly", i.e. the distributions are normal in the sense of the Gaussian bell curve. Standard deviation shows both a „good" behaviour and a safe distance to the given limits.





2 c *Maximum error per frame*

In numbers:

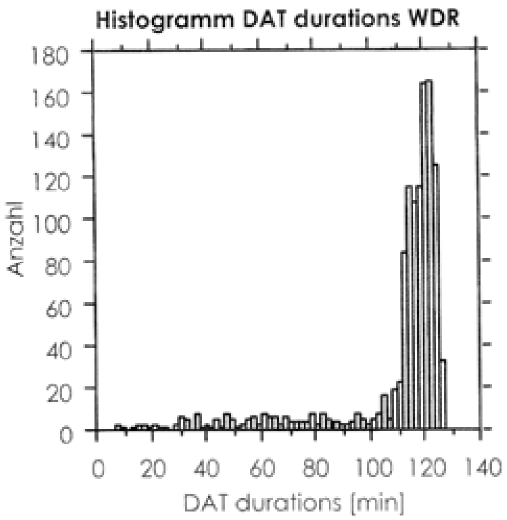
Deskriptive Statistiken

	Max. error
Mittelw.	11,362
Std.abw.	3,055
Std.fehler	,090
Anzahl	1159
Minimum	4,000
Maximum	25,000
# fehlend	27

Deskriptive Statistiken

	Error max.
Mittelw.	9,074
Std.abw.	2,683
Std.fehler	,035
Anzahl	5918
Minimum	,000
Maximum	25,000
# fehlend	8

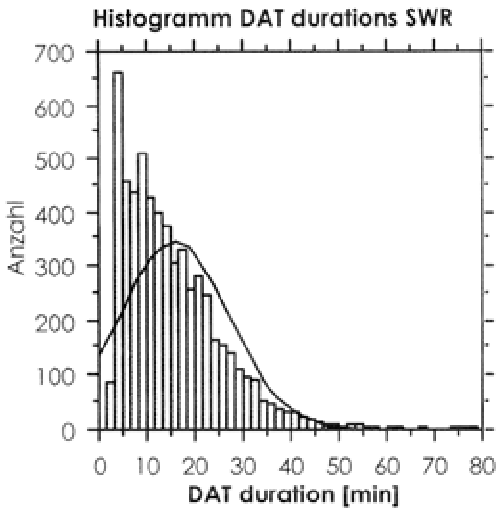
During all the time the number of errors per frame is observed. Their frequency is shown up to the allowed maximum value of 25.
Evidently most of the BLER maxims occur at early TC values, and it is therefore recommendable to start modulation one or two minutes after the DAT has started. However, to understand the indicated decrease completely it is necessary to know the average modulation times on the cassettes as well. There are less contributing DAT´s with higher duration times, and the decrease in the area of more than 5 minutes is partly due to that number.
The average duration between SWR (15,8 min) and WDR (110 min) are rather different, and so it makes sense to compare them in their behaviour separately:



Deskriptive Statistiken

	DAT durations [min]
Mittelw.	109,913
Std.abw.	22,818
Std.fehler	,670
Anzahl	1159
Minimum	7,000
Maximum	127,000
# fehlend	27

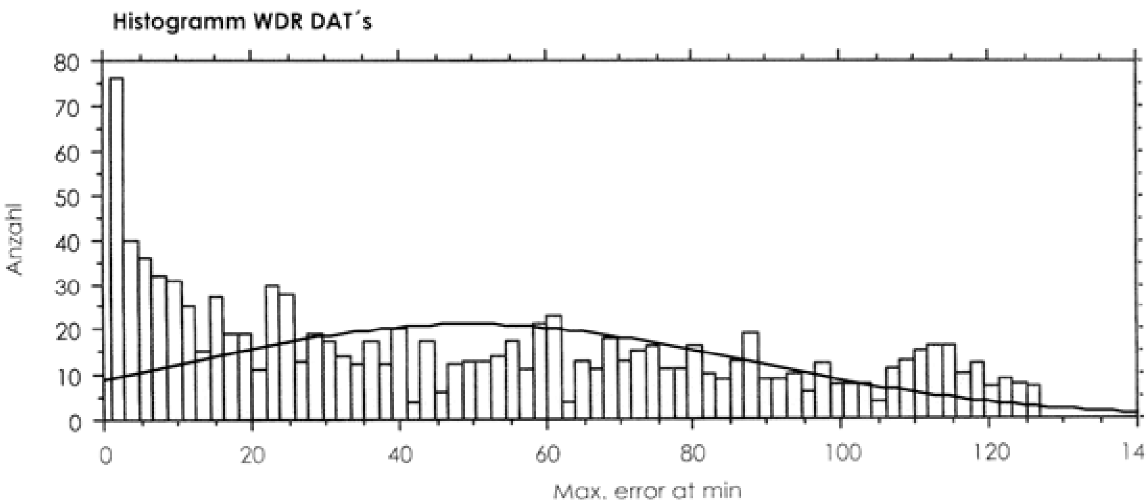
The same numbers for the SWR are:

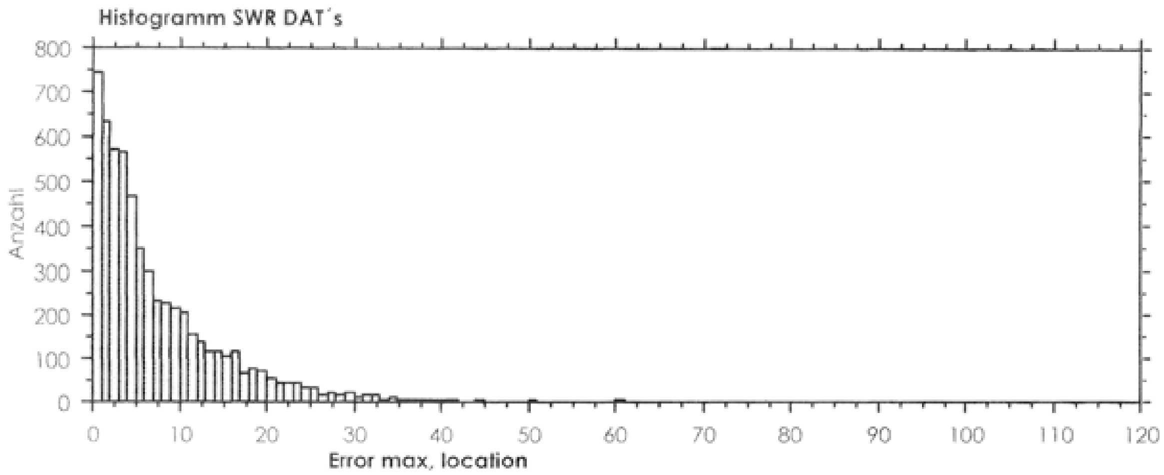


Deskriptive Statistiken

	DAT Laufzeit [min]
Mittelw.	15,798
Std.abw.	11,477
Std.fehler	,149
Anzahl	5919
Minimum	1,550
Maximum	135,600
# fehlend	7

Since it is interesting to known when or where these maxima have occurred, the corresponding locations and their distributions are shown as well:





Summing up it can be stated that the technical quality of the DAT cassettes delivered is much higher than required by the limits set by the SDR.
Finally it has to be mentioned, that in 52 cases DAT´s had to be re-recorded due to (forbidden) averages, and that the measured values vary considerably for the same tape, even if it is reinserted it into the same machine. Yet the medium DAT in toto is very safe as demonstrated by the above given statistics.

C The future: Automated tape solutions for multi TB (Tera Byte) archives

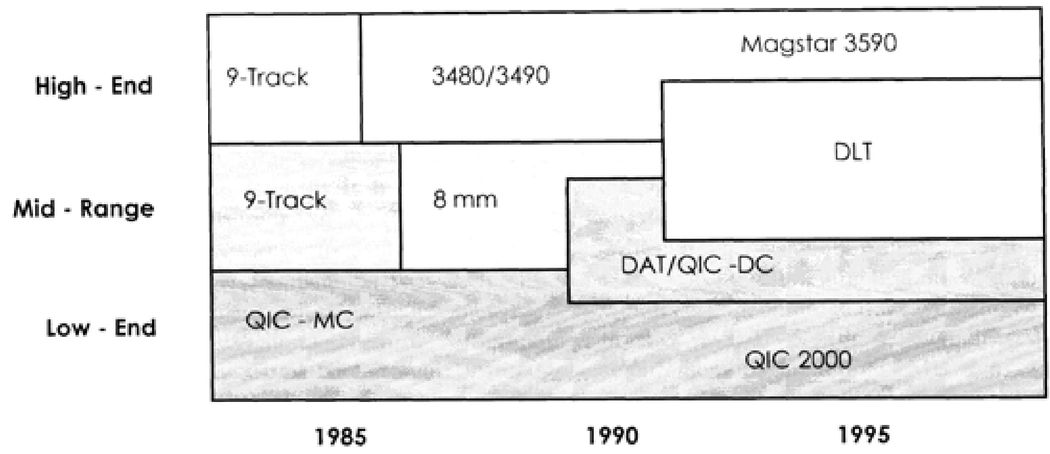
The reported tape-to-DAT conversion is only one step on the way to the fully automated digital archive of the future. As there are large quantity storage systems around within the major bank companies or insurances it is useful to look at their approach, because here we have proven figures. These archives are based on tape solutions in conjunction with automatical access within a minute or less to the desired file and in combination with a hard disk array enable fast and reliable retrieval of files of every kind. Within the next few years such systems will be installed in most of the German Broadcast Corporations replacing the classical studio tape oriented archives.
Looking into the future shows certain evidence, that the mass storage systems common in the computer world will play the major rule for the archives as well. I do not hesitate to say that this means a change in paradigm for the archivist, because from that moment on it is not a single piece of analogue or digital carrier he has to take care of but a computer file and his migration „skills".
As smaller mass storage systems have become available for some time already and have dropped in price considerably they might be considered as a solution for archives from 500 h on. Compared to the now popular CD recording there are tremendous advantages in

• Errorfree operation (as there is no real time demand during storage, all digital errors are below 10^{-15}, practically meaning 0 compared to CD´s and DAT`s)
• Creating „eternal" audio files by automatically lossless copying the Cartridges every 5 years for example.

At the same time, there are some complications in handling:

• You first have to retrieve the selected audio file onto a hard disk to listen to it
• You have to create a digital carrier - CD or DAT - if you want to play the music elsewhere.

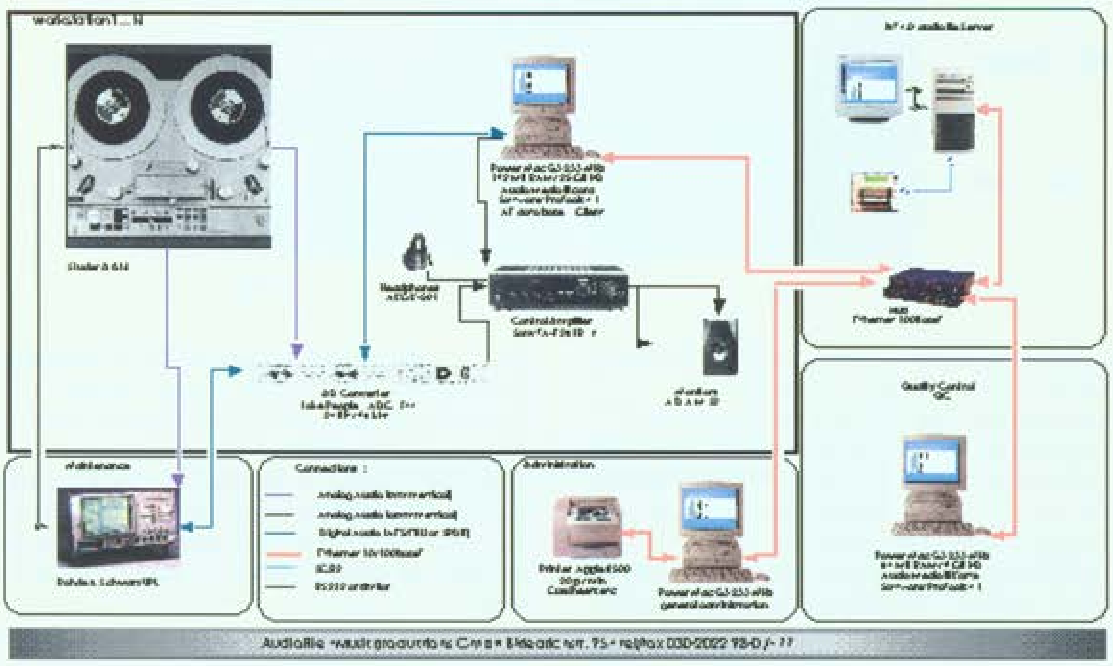
A lot of consideration could be made concerning mass storage systems, but this time there is no room for more detailed discussions. However, up till now, an adequate number of audio files are missing. As it takes years in every Broadcast Company to digitise the main quantities under consideration, one cannot wait until the arrival of the big machines. There is little sense in buying large systems that lack the contents they are built for.
To be prepared for that situation, the SDR Stuttgart for example chose the presented DAT cassettes with incorporated bar codes and user bits as a intermediate storage medium, to be able to transfer these cassettes on an automatical basis to the large system, whatever make and size it will be. A DAT Jukebox that handles the process automatically has been constructed, so that a transfer to mass storage formats can be achieved automatically-
Other solutions for an intermediate format can be imagined as well. Looking at the storage solutions that are common with large computer systems in bigger companies different formats can be found. A short overview can be seen here:



All these different formats can be used to store audio via a back up software for later retrieval.
It becomes apparent, that the back up software used is of great importance because the later transfer to the „big box" has to be absolutely for sure and therefore best scalability and proven migration capabilities to later database applications are the main Focus here.
These consideration lead AudioFile to offer mainly tape-to-DLT transfers in conjunction with „Legato" software, as a riskfree chance to archive tapes now, without having installed one of the major solutions already. This software guarantees especially the transfer to the IBM ADSM database.
Of course, if there is a final format already known, we can produce these Cartridges for direct use within the system.
The safety obtainable here improves the archive situation in a quantum leap. The advantages in reliability and in cost will lead inevitably to such systems, and therefore the digitisation of the selected archive contents has to be done - or better: should have been done - the moment the big system is available.

D How to write on DLT Cartridges

Although there is no mass storage system at the SWR yet there has been a decision to prepare audio files for the moment it arrives.
Since half a year we produce 20 GB DLT Cartridges that have to fond there way into a system whose details are not known yet. To keep complete freedom insofar it has been decided to create pure wave files with no Meta data.
The analogue signal starts from a Studer A 816 and is fed through an analogue-to-digital converter that should have a very good quality. The now digital signal is edited, in- and outfadings are inserted and in the cases where necessary the different tapes are put together to form a new and complete audio file. None of the restauring or denoising techniques is applied; preservation is the only job.
After having finished the file has to be sent to an NT server, that is able to write the files onto a DLT cartridge. The problems involved here are discussed later in more detail.
The finished file collection is controlled for its correct archive number and critical things like faded and paused sections.
The principal Set Up of the equipment looks as follows:



Organising and controlling all the steps while capturing audio and archive data demands a data base application that:

• On the input side takes into account the grown structure of the tape numbers under consideration, (area codes, range and structure of possible numbers),

• Controls all input data on a logical basis as far as possible: no double numbers, no missing numbers or details, conditions for numbers to appear and similar considerations,

• Automatically generates the archive numbers from the existent analogue tape numbers - very useful to avoid errors in this most critical moment,

• Generates barcodes if desired to enable later automatical transfer to large archive systems,

• generates appropriate documentation like cue sheets and booklets from the data captured by the operators,

• Generates various listings to allow systematic controlling,

• Stops work in progress as soon as any data are missing or found to be unlogical in one or another way,

• After finishing the DLT, enables a separate quality control to be executed to ensure the correct relation between original music, attached documentation and finished cartridge. To demonstrate the functionality of the software we follow an incoming studio tape on its way to become a well-documented DLT cartridge.

A corresponding database application has been written. It accompanies the digitisation from the start, where the incoming tapes are registered, and where everything of interest to be found on the box is transferred:

Together with the list the software creates the 8-Digit archive number automatically. So error free operation is guaranteed at that very crucial point within the process.

A cue sheet that automatically appears with the corresponding Meta data and allows noting the times elapsed plus comments concerning audio related problems accompanies the digitising itself. The categories for these problems are selectable, individual remarks can be made as well:

The moment the record is completed a flag is set and the file is ready for the quality check later on.

Cue Sheet DLT

SWR>>

- Die Schweiz in Stuttgart -
Nun singen sie wieder. Ein Requiem

Autor
Frisch, Max

Komponist
Frisch, Max

Interpreten

Archivnr.	**60006154**	**Daten Analogband:**	○ Stereo ◉ Mono
Aufnahmedat.	18.07.47	○ 320 nWb/m ◉ 514 nWb/m	◉ linear ○ Telcom c4
Erstsendedatum	20.07.47		
Ton		**Medium**	**Sampling**
Digitale Arch.	AudioFile Berlin	○ DAT ○ CD-R ○ IBM/M ◉ DLT	◉ 48 kHz ○ 44,1 kHz
Operator	Ritter	**DLT Nr.**	**Margin**
Umschnittsdat.	08.06.99	10	6 dB

Bearb. **Regie**

Band		ID Text	Start ID hh:mm:ss	Mod.ende hh:mm:ss	Zeit/ID hh:mm:ss	Margin
1	Anf.	(Musik) (Ansage) Das Schauspielerensemble…	00:00	21:04	21:04	6 dB
	Ende	…eben eingeschlafen (Schritte, Sirene)				
2	Anf.	(Musik) (Stimmen)	21:04	44:05	23:01	
	Ende	…ich muß. (Geräusch fallender Bomben)				
3	Anf.	(Chorgesang) Nun singen sie wieder…	44:05	80:01	35:56	
	Ende	(Absage) …Claire Schimmel				
	Anf.					
	Ende					
	Anf.					
	Ende					
	Anf.					
	Ende					
	Anf.					
	Ende					
	Anf.					
	Ende					

Cue-Kommentare **Laufzeit** 01:20:01

• Knackgeräusche	
• Kopiereffekt	
• Drop out(s)	
• Pegelschwankungen	bes. ab 55:30

3 Verweisnr.

6061541	
6061542	
6061543	

The detailed delivery notes contain every Studio Tape within the DLT including its history and duration. Furthermore the final control status is ensured and correct samples only reach the customer. Invoicing on a correct price per minute basis is achieved.

Liste eingegangener Bänder mit Archiv# :

Lief (soll DLT#) — QS Liste

Bd.#	Box	Einlieferer	Archiv#		Archiv# LZ	Dauer (Job)	Fak. (Job)	Marg (Job)	Umschn. (Job)	Operator (Job)		file	DLT# #	DLT# ok	int.	ist		QS Liste	
8050	8	04.10.1999	**60020688**	2	63:00	01:13	1,2	5dB	04. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8052	8	04.10.1999	**60020691**	2	65:18	01:23	1,3	4dB	04. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8054	8	04.10.1999	**60023858**	4	76:01	02:15	1,8	4dB	04. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8058	8	04.10.1999	**60023991**	2	52:21	01:35	1,8	6dB	05. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8060	8	04.10.1999	**60023997**	2	57:09	01:08	1,2	2dB	05. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8062	8	04.10.1999	**60024033**	3	78:38	01:36	1,2	7dB	05. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8065	8	04.10.1999	**60024034**	3	86:11	02:22	1,6	5dB	08. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8068	8	04.10.1999	**60024099**	2	58:52	01:13	1,2	6dB	08. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8070	8	04.10.1999	**60024233**	2	58:43	01:07	1,2	6dB	08. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8072	8	04.10.1999	**69001796**	1	14:42	00:25	1,7	4dB	04. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8076	3	24.11.1999	**60002255**	2	69:46	01:36	1,4	7dB	24. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8078	3	24.11.1999	**60002295**	1	28:01	00:49	1,8	5dB	24. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8080	3	24.11.1999	**60002989**	2	38:12	00:52	1,4	8dB	24. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8082	3	24.11.1999	**60007155**	2	57:47	01:32	1,6	6dB	24. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8084	3	24.11.1999	**60012867**	2	78:07	01:48	1,4	5dB	24. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8086	3	24.11.1999	**60019221**	2	57:41	01:30	1,6	4dB	25. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8088	3	24.11.1999	**60020595**	3	85:44	02:09	1,5	4dB	25. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8091	3	24.11.1999	**60020686**	2	53:38	01:31	1,7	5dB	25. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8093	3	24.11.1999	**60020689**	2	56:32	01:08	1,2	6dB	25. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8095	3	24.11.1999	**60020690**	2	40:26	01:06	1,6	5dB	26. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8097	3	24.11.1999	**60020692**	2	51:57	01:10	1,4	4dB	26. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8099	3	24.11.1999	**60020694**	2	61:29	01:16	1,2	4dB	26. 11.99	7	Ritter	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8101	3	24.11.1999	**60024038**	2	49:06	01:20	1,6	6dB	26. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99
8103	20	24.11.1999	**60020706**	2	49:43	01:02	1,3	1dB	26. 11.99	20	Wille	£	26	£		geliefe	02.12.99	Ritter	29.11.99

Datensätze: 24 St. **Analog-Bd.** = 51 St. ø 27:15 ms **Filedauer** : 23:09 h:m **Jobdauer DLT** 33:17 **Faktor** 1,3 5.627 6.527

So, in the end, we are quite sure to send error free DLT cassettes to the Broadcast Corporation and help to develop the archives of the future.

In our case things were somewhat special, as we prefer Apple Macintosh computers, with good reasons however. The Audio workstation we use is a ProTools 24 System, that is well acknowledged within the Broadcast world, and as mentioned before it needs the so-called "Disk Bouncing" to create a wave file. Typically this needs the same time as the original recording, and it would double the time needed for the digitising process. It is not possible to do a batch job, where for example 8 files could be bounced during the night. As the Mac OS is scriptable it is possible to write a small program that opens up the files, starts bouncing and saves the now completed file. Primarily from this reason, others not mentioned, we chose the Mac platform, because the ability to do batch job is vital for a good efficiency.

An additional problem however occurs by the fact that ProTools on the Mac is not able to bounce directly to a wave file, but creates so called SDII (Sound designer II) files instead. So we are forced, after getting the SDII file, to convert to wave files afterwards and send these to the separate Windows NT server, where the DLT station is working.

It has been agreed upon Windows NT as the driving Software to write on the DLT Cartridges because there is a tape solution in the System built in. Every NT based computer with a SCSI connection can handle a DLT or comparable cartridge station and retrieve or reconstruct the contents of the cartridge.

To convert to wave and send the files to the NT server we use the BarbaBatch Software, that works on cross platforms and can handle as many files as we need. As BarbaBatch is scriptable we implements start, file selection and transformation in our Apple Script application and now have a complete chain that takes care of the finished audio material and creates the right format on the right place.

For the mass storage systems to come there are questions of hard- and software to be answered before you can start working. Especially the entrance of externally created files is critical for the Broadcast data base manager. To avoid these problems we work on a pure wave file basis. That means we are not part of the system but deliver Cartridges in a DLT 4000 format, maximum 20 GB uncompressed per cartridge, that contain wave file only and no Meta data. In the future it might become attractive to use the Broadcast Wave Format. So called "chunks" enrichen the original wave file by Meta data containing information about the quality or other related things of interest.

Besides these considerations the only data with Meta character are the names of the files itself, the archive number. It serves as the primary key to find the corresponding data in the database.

When the Cartridges arrive their content is retrieved, that means it is reconstructed on the hard disk of an NT computer, where the entire wave files are in their original playable status. A 1:20 until 1:40 speed can be expected for the retrieving process.

Now the situation is ready to enter the IBM or Management Data world, and the files are transferred, again in a 1:20 until 1:40 speed to the Magstar or DLT cartridge or whatever storage system is used.

Everything now happens within the Broadcast stations, no supervision concerning the music is needed any more, because the transfer reliability of these systems is very high, and optional verifying controls make the archiving absolutely safe.

Working with wave files only gives a free choice of the transportation medium. Within the ARD the above mentioned DLT 4000 Format is recommended. Meanwhile the DLT 7000 is a more common standard, carrying 35 GB or 50 h of AES/EBU 16-bit/48 kHz material. The upcoming innovative solutions like Sony AIT, Tandberg MLR and some others will change the situation within the next 2 or 3 years considerably. Cartridges with up to 500 GB or 750 h of music are announced, and transfer speeds for the SCSI or related busses go up to 160 MB/sec, allowing a 1: 160 speed ratio or more, delivering the content of a complete CD within 5 seconds or less.

Quite evidently this kind of speed and availability will develop great influence of what will happen to the audio archives. The most urgent question concerns MP3, the new and effective audio format that can be distributed via Internet. The reduction in data compared to the classical AES/EBU16 bit/48 kHz format is approximately 1:11, and yet the sound is still quite good. So besides the linear archiving there will be interest to have an MP3 version as well that can be provided on demand on an inviting financial basis.

AudioFile can produce this format either during the archive process itself, or create an additional MP3 version from audio files that are in the digital format already. Although the MP3 files contain such a small number of bytes only it needs special hardware equipment to encode the audio material in less than real time.

Modérateur/Moderator : Dietrich Schüller
(Phonogrammarchiv, Austrian Academy of Sciences - Chairman IASA Technical Committee)

Discussion

Dietrich SCHÜLLER

Thank you very much for this outlook. You have showed us an easy way to transfer analogue holdings into the mass storage system before having even bought it.

Ian GILMOUR

You mentioned that some of the DATs from WDR showed higher error rates. Were these perhaps stored differently? Were different types of tape used?

Klaus HEINZ

All of the DATs used were of the Sony Professional brand. Only the length varied. Their behaviour is not highly logical.

From the floor

Can you explain the difference that distinguishes southwest Germany's error rates from those of other regions? I did not understand.

Klaus HEINZ

When compared to the later minutes of the tape, the first minute shows higher degradation levels. I do not understand why that occurs.

From the floor

The problems that occur on the mechanical rolls affect the first ten layers of the tape. Errors always occur in this position. It may be a matter of tape length, since only a few of your tapes went beyond ten minutes.

Klaus HEINZ

That may be one explanation. In any case, I must emphasise that the tolerance levels supplied by the broadcast stations were quite far from what we measured.

Representative from Danish Film Institute

You advised against recording on one DAT machine and replaying the tape on another machine. Does that not weaken the DAT solution entirely?

Klaus HEINZ

No, very few DAT recordings are subsequently played on other equipment. The problem lies in finding an alternative solution. DAT is much safer than CD-R and far more reliable than any of the current analogue systems. I would suggest you reformulate your opinion on DAT.

Jacob TROCK

My experience with CDs leads to the same conclusion as my tests on block-error rate. The empty spots between sessions create a block-error and always occur in the first minutes. That does not mean that the system is faulty.

Klaus HEINZ

While that is true, the DAT system indeed holds a number of errors.

Modérateur/Moderator : Albrecht Häfner
(IASA Secretary General - Südwestrundfunk, Documentation & Archives Dept.)

Please allow me to give a short introduction for the next three papers. This session is dedicated to digital mass storage systems for audio applications. We must remember that digital mass storage technology has been, already in the 1980s , a matter of fact in areas where very large amounts of data have to be stored before being processed, digital mastering was used such as in satellite-based telemetry, meteorology and astronomy, or even in the bank and assurance branch. Therefore, it was only a matter of time until further applications were found.

In the early 1990s, digital mass storage technology was discussed to offer solutions for all archival problems. Pilot projects were carried out and proved that the equipment available on the market met the technical and economical requirements for the users. Today, a number of such applications in audio archives exist and you could maintain that digital mass storage systems for audio applications are almost to become the state-of-the-art level. Further developments for use in audio-visual and multimedia archives will be based on experiences made with these first applications.

What distinguishes digital mass storage systems from conventional ones is that they are self-checking and self-regenerating. These features result in a plenty of entirely new potential prospects which, in turn, could serve to meet entirely new requirements. Thus, a lot of questions arise. Three of them are:

- How can we design a modern audio, or even multimedia, archive?
- How should we manage its audio and multimedia content?

How can we transfer current audio data to more modern systems without any loss, thereby ensuring the best possible signal quality, as well as meeting economic needs? Well, let's see whether my speakers can give the answers to these questions.

Our first speaker is Mr. Ralf Gradhand, who studied Information Technology in Germany. Since 1998, he as an Assistant Consultant for the Management Data Corporation in Hamburg, focusing on multimedia archives.

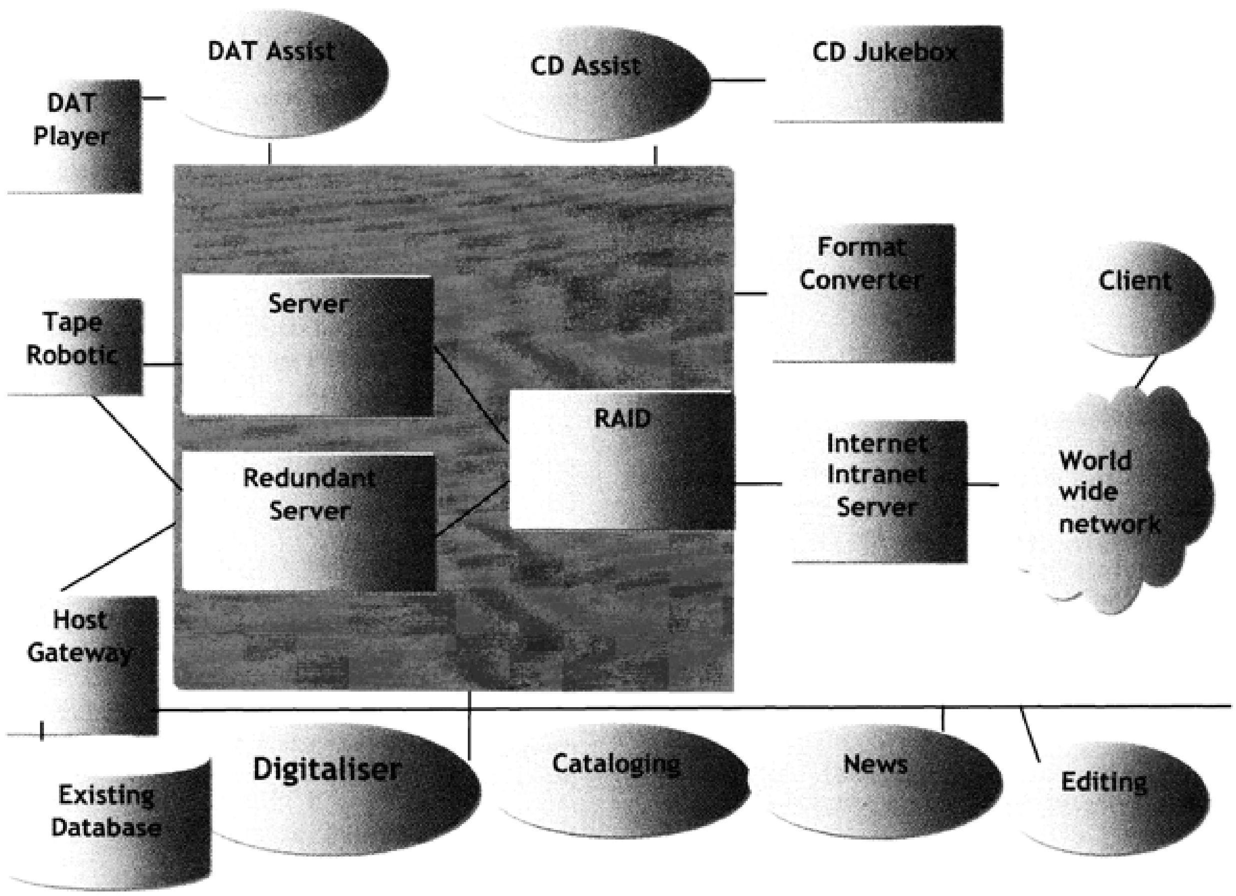
Design Requirements of Modern Audio and Multimedia Archives

Ralf Grahand
(Management data) - Allemagne

Why digitalize your archive?

There are different reasons for the increasing number of projects for computer aided audio archiving.
On the one hand, to days sound carriers will continuously deteriorate over the years to come, so that a copy to the next generation of carriers is required, no matter what.
On the other hand, internet technologies and the workflow in modern broadcasting stations require a quick access to audio and multimedia essentials.

Computer aided archiving solution



Archive Department **News Department/Produktion**

What are the several components of such an archive system, e.g. in a radio broadcast environment ?

In the centre, you see a Server with a connected RAID system. The RAID consists of harddisk drives and is capable of storing the database as well as the required audiofiles in a prelisten quality. The optional Tape Robotic provides mass storage capacity within the solution and should preferably be able to handle several different media formats. DAT Assist and CD Assist are PC-Clients which are responsible for filling the archive with material from CD or DAT.
The Format Converter allows the automatic creation of all required formats (e.g. prelisten or broadcast quality).
Of course there are some specialized clients for Cataloging and Capturing in the archive department.
Search and retrieval of material should be very easy in a browser based application via intranet or internet.
Last but not least, there must be an interface to the existing (host) database that holds the metadata.
Now we try to make a checklist for such a project, which is not entitled to be complete.

Checklist for computer aided multimedia archive

- ✓ Use of standard components (hard- and software)
- ✓ Open interfaces to third party systems
- ✓ Free scalability of the system
- ✓ Easy migration to next generation of carrier
- ✓ Userfriendliness
- ✓ easy searching
- ✓ quick retrieval of content
- ✓ File security
- ✓ Failure redundancy

Use of standard components

The use of standard components not only refers to the central Server, RAID and Robotic system.
It also includes the Clients, the network and the network protocol, where Microsoft Windows, Fast Ethernet and TCP/IP are components with a high market share.

Open interfaces

1. ARCHIVE AS THE CENTRAL SOURCE OF INFORMATION IN A PRODUCTION WORKFLOW

We see a modern Multimedia Archive as the central source of information in a production workflow.

Every user within the workflow should have access to the material.
Therefore, it is necessary to have open interfaces to all the existing applications and to be open to the upcoming new ones, too.

2. INTEGRATION WITH PRODUCTION SYSTEMS

Now we are talking about a Computer Aided Radio (CAR) System as a special kind of application in a broadcast station.
The users want to store News, Jingles and Music in the Archive.
That means, there is a need for interface processes in the archive system that can handle all the required formats for the CAR system.
The same goes for the other way around, when a CAR system user wants to search and retrieve audio or text material.

3. INTEGRATION WITH EXISTING DATABASES

The database of a broadcaster may contain hundreds of thousands of audios and a large amount of datafields in the describing data records.
Besides that, there are often comprehensive search options in the existing database.
These are the reasons why sometimes it is not possible or useful to eliminate the existing database after having taken over the metadata.
In this case, when you are working with two databases, there must be an interaction between the two in order to save the integrity of your data.

4. OPEN INTERFACES WITH RESTAURATION AND EDITING SYSTEMS

Some editing systems have proprietary formats to save not only single audios but complete projects, and sometimes it is useful to support these formats.
But normally a standard format like Broadcast Wave File (BWF) will be stored.

5. AUTOMATION OF CAPTURING PROCESSES FROM DAT

Some suppliers have their own client systems to support the capturing processes.
These systems are more or less unable to make comprehensive quality checks during the capturing process.
For this, you will need to use more specialized tools with of course a higher functionality (and often a higher price).

Following functionalities are available :

- Automatic level controlled start / stop of recording
- Taking over Time Codes
- Automatic detection of peak levels
- Optional rackmountable in the tape robotic

6. AUTOMATION OF CAPTURING PROCESSES FROM CD

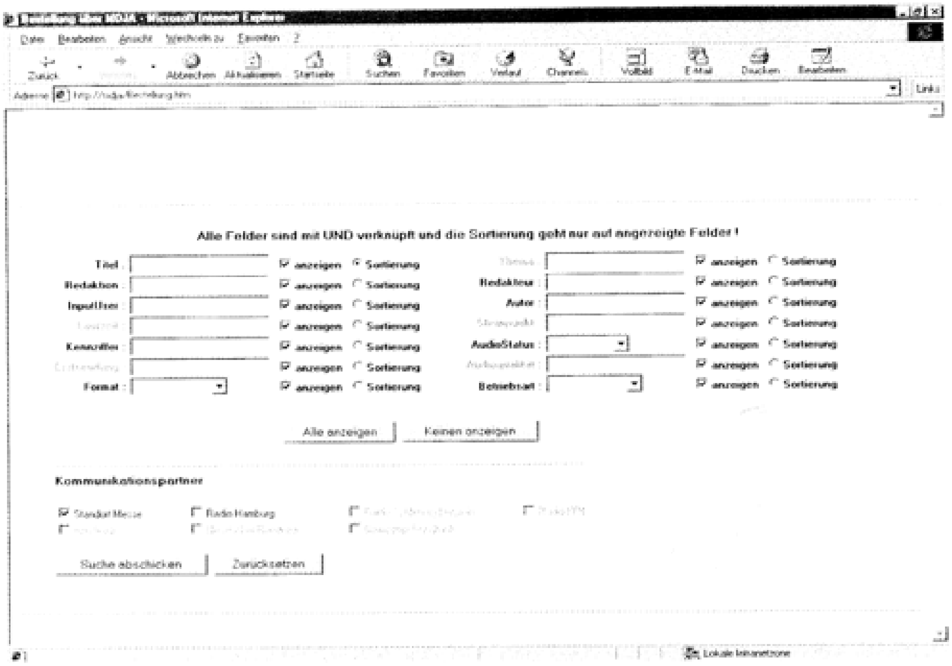
This solution allows the capturing of hundreds of CD's per day, but without a comprehensive quality control.
The capturing speed per drive is at the minimum 8 times faster than real time.
But you have to check the quality by prelistening the material before broadcasting it.

Following functionalities are available :

- Direct grabbing via SCSI in 1/8th real time
- Max. 4 drives simultaneously
- Automatic calculation of average level
- Automatic placement of cross out marker

Userfriendliness

1. EASY SEARCHING BY INTERNET BROWSER



In our opinion the acceptance of the archive system depends heavily on its userfriendlyness.
If, for instance, some hundred or more than thousand users in a broadcast station will have access to the new multimedia archive simply by using the Netscape or Microsoft Internet Explorer, they will feel very familiar with the new system within a short time frame.
Besides that, it will be very easy to install these clients.

2. QUICK PRELISTEN / PREVIEW OF CONTENT

The system should be able to store several formats of the same audiofile for the different purposes of prelistening, broadcasting and internet accessing.
The format conversions should be carried out automatically by the system.
Besides that, additional information like texts, pictures (CD cover) or video clips have to be stored in the system.

3. SEQUENCING CONTENT

Especially for prelistening over slow connections, like the internet, the possibility to jump straight to a cuepoint is very important to prevent long transfer times for the whole audio.
The system should only transfer the requested part of the audio to the client.

Of course, the audio browser has to support the functionality to jump to a certain cuepoint.

Network capabilities of the archive solution

Distributed server systems / Distributed storage

The infrastructure of some broadcasters can be very complex and distributed. The system should support these types of topologies.
It is for instance possible to have different locations for the database, the short term storage (RAID system) and the long term storage (Robotic system).
The complex system structure should be transparent for client users of the system.

Advantages of computer aided archiving for the workflow

- Browsing with standard PC's using MS Internet-Explorer/Netscape
- Availability 24 hours a day / 7 days a week
- Location independent access through modern network
  technology
- Access to both metadata and media objects
- Fast access to key frames / cue points
- Additional links to other types of information

Storage capabilities for editing systems, office communication, etc.

Advantages of computer aided archiving for the daily use

- Access to the online archive without human assistance (24/7)
- Automatic quality check of tapes in the robotic system (infinite file life)
- No loss of quality when copying / generation change

Generation change of carriers (tapes) takes place within the robotic system

Future demands on Multimedia Archive Solutions

An archive solution in the near future will consist of, on the one hand, areas for company internal use only and on the other hand public access areas.
The access to the public areas of the archive (for instance over the internet) can either be free of charge or not.
Of course, firewall systems are very important and useful to protect the archive system from hacker attacks.

Discussion

Albrecht HÄFNER

Thank you for this impressive presentation. This may be the way to design a means for storing multimedia material, both for public broadcasting institutions and commercial broadcasters.

From the floor

My comment may not be relevant, but it does touch upon system architecture in general. It relates to water-marking. Does your system include a pre-listening capability on MP3 before the compressed signal is actually emitted? This would allow you to avoid water-marking.

Ralf GRADHAND

We do not use water-marking. Since the system was designed for broadcasters, Internet functionalities did not appear until a few months ago. We must now begin thinking about them.

Ian GILMOUR

Many archives have already invested a great amount of time to their infrastructure and want to retain their current systems. They have taken the time to make several copies of their material and hold a number of different versions. In making new investments, such archives would only consider systems that could adapt to the existing set-up, rather than developing new functionalities.

Ralf GRADHAND

Are you saying that the system would be too complex?

Ian GILMOUR

I would like to know whether the mass storage system would act as a slave to the new system. Unless the systems are compatible and can support links to existing machines, clients will not be able to access the server through the Internet.

Ralf GRADHAND

We have considered a variety of solutions. We could provide access to the existing database. Our database would only be a mirror of that base. Users from the outside would only be able to access the essentials; they would not be able to use the memory.

Albrecht HÄFNER

Thank you very much. The next theme is Content Management for Broadcast Production Archiving. Our next speaker is Rainer Kellerhals. He holds degrees in Business Administration, Mechanical Engineering and Applied Informatics. Since 1995, he has been working at Techmat Corporation's Digital Media Division. He is also a member of its Board of Directors.

Content Management in Broadcast Production and Archiving

Rainer A. Kellerhals
TECMATH AG - Allemagne

Introduction

This paper about Content Management for Broadcast Production and Archiving explains the terminology used in this field, provides an overview over the user groups and functions involved in content management in broadcasting, describes the workflows associated with content management, introduces a generic software and hardware architecture for content management systems and concludes with some economical considerations.

Terminology

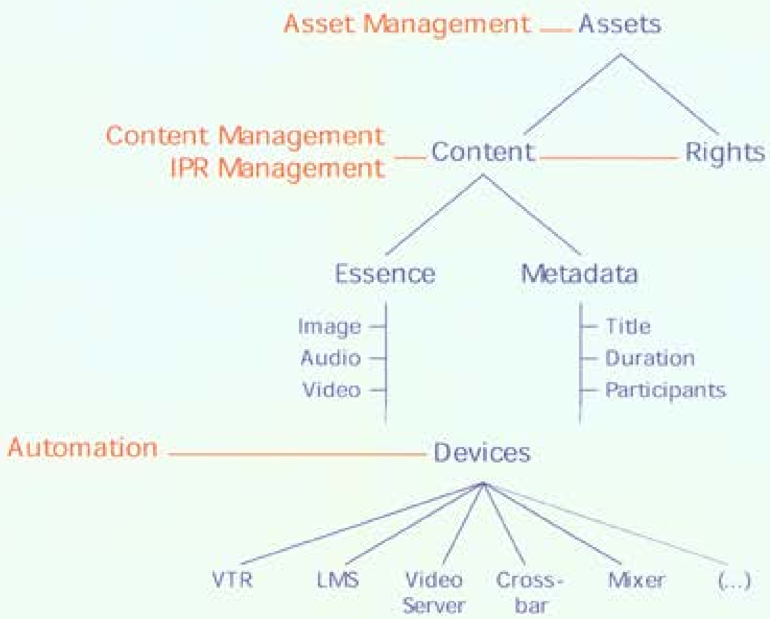


Fig. 1: Terminology

The terminology used in the area of content management is somewhat confusing. Different phrases like "Automation", "Content Management", "Asset Management" are used in quite a similar way and typically are not clearly distinguished. The term most familiar to most readers probably will be "automation", which is a computer-based system controlling various studio devices like video tape recorders, library management systems, video servers, matrix switches and crossbars, mixers and so on. The newer terms "content management" and "asset management" refer to the handling of essence and metadata in an IT-based production environment. According to a definition used by the Society of Motion Picture and Television Engineers (SMPTE), "content" is a term encompassing "essence" and "metadata". "Essence" refers to the audio and video material which is produced, archived and broadcasted in a broadcasting organization. "Metadata" refers to information which is required to organize the workflows in broadcast production and to retrieve the essence once it has been filed, like titles, descriptions, edit decision lists (EDLs) and other descriptive information. Rights actually are a special kind of metadata which, from a technical perspective, are no different from the other metadata. From a commercial perspective, they are very important, though. Owning the rights to content allows the content owner to distribute and to use that content for commercial purposes – turning the content into an asset with a commercial value.

User Groups and Functions in Content Management

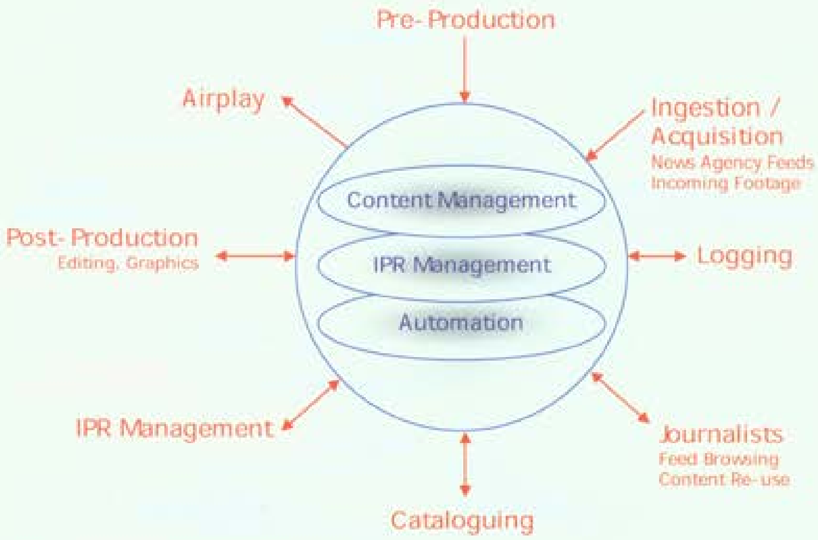


Fig. 2: User Groups and Functions in Content Management

In content management, quite a number of user groups are involved, and quite a number of functions need to be supported. It starts with pre-production, where new programs are planned and resources for the production of these programs are allocated. In this stage, a lot of metadata is created, typically before the first audio or video item has been shot. The next function is ingestion and acquisition, where incoming news agency feeds are recorded and incoming footage from electronic news gathering teams is filed. In this stage, the audio and video material (essence) which has been planned for in the pre-production stage actually becomes available to the broadcasting organisation and typically is registered with the content management system. In parallel with the ingestion or filing process, logging of the audio and video material takes place. In this process, the material is segmented and, in some cases, also annotated. In the case of incoming news feeds this is a real-time process requiring constant attention by an editorial assistant who takes care of the logging. In the case of feature production, typically the producer who has shot the material does the logging, selecting the items which are going to be used in the final program. The next user group, the journalists, need to access the material which has come in as soon as possible. For this purpose, browse copies of the incoming audio and video material are created which are accessible via desktop PCs. Using these browse copies, the journalists can select and sequence the essence and create edit decisions lists (EDLs). These EDLs can be transferred to the post-production unit where they are conformed and final editing is performed. Obviously, the post-production unit needs to have access to production quality audio and video material, not only to the browse copies. After the completed program has received its finishing touches, it is transferred to playout servers which play the program to air. After broadcasting, the completed program is catalogued by librarians who create detailed descriptions of the content. Another department adds information concerning the intellectual property rights (IPRs) associated with the program. All these user groups make use of

- a content management system,
- the intellectual property rights management system which needs to be interfaced to the content management system, and
- the device automation system which controls the various studio devices and is also interfaced with the content management system.

Workflow

The content management workflow is build around two processes: Input and output. In the following, the input and output processes are described for incoming news feeds which are retrieved and browsed by journalists.

Workflow – Input

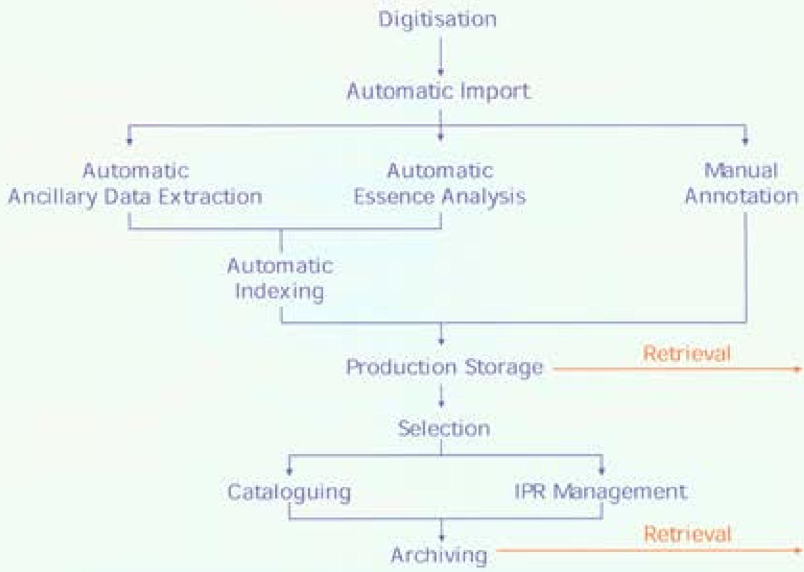


Fig. 3: Workflow - Input

Incoming feeds are encoded to different quality levels in real time, among them a reduced resolution copy (MPEG-1) for previewing purposes. The material is imported and formal descriptions like duration or video format are derived directly from the input material. In addition, existing documentary information such as abstracts, shot lists, teleprompter texts, edit decision lists and other such information is collected and linked to the essence as metadata. The material is then subjected to an automatic content analysis which detects scene changes and extracts keyframes representative of the visual content. Incoming live feeds can be annotated in real time to make them searchable immediately. Metadata provided through automated data transfer or automatic content analysis can be used for automatic indexing of the material. Finally, the essence, the preview copy, keyframes and metadata are linked through timecode references and stored as a media object. Later, material worth of long-term archival is selected, documented on a deeper level and transferred to long-term storage.

Workflow - Output

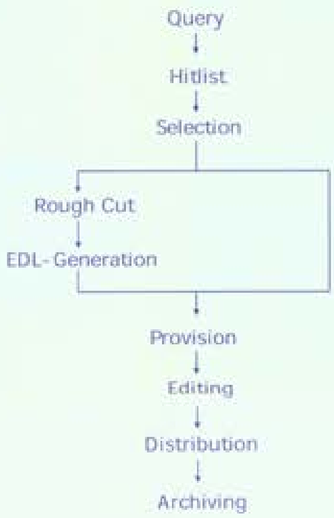


Fig. 4: Workflow - Output

With a content management system, retrieval becomes more efficient. After identifying relevant objects through a full-text or field-based search on the metadata, direct online previewing/prelistening is available for immediate relevance assessment. In addition to this, image material can be previewed in a storyboard format - with the extracted keyframes creating a visual abstract that is very easy to comprehend. Based on this information, relevant media objects are selected. Rough cutting facilities for audio and video material complete the tool set available, and enable assembly of new material from repository contents. Rough cuts can be exported as electronic decision lists (EDLs) in various formats. Using these EDLs, the user may retrieve parts of media objects and transfer the production quality material along with the EDL to high-quality editing equipment for broadcast level post-production.

A Generic Software Architecture

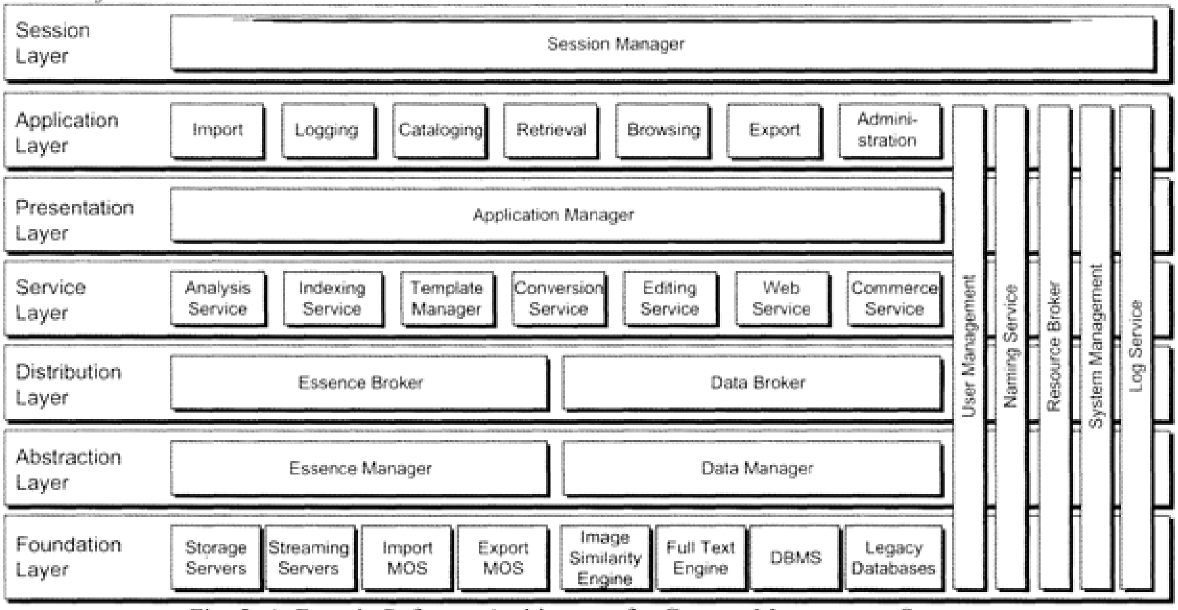


Fig. 5: A Generic Software Architecture for Content Management Systems

Content Management Systems need to provide an open, modular, scalable and adaptable platform for television production and archiving. They consist of several building blocks (Fig. 5). The Foundation Layer consists of a set of server systems, storage units and databases to store and provide essence and associated metadata, distributed over numerous remote sites. So-called Managers provide an abstraction layer to allow other system components to transparently access this foundation. It is important to allow for the integration of third party or legacy systems into the Foundation Layer.

Brokers route requests to Managers and other Brokers, thus providing the capability to distribute content and metadata over a heterogeneous, distributed, IT infrastructure.

Several services may access existing essence or metadata and may generate new essence or metadata. There are the Analysis Service that automatically analyses media objects and provides indexing information, the Indexing Service that transforms generated and provided information to documentation terms, the Conversion Service that handles format conversions, the Template Manager that delivers configuration and programme templates to analyis and indexing services as well as applications, the Editing Service that handles simple editing operations on essence like trimming, or split & merge of audio and video tracks, the Web Service that provides web–based access to internal and remote users, and a Commerce Service that tracks system activities, provides statistical information and handles electronic commerce.

The Application Manager provides a push–update facility for automatic administration and installation of large numbers of client machines.

Several applications are required to allow for import, logging, cataloguing, retrieval and export, display, and manipulation of content, and system administration. Content management systems typically are supported by a User Management System to qualify all user accesses. Distributed systems also have a Naming Service to provide the system with means to identify the whereabouts of all services and brokers, and a Resource Broker to establish connections for media content access with guaranteed quality of service, track system activities and provide statistical information. Moreover, there is the System Management to provide the general system management facilities. On top of all is the Session Manager providing user validated access to the applications.

The Import Client is designed to control the ingest of material into the content management system. Import can be done either as batch processes, scheduled by time or a certain event, or ad hoc. For batch processes the Import Client accesses the Scheduler to schedule the various import jobs. The system should support one-time jobs as well as periodic jobs. For ad–hoc import, the Import Client immediately accesses the local Import MOS and initiates the transfer. It is possible to select various formats imported material should be transcoded to after or while importing. The transcoding process itself is done by the Conversion Service.

The Logging Client is designed to support fast, on-line logging of incoming material, e.g., news feeds. It is designed to provides the initial minimum set of data necessary for editors to retrieve the incoming content. To start logging, the user selects an incoming (or existing) stream. Some of metadata is suggested automatically, like item number or time code information, other metadata is entered manually. To optimise performance, the logging results are normally kept on client side and are not automatically transmitted to the content management server. It is, however, at any time possible to actively initiate an update, which will then immediately transmit all changes to the content management server. Automatic transfer is initiated after completion of logging of an item and at the end of the logging process.

The Cataloging Client accepts the formal metadata to be kept, and to provide also the functionality of segmented, stratified, documentation. It is used for in-depth documentation of the material and adjustment of the results of the automatic analysis process.

The Retrieval Client is a Web–based application, driven by the Web Server and designed to query the content management system's database as well as existing database applications. The Retrieval Client queries a Data Broker, which federates the queries to various Data Managers. A customised Data Manager has to be provided for each existing system that has to be integrated.

The Browsing Client is used to play back material and allow for rough cut and creation of edit decision lists (EDLs) in various popular formats. For use with unsupported editing systems, additional EDL formats can easily be introduced.

The Export Client controls the export of material and metadata to various external systems. An important application for this is exporting to production systems, for versioning and re-use. Like import, export jobs can either be batch processes, scheduled by time or a certain event, or ad hoc jobs. For batch processes the Export Client registers the respective periodic or one–time export jobs with the Scheduler. For ad–hoc export, the Export Client immediately accesses the local Export MOS and initiates the transfer. It is possible to select a target format to which the material is transcoded prior to export. The transcoding process itself is done by the Conversion Server.

The Administration Client allows to configure the user management, the service parameters and more. As a part of the service parameter configuration the Administration Client enables the user to set the source and target formats for system–wide or selective transcoding.

Stratification

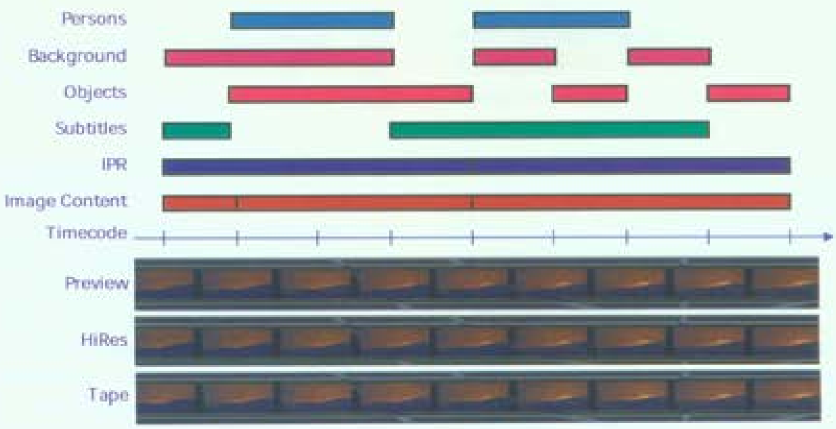


Fig. 6: Stratification

La préservation des données issues des missions spatiales : approche pragmatique, modèle formel et généralisation

Claude Huc, Anne Jean-Antoine
DTS/MPI/PS/VD Centre National d'Etudes Spatiales - France

Introduction

Le sujet traité ici concerne la préservation à long terme des données issues des missions spatiales, données qui existent exclusivement aujourd'hui sous forme numérique (au sens de digital en anglais). Par long terme, nous entendons une durée qui est supérieure à la durée de vie des technologies utilisées aujourd'hui.
Face aux multiples difficultés rencontrées dans ce domaine, un certain nombre de régles à caractère pratique ont été définies et mises en œuvre avec un certain succès. Ces règles pratiques ne constituent en fait que la mise en application concrète mais partielle d'une réflexion normative générale. Cette réflexion, conduite dans un large contexte international, a abouti à l'élaboration d'un Modèle de référence ouvert pour les systèmes d'archivage d'information.

1. Arrière plan : l’expérience de l'archivage des données spatiales depuis près de 30 ans

Les données issues des expériences spatiales présentent un certain nombre de caractéristiques spécifiques dont nous retiendrons :

- La diversité : les données sont produites par des instruments de nature très variées, en fonction des multiples applications scientifiques, opérationnelles ou commerciales pour lesquelles ils ont été conçus. Cette diversité implique une diversité dans l'organisation, la structure et le codage de ces données,
- La complexité : la complexité des données est en relation directe avec la grande complexité des instruments embarqués. Ces instruments sont presque toujours munis de dispositifs intelligents qui leur donnent une relative autonomie de fonctionnement, qui leur confèrent un réel pouvoir de décision incluant la gestion de multiples modes de fonctionnements mais qui, en final, complexifient la structure des données,
- Le volume des données : il peut être extrêmement élevé, de l'ordre de plusieurs centaines de teraoctets pour les missions d'observation de la terre
  Sur la période considérée, ces données n'ont pas toujours et pas toutes été préservées ni maintenues accessibles à la communauté des utilisateurs. Plusieurs facteurs distincts ont contribué à cet état de fait.

Facteurs techniques :

- Les changements constants et de plus en plus rapides des technologies utilisées avec pour conséquence la disparition des technologies obsolètes : Les données dont la structure dépend d'un système d'exploitation devenu obsolète doivent être migrées, les données stockées sur des supports de stockage en voie de disparition doivent être recopiées....
- Une description des données au plan sémantique et au plan syntaxique incomplète ou incorrecte,
- Des difficultés majeures pour maintenir en fonctionnement une multiplicité de systèmes d'accès aux données dédiés à chaque mission spatiale.

Facteurs organisationnels :

- Les missions spatiales sont souvent organisées sous forme de 'projets'. Au sein des agences spatiales, les projets sont des entités non pérennes qui disparaissent lorsque le projet à atteint les objectifs qui lui ont été fixés. La responsabilité sur la préservation des données qui subsistent n'a pas toujours été clairement établie.

Facteurs scientifiques :

- La capacité à utiliser et interpréter correctement les données préservées implique une connaissance approfondie de la discipline concernée et des principes de mesures. Cette connaissance experte a parfois disparu avec le temps.

Les multiples difficultés rencontrées pour préserver ces données, nous ont conduit à élaborer peu à peu un ensemble de règles concrètes fondées essentiellement sur notre pratique et sur notre expérience de ce qui marche et de ce qui ne marche pas.

2. Quelques règles pragmatiques pour la préservation des données

2.1 REGLES APPLICABLES AUX DONNEES

Nous ne retiendrons que deux règles simples à définir, simples à mettre en œuvre. Ces règles sont pourtant rarement appliquées :

- Faire en sorte que les données soient totalement indépendantes des systèmes utilisés pour les créer et les gérer. Cette règle concerne la structure des fichiers et les modes de codage utilisés. Elle suppose que l’on n’utilise pas aveuglément les calculateurs et les fonctions qu'ils proposent mais que l'on rejette systématiquement toutes les structures de données dites 'propriétaires', tous le modes de codages non standards. Les données doivent être neutres. Elles ne doivent en aucun cas porter la marque du calculateur utilisé pour les créer.

- Disposer d'une description des données - au plan syntaxique et au plan sémantique - qui soit exhaustive et conforme aux données. Sans cette description, la réutilisation des données dans le futur est évidemment compromise.

2.2 Regles applicables aux systemes d'archive

Par nature, la question ici est plus complexe puisque ces systèmes sont évidemment construits avec les technologies d'aujourd'hui et donc soumis aux phénomènes périodiques d'obsolescence et de renouvellement des technologies. Les règles pratiques mises en place visent donc à mieux gérer ces évolutions et à en limiter les effets pervers.

- **Séparation des fonctions principales en services aussi autonomes que possibles** : ingestion, stockage, gestion des données, accès aux données. Chaque fonction utilise les technologies disponibles à un moment donné. (calculateurs, systèmes d'exploitation, moyens de stockage, SGBD, protocoles de communications....). La recherche d'une autonomie maximum de chacune des fonctions a pour but essentiel d'empêcher qu'un changement technologique majeur dans un domaine ait des effets en chaîne sur toutes les autres fonctions du système. En outre, cette autonomie a deux conséquences positives importantes :
  - Elle permet la mise en place d'architectures réparties : certaines fonctions peuvent être prises en charge par des sites spécialisés géographiquement éloignés les uns des autres.
  - Elle permet la concentration des compétences et des savoir-faire adéquats au niveau de chaque fonction.
- **Généricité** : par des approches aussi générales que possibles, on supprime les systèmes dédiés à telle ou telle mission spatiale pour les remplacer par des systèmes génériques utilisables pour un ensemble de missions.

3. Un exemple de service : le STAF

Le STAF (Service de Transfert et d'Archivage des Fichiers) est le service en charge du stockage et de la préservation physique des données du CNES.

A l'origine, les données numériques étaient stockées sur des bandes magnétiques. Chaque projet était 'propriétaire' de ses bandes. Les bandes étaient stockées dans un service centralisé au centre Informatique du CNES (la bandothèque), mais chaque projet avait la responsabilité de l'entretien de ses propres bandes. Cette situation a mis en évidence plusieurs difficultés majeures :

- Les projets n'étant pas pérennes, cet entretien n'a pas toujours été assuré,
- La disparition progressive de certaines densités d'enregistrement a nécessité des migrations de données pour lesquelles nous n'étions pas toujours préparés,
- Enfin et surtout, les données stockées sur les bandes n'étaient pas toujours portables et donc par lisibles sur les nouvelles générations de systèmes. Ceci a induit des migrations de logiciels couteuses qui auraient pu être évitées si les règles énoncées plus haut avaient été prises en compte.

C'est sur la base de l'analyse de ces constats que la décision de mettre en place un service de stockage autonome a été prise. C'est le STAF. Le STAF est un service d'archivage et de restitution de fichiers qui prend en charge**, de façon transparente pour l'utilisateur,** la gestion des fichiers et des supports associés. Sa mission est d'offrir :

- Le stockage structuré des données sous forme d'arborescences de fichiers,
- La pérennité physique des données et la gestion transparente des supports physiques,
- La confidentialité et l'intégrité des données, la restitution et la mise à disposition des données dans un monde hétérogène.

Ce service repose sur deux éléments bien distincts :

1. Un produit informatique dont l'interface avec les utilisateurs est indépendante du système d'exploitation et garantie compatible ascendante dans le temps,
2. Les équipements d'accès et de stockage dont les évolutions sont totalement invisibles pour les utilisateurs.

La séparation entre les moyens d'accès au service et les équipements de stockage permet une meilleure évolutivité de chacun de ces deux éléments. Ici encore, on cherche à partitionner le système global pour rendre chaque partie plus évolutive.

Le schéma fonctionnel du STAF dans son environnement est présenté sur la figure 1 ci-après :

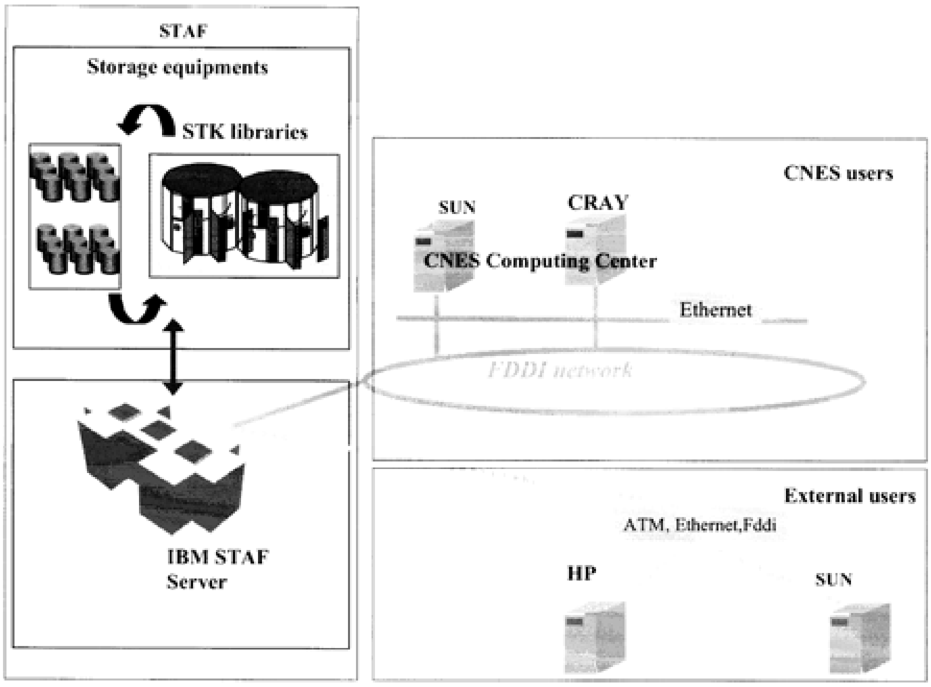


Figure 1 : schéma fonctionnel du STAF

L'utilisateur manipule des noms logiques de fichiers qu'il choisit alors que le système de stockage lui manipule des noms physiques de fichiers. Dans le cadre du STAF, le lien fichier logique / fichier physique est référencé dans une base de données DB2 IBM et l'accent a été particulièrement mis sur le contrôle d'intégrité entre les données logiques et les données physiques. Le système contrôle les accès au service ainsi que l'accès à toutes les entités en jeu (projet, nœud, fichier).

L'utilisateur dispose d'un ensemble de commandes lui permettant d'archiver et de restituer les fichiers mais aussi de gérer et d'organiser son espace de stockage. Ces commandes sont identiques quelques soient les systèmes d'exploitation des machines de traitement (Hp-Ux, Unicos, Solaris, ...).

Concrètement, STAF propose pour l'instant aux utilisateurs des classes de stockage selon la hiérarchie suivante :

- Média on-line, réservé à des fichiers de tailles faibles et accessibles rapidement : disques magnétiques de la gamme IBM et EMC2
- Média near-line, réservé à des fichiers plus volumineux et accessibles moins rapidement : cartouches de la gamme Storagetek (Timberline 1Go/2Go et 9840 20Go) rangées dans des librairies robotisées de StorageTek.

Lorsque l'utilisateur demande l'archivage d'un fichier, il doit définir la classe de service à appliquer à ce fichier. Cette classe de service correspond à la combinaison d'un temps de mise à disposition du fichier et d'une garantie de stockage (duplication ou pas du fichier).

En cas de changement de technologie de stockage, l'utilisateur n'est pas impacté. Le système de stockage assure au fur et à mesure le recyclage des médias d'ancienne génération vers les nouveaux médias. Ce fut le cas pour le CNES lorsque les médias Redwood (10Go) de la gamme Storagetek ont été remplacés au profit de la nouvelle gamme 9840 (20Go).

La préservation physique des données est assurée à 2 niveaux :

- Hardware : les systèmes de disques proposent plusieurs niveaux de redondance RAID (disque miroir, disque de parité) : en cas de crash, le disque de données est automatiquement reconstitué.
- Software : la duplication du fichier par les fonctions de backup du système.

Le STAF est en service depuis 1995. Il offre 24 heures sur 24 un service fiable et sûr utilisé par plusieurs dizaines de projets dont nous décrirons un exemple très significatif en terme de volume de données.

4. Un exemple d'archive : l'archive des données SPOT

Cet exemple illustre à la fois la capacité du STAF en terme de volume de données et d'autonomie par rapport aux projet utilisateurs.

SPOT est un programme civil national d'observation de la terre par satellite. Il est constitué d'un ensemble de satellites assurant un service permanent depuis 1986. C'est la société SPOT-image qui a en charge l'activité de traitement, de gestion et de commercialisation des images SPOT.

De 1986 à mi 1999, les images Spot ont été successivement stockées sur des bandes HDDT, puis sur des bandes optiques puis, enfin, depuis 1995, sur des cassettes Sony. Les mesures permettant d'assurer la préservation des données étaient propres à chaque type de stockage. En outre, la télémesure stockée n'était pas purement numériques. Des équipements électroniques de synchronisation étaient nécessaires pour relire les données.

En 1998, le STAF a été choisi pour être le dépositaire unique de l'Archive des images SPOT et garantir sur le long terme leur pérennité physique. Les images existantes doivent être relues depuis les médias d'origine et transposées dans un format numérique. Les données nouvelles produites par les satellites actuellement en vol sont directement archivées dans le STAF. Les différents paramètres de la prise de vue seront décrits dans des fichiers descripteurs, assurant ainsi la pérennité logique des données.

Cette opération, qui a démarré mi-1999, implique l'insertion quotidienne de 75 gigaoctets dans le STAF. Ces volumes vont presque doubler à partir de 2002 avec le lancement du satellite SPOT 5. Le volume de l'archive SPOT sera de 27 teraoctets fin 2000, 150 teraoctets fin 2003. Il sera rapidement porté à plusieurs centaines de teraoctets.

Le site d'archivage dans le STAF, géré par le CNES et le site de traitement et de distribution des données, géré par SPOT-image sont distants. Pour réaliser l'archivage et permettre également l'extraction des données de l'archive pour la clientèle de SPOT-image, un réseau haut débit ATM (Asynchronous Transfer Mode) a été mis en place. L'interface d'utilisation du STAF étant stable, les deux sites sont totalement autonomes quant à la gestion de leurs évolutions.

5. La réflexion normative

La recherche de solutions générales aux problèmes nouveaux posés par la pérennité des données numériques au CNES date en pratique du début des années 1990. Parallèlement, une réflexion théorique et normative a été entreprise sur ce sujet depuis 1995 par le CCSDS (Consultative Committee for Space Data Systems) à la demande de l'ISO (International Standard Organization).

Le CCSDS constitue un groupe international mis en place par les agences spatiales et dont la fonction est de développer des standards et des recommandations dans le domaine des données. Le CCSDS est depuis 1990 un groupe de travail (working body) pour l'ISO TC20/SC13 (TC20 : Aircraft and Space Vehicles, SC13 : Space Data and Information Transfer Systems)

L'ISO a suggéré que le SC13 entreprenne le développement de standards relatifs aux questions d'archivage des données produites et utilisées dans les missions spatiales.

L'analyse de cette proposition a montré :

- Qu'il n'existait pas de cadre largement reconnu permettant de définir immédiatement des standards dans le domaine de l'archivage,
- Qu'il convenait en premier lieu de développer un 'Modèle de Référence' pour établir un vocabulaire et des concepts communs,
- Qu'il ne fallait pas restreindre cette réflexion à la communauté spatiale mais qu'il fallait l'élargir au maximum, en relation avec les archives traditionnelles.

De multiples Ateliers et réunions internationales ont été tenus dés 1995 aux USA et en Europe. Le travail dans ce domaine s'est poursuivi pendant 4 ans et a abouti en novembre 1999, à la publication d'un livre rouge CCSDS qui a le statut aujourd'hui de 'Draft International Standard'. Ce document s'intitule **'Reference Model for an Open Archival Information System (OAIS)'**

Ce travail a été essentiellement conduit par Don Sawyer (NASA/NSSDC) et Lou Reich (CSC) et une large partie de ce qui suit est directement extraite du modèle de Référence.

6. Le modèle OAIS - Open Archival Information System

6.1 QUELQUES DEFINITIONS INDISPENSABLES POUR COMPRENDRE LE MODELE.

- Open signifie que ce modèle est public et disponible pour qui voudra bien l'utiliser,
- Par Information, nous entendons toute connaissance qui peut être échangée, indépendamment de la forme que prendra cette information. Une donnée est définie comme une forme de représentation de l'information,
- Un système d'archive d'information est constitué par un ensemble de moyens matériels, logiciels et humains en charge de l'acquisition, de la préservation et de la distribution de l'information archivée.

6.2 CIBLE ET OBJECTIFS

Le Modèle de référence est destiné tout à la fois aux concepteurs d'archive, aux utilisateurs d'archives, aux gestionnaires d'archives et aux groupes chargés de développer des standards dans ce domaine.

La terminologie retenue constitue une synthèse des terminologies utilisées dans différents contextes : archives traditionnelles, bibliothèques numériques (digitales), centres de données scientifiques.

Les objectifs principaux de ce modèle peuvent être résumés comme suit :

- Etablir un cadre pour une compréhension globale et commune de la question de l'archivage long terme des données numériques. Ce cadre doit permettre notamment de comparer les architectures et les modes de fonctionnement des archives actuelles et futures,
- Constituer une base pour le développement de standards complémentaires dans le domaine

Le Modèle OAIS ne constitue pas une spécification d'implémentation.

6.3 SITUER L'ARCHIVE DANS SON ENVIRONNEMENT

L'environnement externe à l'archive, schématisé figure 2, est constitué de trois catégories d'intervenants :

- Les producteurs qui fournissent les informations à préserver
- Le management qui définit la politique globale en matière d'archivage,
- Les consommateurs qui récupèrent, à partir de l'archive, les informations qui leur sont utiles.

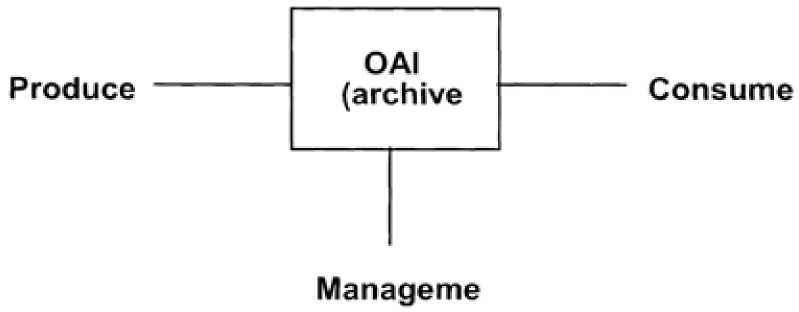
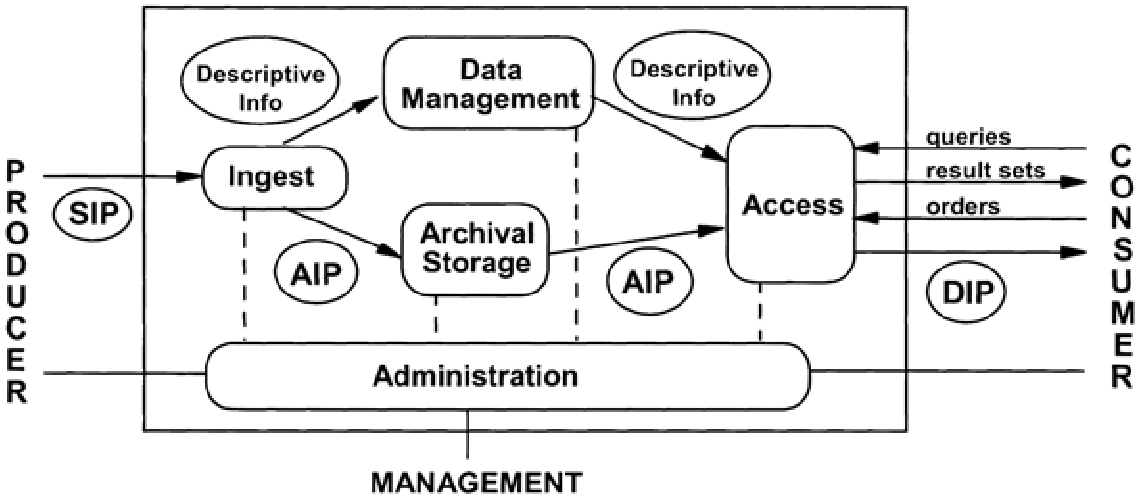


Figure 2 OAIS functional entities

6.4 UN MODELE FONCTIONNEL

L'archive peut être vue comme un ensemble d'entités incluant les fonctions suivantes : Ingest, Data management, Archival Storage, Access and Administration. La figure 3 c ci-après montre ces entités et leurs liens internes et externes.



SIP : Submission Information Package
AIP : Archival Information Package
DIP : Dissemination Information Package

Figure 3. Functional Model of an OAIS

6.5 UN MODELE D'INFORMATION

Sans rentrer dans les détails techniques, indiquons ici que le modèle d'information permet en premier d'identifier de façon claire, quelle est l'information principale que nous voulons préserver. Partant de cette information principale , on pourra déduire un certain nombre d'autres informations nécessaires à la préservation de notre information principale mais qui ne doivent pas être confondues avec elle.

Par exemple lorsque l'information principale à pérenniser est constituée par un ensemble de mesures issues d'un instrument scientifique et stockées sous forme de nombre entiers et réels, nous devons naturellement pérenniser le document électronique qui décrit la syntaxe et la sémantique des fichiers de données. Lorsque ce dernier document fait référence à des normes, existant elles-mêmes sous forme de documents électroniques, nous devons également pérenniser ces informations. On voit apparaître ici un réseau des représentations de l'information qui nous permet de mesurer la complexité du problème lorsqu'il est posé de façon formelle.

Le modèle d'information permet également d'associer à notre information principale, un ensemble

d'informations complémentaires relatives par exemple à la provenance de l'information principale, à son identification, à ses liens contextuels avec d'autres informations, etc.
Le modèle de référence aborde un certain nombre d'autres sujets importants comme la classification des types de migrations et l'interopérabilité entre archives. Pour en savoir plus, on se référera au site Web http://ssdoo.gsfc.nasa.gov/nost/isoas/ref_model.html

Conclusions

Le modèle OAIS, avant même sa standardisation ISO, est déjà largement référencé par de multiples sites Web américains et européens. Il est déjà pris en considération par un certain nombre de projets. Citons notamment le cas du projet NEDLIB mené en coopération entre les différentes bibliothèques nationales européennes (http://www.konbib.nl/nedlib/) .
Le modèle OAIS constitue à notre avis, une base de réflexion essentielle pour parvenir à court terme à résoudre la question essentielle : comment pérenniser de l'information avec des moyens qui n'ont aucune pérennité ?

Discussion

George BROCK-NANNESTAD

D'un côté, vous avez distingué informations et données dans les travaux de normalisation ; de l'autre, vous avez dit que toute conversion des données devait être faite avant l'utilisation et non avant l'archivage (les données sont archivées telles quelles sans modification). Or les utilisateurs ne peuvent échanger que des informations. A quel moment procède-t-on à la conversion des données en informations ?

Claude HUC

Cette conversion n'est pas une opération technique. A partir du moment où nous disons qu'une information est une connaissance particulière qui peut être échangée entre des individus, cela reste un concept abstrait. La donnée est la façon dont cette information va pouvoir être représentée à l'intérieur d'une machine, c'est-à-dire codée avec un certain langage et un certain nombre de règles. Finalement, le passage de la donnée à l'information est le processus intellectuel par lequel, par exemple, vous lisez un document et vous le comprenez. Le document lui-même, lorsqu'il est sous forme électronique, est ce que l'on appelle une donnée. Lorsqu'il est lu et compris par un individu, il s'agit pour lui d'une information.

George BROCK-NANNESTAD

Je prendrai l'exemple, dans le domaine de l'audio, de la conversion de 44 à 48 kilohertz. La question qui se pose est : doit-on préserver les données dans leur état d'origine ou faire la conversion dans un autre format avant l'archivage ? Pour ma part, je préfère votre point de vue de conserver les données dans leur état d'origine.

Claude HUC

En fait, dans le modèle de référence dont j'ai parlé, il y a une classification des différents types de migration. Nous ne traitons pas des migrations qui passent de l'analogique au digital mais des migrations digitales, qui seront partie intégrante de tous les systèmes d'archivage du futur. Dans ces migrations digitales, il y a des migrations sans perte d'information mais avec l'enchaînement des modifications de leur représentation et des migrations avec certaines pertes d'information parce que nous n'avons pas de solution technique pour faire autrement.

Ian GILMOUR

The interest in space data goes back many years ago. Our colleagues Ampex and JPO were the first to discover problems with tape binder failure on half-inch data tapes. That information led us to much of what we know today on the subject of decomposition. Have you experienced any problems with older tapes, some of which were made at a time when the chemistry was not yet founded?

Claude HUC

Nous avons achevé en 1999 un vaste programme de transfert de tout ce qui existait sur bandes magnétiques traditionnelles vers notre système d'archives, le STAF. Ce fut une opération longue et laborieuse, qui a duré sept ou huit ans. Les bandes en question étaient des bandes qui avaient été enregistrées à partir des années 1975 ; certaines avaient été recopiées depuis, d'autres non. Nous avons rencontré un certain nombre de problèmes physiques mais en petit nombre. 2 % des bandes ont présenté des difficultés de lecture mais comme pour tous les projets importants, nous avions pris la précaution de dupliquer systématiquement l'information sur plusieurs bandes, les informations perdues pour des raisons physiques ont été relativement faibles. Par contre, pour des projets menés à la fin des années 70, nous avons récupéré des informations mais nous sommes dans l'incapacité de les utiliser parce que nous n'avons pas leur description syntaxique et sémantique : tous les acteurs de ces projets ont disparu et nous n'avons pas d'élément documentaire précis sur le codage de ces informations.

Dietrich SCHÜLLER

I would like to thank you for your interest. The last paper, which will be presented by Ed Zwaneveld, Assistant Director for Technical Research and Development at the Office National du Film in Canada.

NORMES ET NOUVELLES STRATÉGIES TECHNOLOGIQUES POUR LA PRÉSERVATION DE CONTENUS SUR SUPPORTS MAGNÉTIQUES ET SUR DISQUES

Ed H. Zwaneveld
(Office national du film du Canada) - Canada

INTRODUCTION

Le 21 octobre 1999, l'Association of Imaging Technology and Sound (ITS) des États-Unis tenait une journée d'action législative, au cours de laquelle treize membres ont adressé à vingt-deux sénateurs américains une pétition demandant qu'un dégrèvement fiscal leur soit accordé pour raisons technologiques.

Des maisons de postproduction américaines se trouvent aujourd'hui exposées à devoir investir des centaines de millions de dollars en biens d'équipement pour respecter les normes de la télévision numérique et son menu de quelque 36 options – et ce, juste pour demeurer dans la course. Ces sommes sont déjà six fois supérieures aux bénéfices nets annuels de ces entreprises. Ce secteur est déjà reconnu comme un secteur caractérisé par un haut degré d'endettement et une haute activité capitalistique, et c'est pourquoi il demande que l'on change le droit fiscal afin de réduire la période d'amortissement des équipements de cinq ans à trois ans, soutenant que la plupart de ces équipements pilotés par logiciels sont désuets et improductifs au moins deux ans avant la fin de leur période d'amortissement.[2]

Malheureusement, il semble qu'aucun archiviste n'était présent à cette réunion! Il faudrait pourtant que des archivistes du monde entier unissent leurs efforts pour élaborer des politiques de gestion des œuvres audiovisuelles numériques afin d'aider à établir des normes et à mettre fin au chaos actuel. Les normes de la SMPTE et de l'ANSI n'ont qu'une portée très limitée et touchent surtout les structures de signal et l'échange de produits entre fabricants d'appareils et fabricants de supports. Dans l'intervalle, en l'absence de normes si nécessaires régissant l'échange de contenu, les maisons de postproduction et les archives audiovisuelles en sont réduites à demander des dégrèvements d'impôt pour affronter les changements rapides dans les technologies. Il importe que l'industrie se penche sérieusement sur la question.

LE PROBLÈME RÉEL

Les conservateurs de documents audiovisuels, et les maisons de production et de postproduction qui réalisent les œuvres dont ils ont la charge, sont en pleine période de transition entre les systèmes antérieurs qui évoluaient de manière logique et les nouveaux systèmes dont on ne peut pas extrapoler les résultats en se basant sur leurs prédécesseurs. Les conservateurs sont aux prises avec ce problème et doivent réagir même si l'issue est imprévisible.[3] Les œuvres audiovisuelles dont ils ont la garde sont des organismes qui évoluent, mutent, s'adaptent et peuvent en fin de compte devenir de nouvelles entités un peu comme un roman peut engendrer un film puis faire l'objet d'un nouveau livre. Quand elles sont gérées intelligemment, les œuvres peuvent non seulement survivre, mais elles peuvent poursuivre une carrière florissante. Nous savons que les méthodes traditionnelles en usage dans les cinémathèques et que les supports à propriété exclusive ne suffiront pas, et que des pertes inacceptables dans la « chaîne de valeur des images » se produiront tant qu'on n'aura pas réglé certains aspects essentiels de la préservation des documents audio et vidéo dans ce nouvel environnement.[4]

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[2] Terence Rainey, « ITS Goes to Washington », *DTV Business*, 12.13.99. p. 6.

[3] Ed H. Zwaneveld, « Paving The Way for Future Television Archives », *EBU-IFTA presentation*, Vienna, Austria, June 1999.

[4] E.H. Zwaneveld, « Extending Video Content Survival Beyond 25 Years-When All Odds Seem Stacked Against It », (Tutorial) *SMPTE Journal*, October 1999, pp. 713-717.

Concernant les supports à propriété exclusive, les mots de Kevin Perry, directeur du marketing et du développement de l'entreprise chez Seagate Removable Storage Solutions de Costa Mesa, en Californie, portent à réfléchir : « Ce qui caractérise ces supports, c'est leur fragmentation, qui déroute le client, augmente les risques, diminue la concurrence, ralentit le développement technologique, empêche une large pénétration du marché, et le fait qu'on ne peut les utiliser qu'en applications verticales. » S'il dit vrai, il n'y a donc aucun avenir dans la fabrication de systèmes d'enregistrement vidéo à propriété exclusive puisque tous ces inconvénients entravent le développement de l'industrie de la vidéo. Ces systèmes ont pour effet de détruire les archives qui témoigneront de notre époque et ils sont un monopole dans les mains d'une poignée de fabricants qui tiennent leurs clients en otage et mettent en péril les sommes investies dans la production.

Il faut établir des normes pour pouvoir changer de support de manière transparente, quel que soit le système de stockage, le type de support ou d'encodage ou le mode de transport. Malheureusement, l'élaboration de ces sortes de normes et de pratiques recommandées peut prendre des années.

L'ÉDITIQUE, SOLUTION D'AVENIR

La gestion des œuvres audiovisuelles évolue dans un sens analogue à celle des documents en ligne, c'est-à-dire que les œuvres ne seront jamais finies et que de nouvelles « éditions » verront le jour à mesure qu'une nouvelle information y sera intégrée. De plus, le contenu des œuvres audiovisuelles deviendra « bon à citer » et pourra figurer dans d'autres documents qu'on n'avait pas prévu de produire à l'origine. On s'attend non seulement à ce que cela augmente la valeur des collections faisant l'objet d'un droit de propriété intellectuelle, mais que cela permettra d'assumer la migration et la conservation nécessaires de tout contenu stocké numériquement.

Étant donné que les systèmes de gestion des biens et des produits s'appuieront sur les mêmes infrastructures informatiques qui permettent l'échange peu coûteux de contenu, ces productions bien conservées continueront également de muter sous divers modes nouveaux de distribution au fur et à mesure des progrès technologiques.

LA FIN DE VIE DES SYSTÈMES

On s'étonne de constater que, jusqu'à récemment, on ne s'est pas tellement préoccupé de la durée de vie des contenus. Malgré des paroles lénifiantes sur le prétendu miracle numérique – en réalité une série de solutions partielles donnant lieu à de multiples corrections pour régler les lacunes et les erreurs non prévues qui se manifestent au bout de quelques mois – les organismes de normalisation doivent prendre en compte la durée de vie des technologies que leurs normes régissent. Compte tenu de la variété des supports vidéo et disques optiques inscriptibles offerts sur le marché, les fabricants doivent établir à quelle date leurs produits seront retirés du marché et qu'ils en fassent part à leurs clients et aux conservateurs. Les bases de données qui gèrent les œuvres audiovisuelles et leur conservation doivent être capables de déclencher la migration du contenu si l'on a introduit dans le système l'année où le produit sera retiré du marché. La version la plus récente de toute norme doit préciser l'année où le support termine sa vie pour que quiconque possède de tels enregistrements les fassent migrer sous peine d'en perdre le contenu.

Si ces propos vous semblent trop alarmistes, songez qu'on estime à 320 millions le nombre de CD-R produits en 1999, et que ce nombre devrait dépasser les 500 millions d'ici la fin de l'an 2000. Malgré cet énorme volume, il faut préciser que la moitié des fabricants produisent des disques qui ne durent pas plus de cinq ans, à cause de facteurs telles la température, l'humidité, la dégradation des couleurs et la pollution. La dégradation imprévisible des CD-R numériques (qualifiée de « disgraceful degradation ») pouvant soudain rendre un disque illisible, il faut en assurer la migration juste à temps pour essayer tant que faire se peut d'en sauver le contenu. [5] [6]
Seules des normes rigoureuses qui énoncent comment protéger votre investissement, quels essais faire et comment en analyser les résultats sauveront du désastre les collections de CD-R. Ces normes n'apparaîtront pas par magie. Le travail réalisé par la Commission technique mixte Audio Engineering Society (AES) / Photographic and Imaging Manufacturers Association (PIMA) est un exemple de la manière dont on peut chercher des solutions pratiques à ce problème.

Nombre d'initiatives et de contre-mesures prises par les utilisateurs concernant la désuétude des systèmes sont discutées, mais les choix faits par les fabricants et les maisons de postproduction ne font l'objet d'aucun débat. [7] Nous croulons déjà sous le nombre des bandes magnétiques offertes sur le marché, et nous continuerons d'en être inondés parce qu'à l'heure actuelle la bande est le support archivistique logique. [8] [9]

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[5] Jacques Lemaire, Nicolas Pichon, Jean-Marc Fontaine, « Microspectrophotometric Analyses of Changes in the Organic Materials used in Optical Discs », *JTS Proceedings*, 1995, pp. 88-95.

[6] Jean-Marc Fontaine, « Relevance of the Parameters Defining the Quality of CDs », *JTS Proceedings*, 1995, pp. 96-108.

[7] Hugh Bennett, « History Lesson-DVD-R Needs a History Lesson », *TapeDisc Business* Oct. 1999, pp. 8, 120-122.

[8] Dan Daley, « Audio Archaeology », *TapeDisc Business*, Nov.1999, pp 2,100-101.

[10] [11]Toutefois, les normes ne préconisent pas grand chose pour assurer la pérennité des productions et leur intégrité, à laquelle sont en droit de s'attendre les utilisateurs et sur laquelle ils misent.

LES MODALITÉS D'ÉTABLISSEMENT DE NORMES : SMPTE, ANSI, ISO

Selon la Society of Motion Picture and Television Engineers (SMPTE), une Norme est un document «qui énonce les principales spécifications, dimensions ou critères nécessaires à l'échange ou à l'interconnexion efficaces au sein du système décrit. Elle peut aussi définir la forme que doit prendre la réalisation efficace de l'échange entre utilisateurs ou la fonction nécessaire. » Ce faisant, la SMPTE met l'accent sur la documentation qui devrait venir avec les systèmes d'enregistrement, sur leurs caractéristiques et sur les interfaces entre les signaux. L'interchangeabilité du contenu en tant que tel n'a pas encore reçu l'attention qu'elle mérite, surtout dans le nouvel univers numérique dans lequel nous sommes entrés.

Par exemple, on attend des promoteurs de la vidéo numérique et de la norme Pro-MPEG qu'ils préconisent un échange sans perte de contenu. Autrement, il y aura incessamment une ruée sur les systèmes ouverts standard qui cadrent mieux avec les méthodes modernes de production et de gestion intégrée des contenus que les magnétoscopes traditionnels.

Nous avons besoin de nouvelles normes pour régir la vie du contenu car telle est la principale préoccupation des gestionnaires d'œuvres audiovisuelles. On pourrait comparer cette situation à la condition humaine. La longévité des personnes âgées n'est pas prolongée par le grand air et les oreillers moelleux, mais elle est fonction du mode de vie sain qu'elles ont adopté bien avant le terme de leur vie. Pourtant, toute personne prenant soin d'un vieillard s'efforce de lui apporter un certain bien-être, tout inefficace qu'il soit à prolonger sa vie. Pour les supports et leur contenu, et pour les conservateurs et conservatrices qui en ont la charge, c'est la même chose.

L'industrie de la vidéo est un labyrinthe inextricable de dialectes exclusifs, dont chacun est amélioré par rapport au précédent. Les gestionnaires détiennent parfois les biens audiovisuels sur bandes mais n'ont pas les lecteurs nécessaires pour les lire et les décoder. Leurs points de vue devraient alimenter la réflexion à l'ordre du jour actuellement à la SMPTE. Le Groupe de travail mixte UER/SMPTE qui a récemment annoncé un important remaniement des normes industrielles est un excellent signe de renouvellement. L'ANSI aussi déclare qu'il est urgent de voir les choses autrement. Le projet mixte actuel UER/FIAT sur les futures archives télévisées sera également une autre occasion rêvée d'établir des normes pratiques SMPTE et ISO/CEI visant à assurer la protection des œuvres audiovisuelles. L'ISO admet que la conservation du contenu et le commerce de tels biens intellectuels « ne devraient pas être entravés par des intérêts de propriétaire ». Elle déclare que « l'industrie informatique … a besoin d'être rapidement, progressivement et mondialement normalisée. » Et elle ajoute : « Une compatibilité totale entre systèmes ouverts favorise une saine concurrence parmi les producteurs (fabricants) et offre de véritables options aux utilisateurs puisqu'elle est un puissant catalyseur d'innovation, améliore la productivité et diminue les coûts. »

D'après l'ISO, voici les éléments profitables au commerce :

(1) « meilleure qualité et meilleure fiabilité à un prix raisonnable »
(2) « meilleure protection de l'environnement et diminution des déchets » (la migration répétée et à grande échelle épuise les ressources et menace l'environnement.)
(3) « meilleure compatibilité et interopérabilité des biens et des services » (par exemple, l'échange de contenus entre différents utilisateurs)
(4) « simplification » (meilleure facilité d'emploi du contenu sans nécessité de créer des musées à la mémoire des appareils désuets)
(5) « réduction du nombre de modèles, et donc réduction des coûts »
(6) « meilleur rendement de distribution et plus grande facilité de conservation » (nos sociétés paient trop cher pour les nombreuses générations de systèmes évolutifs que les fabricants écoulent chez les utilisateurs).

Bien qu'il ne réponde pas encore aux besoins de débit des données vidéo, on pourrait citer comme exemple d'architecture d'enregistrement ouvert la LTO (Linear Tape-Open) distribuée par IBM, Seagate et Hewlett-Packard.[12] Ce support de données est un nouveau support ouvert de stockage sur bande à haute capacité et à haut rendement. Ses promoteurs soutiennent qu'il sera le nouveau point de référence en matière d'intégrité et de fiabilité des données, qu'il servira de carte routière technologique crédible aux capacités de croissance à long terme, qu'il offrira aux utilisateurs des choix de supports supérieurs et aux fournisseurs des solutions multiples et qu'il répondra aux divers besoins des utilisateurs et des applications sur bande.

Cet exposé ne serait pas complet si je ne mentionnais pas, plus spécialement dans le domaine de l'archivistique, un nouveau produit Kodak. Cette

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[9] Aris Silzars, « But What About 50 Years from Now? », *Information Display* 1/00, pp. 4, 36-37.

[10] Junko Yoshida and Margaret Quan, « Connectivity Issues Blur Home-Net Vision », *Electronic Engineering Times (EETimes)* Jan 10,'00, pp. 1, 132.

[11] Dan Daley, « Ground Zero for Audio-Formats », *TapeDisc Business* Dec. 1999, pp. 51-55.

[12] Clare Goldsberry, «Tape takes IRMA's Tech Stage », *Replication News*, December 1999, p.12 and « LTO Rollout « *Replication News*, December 1999, p. 32

compagnie est réputée pour mettre sur le marché des supports durables. Elle met actuellement au point une bande optique de haute capacité à transitions de phase, non réinscriptible mais dont le nombre de lectures est illimité (WORM – Write Once Read Many Times). Cette bande devrait avoir une durée de vie utile de plus d'une centaine d'années et être inaltérable de sorte qu'il soit possible de remonter la piste des droits de propriété intellectuelle. [13]Ce genre de produit, s'il devient une norme ouverte, comme ce fut le cas avec le film 35 mm, pourrait servir pour longtemps de support d'archivage inactif tout autant que dynamique. MicroContinuum, une compagnie secondaire de Polaroid, met actuellement au point un produit similaire qui permettrait de réutiliser une bande après qu'elle a été complètement effacée. On s'attend à ce que des essais pilotes des deux produits soient conduits dans le dernier trimestre 2000 ou le début 2001.

L'INITIATIVE UER/FIAT

Le projet mixte Users Initiative UER/IFTA a permis d'ouvrir un dialogue productif entre les archives télévisées des 50 pays membres et des fabricants intéressés par les nouveaux marchés florissants des systèmes de gestion d'œuvres audiovisuelles et des organismes de normalisation. Ses membres s'emploient à établir les spécifications sur lesquelles pourrait s'appuyer un nouvel ensemble de normes exhaustives pour des produits intégrables pouvant s'étendre à d'autres technologies ou être combinées avec d'autres. Ces normes traiteront de l'intégrité du contenu et d'un système d'identification unique, définiront les métadonnées essentielles devant suivre les enregistrements et l'interopérabilité des dispositifs et des systèmes de commande qui supportent les anciens et les nouveaux protocoles (ou des serveurs mandataires qui traduisent les protocoles). Il proposera aussi des stratégies de migration pour les bandes vidéo patrimoniales, des systèmes de prédiction des défaillances pour assurer la migration à temps et des techniques de transfert de fichiers visant à produire un clone du document audiovisuel original. À noter que seuls les systèmes d'enregistrement possédant une interface données transparente (SDTI ou FTP) peuvent produire des clones sans perte par rapport au document source. Les supports qui ont ces caractéristiques sont DVCPRO50, DVCPRO100, DVCPRO25, D9, Betacam SX et MPEG-2 422 50.

DES PERCÉES

Un dispositif d'évaluation de la qualité de l'image Tektronix PQA-200, mis au point à l'origine par le Sarnoff Research Center du New Jersey, a reçu récemment un prix Emmy. Grâce à lui, on n'a plus à effectuer l'assurance et le contrôle de la qualité au jugé mais on peut comparer objectivement le résultat qualitatif produit par divers systèmes d'enregistrement.

L'Institut für Rundfunk Technik (IRT) de Munich et le BBC Research Centre de Londres et le Swedish Broadcasting Corporation ont également mené d'importants travaux d'évaluation et de comparaison des systèmes d'enregistrement. Ils soulignent les pertes produites par le décodage et le réencodage et les pertes de MJPEG dans une chaîne de production.

Le *Fachzeitschrift für Fernsehen, Film und Elektronische Medien* de Berlin, le *Fernseh und Kinotechnik (FKT) Journal* ont également fait œuvre très utile en publiant les résultats de cette importante recherche. [14]Cette dernière publication se distingue également par ses précieux comptes rendus sur les systèmes de gestion des collections et leur stockage. [15] [16]Nous avons récemment demandé au rédacteur en chef s'il voulait bien assurer une plus grande diffusion de ces informations en soumettant certains de ces articles au journal de la SMPTE, un autre outil précieux de référence technique pour la gestion des collections audiovisuelles.

CERTAINS PRINCIPES À RESPECTER

1. Gérer, plutôt que subir, le changement. Les propriétaires des œuvres audiovisuelles dont vous avez la garde n'attendent rien de moins de vous.

2. S'il vaut la peine de produire, il vaut la peine de préserver (et de prévoir cette préservation dès le début).

3. Le conservateur ou la conservatrice est membre de l'équipe de production et protège l'intégrité du contenu et son « mode de vie », et ne se contente plus de prendre des mesures à la fin de vie de l'œuvre. Son point de vue au sein de l'équipe de production vise surtout l'exploitation à long terme de l'œuvre tandis que la principale préoccupation des autres membres est de faire en sorte que la production soit terminée dans les plus bref délais possible.

4. Une collection électronique est morte, inutile et sans valeur si on n'en prend pas soin. Jusqu'à présent, seuls les disques vinyl analogiques ont prouvé qu'ils pouvaient résister aux assauts du temps, à condition de ne pas se briser ou de ne pas être utilisés trop souvent.

5. Un système moderne doit comprendre un dispositif de surveillance automatique des erreurs et de leur

[13]Clare Goldsberry, « Tape takes IRMA's Tech Stage », *Replication News,* December 1999, p.12

[14]Prof. Dr.Ing. Rolf Hedtke, "Task Force for Harmonized Standards for the Exchange of Program Materials as Bitstreams-Beschreibung und kommentierung des Final Reports, Teil 2. Datenkompression" *Fernseh-und Kinotechnik* 53.Jahrgang Nr. 4/1999, pp. 176-189.

[15] F. Fell-Bosenbeck, "DV-Kompression-Grundlagen und Anwendungen", *Fernseh- und Kinotechnik* 53. Jahrgang Nr. 6/1999, pp. 336-345.

[16]Dr. Ing. Jürgen Heitmann, "Demonstrationen des Pro-MPEG-Forums und der DV-Familie auf der NAB'99", *Fernseh- und Kinotechnik* 53. Jahrgang Nr. 7/1999, pp. 416-421.

correction. Ainsi s'estompe l'idée que les systèmes analogiques sont trop coûteux à conserver. Le système doit signaler quand est venu le temps de la migration.

6. Il n'y a pas de saine migration sans assurance de l'intégrité du contenu, sans contrôle de la qualité et sans carte routière technologique d'une migration sans perte. Exigez que ces renseignements figurent sur les fiches signalétiques des fabricants.

7. L'assurance de la qualité doit être basée sur des repères et des mesures objectives des conditions approuvées, quand il s'agit de nouvelles conditions.

8. La désuétude d'un système d'enregistrement est l'indicateur qui déclenche le compte à rebours de la migration.

9. Un identificateur unique de document (Unique Material Identifier - UMID) est indispensable pour assurer la communication de système à système et de système à appareil. Cet identificateur doit accompagner le document d'un support de stockage à un autre et d'un système à un autre comme toute métadonnée essentielle.

10. De plus en plus d'archives seront dynamiques et liées à des activités qu'on tentera de changer ou qui en produiront d'autres. La production et la postproduction seront intégrées, de nouvelles éditions pourront être réalisées à prix modique, on pourra réutiliser le contenu et réaliser ou « publier » de nouvelles œuvres ou versions.

11. Assurer l'automatisation totale du transfert, de l'enregistrement, du stockage, de la récupération, de la diffusion, de la conservation, de la surveillance des erreurs, de l'évaluation de la désuétude, de la migration et de la gestion des enregistrements.

12. Par « longévité », on entend l'échange sans perte de contenu, peu importe le système d'enregistrement, le nombre de migrations ou les modes de transport utilisés et, bientôt, espérons-le, un système de stockage unique à long terme comme pour la pellicule en polyester.

13. Compression
La compression entraîne habituellement une perte; n'empirons pas la situation. Gardons le nombre de méthodes de compression et les changements de paramètres au minimum et réduisons tant que possible le transcodage. Il ne faudrait pas effectuer plus d'un passage d'un système analogique à un système numérique. De plus, dans les archives, il ne devrait pas y avoir dans les documents sources de séquences compressées par système Motion JPEG, qui est presque entièrement à propriété exclusive et qui n'est pas standardisé. Ce qui implique que tout document produit sur Avid suivant la norme MJPEG, peu importe que le support de départ ou d'arrivée soit un Bétacam numérique, est inacceptable.
Le comité ISO JPEG2000 publiait dernièrement une spécification concernant la compression par ondelettes[17], mais la deuxième partie portant entre autres sur les options de « mouvement » ne sera terminée qu'en 2001. Il faudra alors soumettre la technique à de rigoureux tests pour voir si elle peut être considérée comme transparente. Les processus sans compression ou de compression sans perte sont permises pour la copie de migration, dont le ratio de compression maximum se situe à environ 3.3:1 (DVCPRO50, D9, MPEG-2 422 50). Si la source est DV (digital video/vidéo numérique) ou MPEG-2, restez dans la même famille pour réduire la perte au minimum en attendant que, dans leurs camps respectifs, les fabricants reviennent à la raison. [18]

14. Les décisions relatives à la compression doivent être prises à la source et tenir compte des générations à venir. N'acceptez aucun système de compression qui laisse moins de 30 p. cent (ratio de 3.3:1) d'information source.

15. Établissez la valeur des documents sources de vos collections. Tous les dix ans, examinez lesquels méritent ou exigent telle ou telle espérance de vie. Sur cette base, prenez vos décisions concernant leur conservation et leur migration durables.

16. Il ne suffit pas d'évaluer subjectivement les différences visuelles d'une seule génération pour assurer la qualité de préservation du contenu. Il faut utiliser des outils objectifs mesurant exactement la perte. Les systèmes d'avenir devraient être capables de suggérer de meilleures solutions. En attendant, faites des essais, ET N'OUBLIEZ PAS D'EN PUBLIER LES RÉSULTATS.

EXEMPLE D'ÉNONCÉ PRATIQUE DES EXIGENCES

Dans les travaux que mène actuellement le comité mixte UER/PIMA en matière de Work Package 1 et Work Package 2, on cherche à définir des aides à la prise de décisions en matière de migration des collections vidéo patrimoniales qui pourraient mener à l'établissement de méthodologies sur les modes de migration les plus sûrs parmi la multitude d'options. Les milieux des archives et de la production, ainsi que l'UER, la PIMA et l'Association of Moving Image Archivists, doivent insister pour que les promoteurs qui ont choisi les camps Pro-MPEG ou VN identifient les éléments communs qui existent dans leurs systèmes, un peu à la manière dont l'acide désoxyribonucléique (ADN) porte et autoproduit l'information génétique d'une cellule à travers les générations humaines.

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[17] R. Colin Johnson, "Codec due for photorealistic JPEG2000 spec", *Electronic Engineering Times*, November 22, 1999, p.59

[18] Oliver Morgan, "Draft Pro-MPEG Forum Code of Practice for Television-Media Exchange Format (MXF)", February, 2000. (oliver_morgan@avid.com).

Nous posséderons ainsi la formule permettant l'échange de contenu sans perte entre les systèmes et non pas seulement entre leurs modes de compression respectifs. Panasonic a récemment prouvé son avance en la matière en mettant sur le marché le convertisseur de support universel AJ-UFC1800 ATSC-DTV. Il nous faut maintenant de l'aide pour nos protocoles anciens et nouveaux, ou des serveurs mandataires qui les traduisent.

Nous sommes certain que des compagnies comme Snell & Willcox du Royaume Uni et Miranda du Québec (Canada) et d'autres mettront au point les outils dont nous avons tous besoin pour assurer la protection à long terme de nos productions. À titre d'exemple, le modèle ci-après pourrait être un bon point de départ pour établir nos priorités.
État d'obsolescence Classe-1 :
NE (Near-Extinct / presque disparu)
Bande : disparue du marché
Appareil de lecture : n'est plus fabriqué
Support de signal : deviendra désuet
État d'obsolescence Classe-2 :
ME (menacé)
Bande : encore offerte sur le marché
Appareil de lecture : n'est plus fabriqué; appareil en fin de vie, toujours sur le marché, mais qui devrait disparaître dans les sept ans suivant son abandon.
Support de signal : deviendra désuet

État d'obsolescence Classe-3 :
VU (vulnérable)
Bande : encore offerte sur le marché
Appareil de lecture : les ventes ont baissé
Support de signal : courte durée de vie

État d'obsolescence Classe-4 :
SU (sûr)
Bande : Facile à obtenir
Appareil de lecture : Bien connu. Conforme aux spécifications du Groupe de travail mixte UER/SMPTE pour la production d'émissions destinées à la télévision généraliste; a fait l'objet de rigoureux essais; est bien implanté sur le marché.
Support de signal : Bien connu. Ses paramètres sont conformes aux exigences de diffusion actuelles et à moyen terme. S'il est basé sur la norme MPEG, il n'est normalement pas interopérable.

État d'obsolescence Classe-5 :
XTL (Extended-Life-Expectancy)
Bande : Support de stockage et d'utilisation standardisé à haute capacité qui permet l'échange transparent du contenu audiovisuel, peu importe le mode de production ou de postproduction ou le système de stockage, le type de support, le support d'encodage ou le mode de transport employés. Facile à obtenir auprès de nombreux fournisseurs. A fait l'objet de rigoureux essais et a été testé auprès de nombreux utilisateurs. Est censé avoir une espérance de vie de plus de 100 ans.
Appareil de lecture : Système ouvert dont de multiples fournisseurs de biens et de services peuvent offrir des versions concurrentielles. (Tout système qui est la propriété exclusive d'un fabricant et qui est non interopérable avec d'autres composantes est inacceptable.) Vendu par de nombreux fournisseurs qui se sont engagés à le fournir pendant longtemps.

Support de signal : Normalisé, il est entièrement transparent et peut être « cloné » sans perte. Offre une sécurité contre l'effacement et comprend des normes de chiffrement, de déchiffrement et de destruction. Est entièrement échelonnable et peut s'étendre à différents marchés, applications de production et de postproduction, systèmes de gestion des actifs et plates-formes d'affichage. Permet des générations successives au moyen d'améliorations rentables et économiques comportant un excellent degré de compatibilité tant avec les systèmes passés que futurs. [19]

Actuellement, il n'existe aucun système de stockage électronique qui réunisse les conditions voulues à long terme, et c'est ce que nous espérons voir changer.

EN CONCLUSION

Même des maisons de postproduction bien établies dans un des pays les plus riches au monde demandent des dégrèvements fiscaux pour pouvoir continuer d'exploiter leurs entreprises. Les conservateurs et conservatrices ne peuvent plus s'y retrouver dans le flot ininterrompu de supports d'enregistrement vidéo dont l'introduction périodique n'améliore guère les choses. L'auteur souligne que des normes devraient être établies pour assurer l'échange transparent des contenus audiovisuels, peu importe le système de stockage, le type de support, le support d'encodage ou le mode de transport utilisés. Dans nos entreprises modèles, l'accent est mis de plus en plus sur la valeur du bien audiovisuel et sur l'accroissement de cette valeur grâce à la remise en distribution et à la publication électronique.

Cela suppose l'intégration des systèmes de production, de postproduction, de gestion et d'archivage dynamique des œuvres. Le processus d'établissement de normes doit se faire en plus étroite collaboration avec tous ces milieux afin de protéger les investissements, préserver le présent, maîtriser les coûts et limiter le gaspillage. L'auteur analyse les avantages du support ouvert, plaide en faveur de solutions à long terme et propose comme norme possible la bande optique WORM, un peu comme le fut la pellicule 35 mm pour le cinéma.

Les conservatrices et conservateurs sont fortement encouragés à publier les résultats de leurs comparaisons objectives pouvant permettre de trouver des modes sûrs de migration pour tous les supports vidéo présents ou passés. Les fabricants qui sont dans le camp favorable aux technologies d'enregistrement sur vidéo numérique et en faveur de la norme MPEG sont aussi fortement encouragés à fournir les moyens

[19] Joerg D. Agin, "Kodak and the Future", *SMPTE Journal*, January 2000, pp. 20-22.

d'échanger des contenus sans perte entre leurs familles respectives.

Certains principes à suivre sont fournis comme balises philosophiques pour l'élaboration de politiques de gestion des œuvres audiovisuelles numériques par les parties intéressées dans les domaines de la production et de l'archivistique, lesquelles pourraient servir à établir la priorité des normes à établir. Enfin, l'auteur donne en exemple un énoncé d'exigence publié récemment par le groupe UER/PIMA/SMPTE pour illustrer la nécessité de trouver un moyen d'évaluer le degré d'obsolescence des collections vidéo.

Discussion

Ian GILMOUR

I would like to make a proposition. Whenever archivists put these dilemmas to manufacturers, the latter tend to respond by saying that they allow recording and transfer of video without loss to those who can afford it. In our line of work, there already exists a standard for this: CCIR 601. Any D5 machine can perform 10-bit resolution. D6 machines can be used when high resolution is necessary. The problem lies in the fact that most organisations need to be reminded that such is the standard. I do not have much faith in the sway of archivists. The professional tape market is too small: it accounts for less than 1% of the entire magnetic media market.

Ed ZWANEVELD

First, allow me to say how much I appreciate the work you are doing in Australia, where I lived previously. In response to your question, I feel that there is truly no need for us to support prostitution. We are being "raped"! It is not enough for archivists to link themselves with manufacturers, who are perpetuating a system that does not support our needs. Instead, we should support the data business, which is far more capable of meeting our needs. Maybe it would be most sensible to convert to data storage systems as quickly as possible, rather than to perpetuate current systems. We all have our own problems. The media have a short life, but are nonetheless able to support automation of many functions that must currently be carried out manually. Our system is becoming redundant.
Archivists constantly complain that they do not have any influence or buying power. That is not true. You are asset managers, not cemetery keepers. You are in the driver's seat. That is why you must create strategic alliances.

George BROCK-NANNESTAD

Some users of these media have fared better than others. Half-inch computer tape reigned for innumerable years, yet financial institutions and banks have not suffered from changes of media. That is because their single purpose is to protect data and preserve traceability at all times. That could become our major intention. Manufacturers would bow to our needs. As you stated, we must manage change by making intelligent choices.

Expertise technique d'une collection de 50.000 cassettes grand public déposées à la Bibliothèque nationale de France entre 1978 et 1992 : mise en place d'une stratégie de conservation (présentation par affiches)

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Denis Garcia
(Capital Vision, BnF - Dpt de l'Audiovisuel) - France

Texte non reçu

Paper not submitted

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FIAT Internet Project for Endangered Archives (Poster)

Dr. Peter Dusek
FIAT President and ORF Head of Documentation and Archives - Autriche

Dear Colleagues,

This meeting is called an international gathering for all specialists of the audiovisual, cinema and sound heritage. But I, as the President of one of the three organisations that are running this Joint Technical Symposium in Paris want to tell you about a project which is not only for high developed countries. The challenges of the 3rd millenium are not only for those who are the winners of the new globalisation and information technology. Audiovisual archives are not only in those countries and continents which are normally represented at our meetings. If you look around you find the representatives of the majority of European countries, some delegates of oversea – from the United States, from Japan – but there are huge white spots on the landscape of the globe. There are our colleagues from Africa, from most of the Latin American countries, from the Arab World or India or Pakistan. When I look back to the last 10 years of all FIAT conferences, we could invite some of our colleages: we had the Head of the State Archive of Senegal, his colleagues of Mozambique and Namibia. In the last years we met the colleagues of Maroco, Algeria and Tunesia. They all told the same story. There are thousands of magnetic tapes in bad conditions because of the high temperature, the high humidity and sometimes the dust. There are no machines to copy and restore this audiovisual heretige, there are no technicians. Sometimes there are not even shelves. You can find these endangered tapes on the floor in the cellar of television stations or in state archives.

What's to do?

When I was elected FIAT President in October 1998 in Florence one of my main targets of my presidency was to develop a project for these endangered archives. The main idea is very simple. In a first step I want to bring up a pilot project for several archives with endangered material in the Mediterranean area, Africa or Asia. A translation should be made of the documentation of some of these archives, transferred into the internet and offered to the audiovisual market. There are some firms like Tecmath, Siemens, Sony and Panasonic or Adic/Grau, which are willing to pay a supporting fee for FIAT to start this project. Tecmath, which was one of the main partners of the EUROMEDIA Project, which was developed within FIAT members like SWF, SVT, BBC and ORF, is preparing a homepage for these English translations. This pilot project will start in this year 2000 and will be demonstrated the first time at the FIAT General Assembly in Vienna in mid October 2000.

From catalogueing to restoration

The next step will be the most important because the idea behind this project is to offer forgotten endangered material to the world of audiovisual production, to the journalists which are working for documentaries, for the historians who want not only to recover history with written documents – with one word to open this audiovisual heritage for the information technology market. And at the end of this process there should be enough money in these endangered archives to allow them to link their material with the technological revolution.

Soros Foundation

This was a short presentation of my FIAT project for endangered archives. When I started my first meetings with representatives with the information industry I had no idea that the Soros Foundation was planning very similar activities for film archives in Russia, Africa and Asia. But when I had a first meeting Prof. Istan Rev in Budapest some months ago, it was very clear that they have the same interests, but concentrated on film archives. So it was a logical development that we now try to combine those activities, i.e. the Soros Foundation wants to bring the catalogue of the Krasnagorsk Film Archive in Moscow in an English version to the internet and also wants to find users who pay for restoration and fees for their material. Why not have one home page for endangered television and film archives? Who has the money to recover forgotten film material, if not the television production companies. But the Soros Foundation, that spends a great amount for bringing the catalogue in the net has the idea to found a restoration fund and I want to discuss this with you, the representatives of audiovisual archives and technological industry. Let's propose a big international activity to save the audiovisual heritage. Let's proclaim 2001 as a year of the audiovisual salvation. We need to fight against air polution, against poverty, against discrimination, but also against the rotting of the audiovisual past, because for all these institutions in Africa, the Arab World or in Asia it's not only a question of undiscovered audiovisual treasures, it's a question of cultural identity – and that's one answer to the challenges of the globalisation of the 3rd millenium.
I hope we can start the discussion in Paris and we will continue in Vienna between October 15th- 18th at the FIAT General Assembly.

Modérateur/Moderator : Adam Lee, BBC Resources Information and Archives

Adam LEE

I was kindly asked to moderate this afternoon's session along with George Boston, who will take over at a later time. There is a change to the printed programme: Sean Davies has agreed to speak in the place of Horst Schachlbauer. Although Horst could not be present this afternoon, his work has been cited by many speakers and has guided the event.

The classic definition of metadata is data about data. However, its meaning is understood differently by software salesmen, librarians and archivists. An enormous amount of work is being carried out on this topic. The BBC, for example, has been studying metadata for the past year. Industry, the archive world and the library world have all shown their interest in it. It is, without a doubt, a confusing field.

Elizabeth Guiliani, our first speaker, is the Chief Curator in the Audiovisual Department at the Bibliothèque nationale de France. She is also leader of the French Committee of AFNOR and plays a key role in the ISO's work on these topics.

La normalisation des métadonnées

Elizabeth Giuiliani
(BnF) - France

A l'heure où se développe la diffusion en ligne des documents et des informations, on assiste à l'explosion des entreprises visant à identifier et indexer automatiquement, cette information volatile. Il n'est qu'à considérer, par exemple, la multiplication des groupes de travail sur les métadonnées, au sein des organismes traditionnels de normalisation (tels l'ISO ou l'IFLA) ainsi que dans les instances particulières plus strictement liées à des projets sectoriels (NASA, OCLC, US Air Force).

Définition

Ce terme qui paraît de plus en plus fréquemment sur les documents en discussion dans les instances de normalisation et envahit également la littérature professionnelle, voire les conversations, mérite encore d'être défini.

Les Métadonnées sont des données sur des données, des informations sur des informations. Plus spécifiquement, elles constituent l'information secondaire relative à une ressource électronique. Ce sont les ressources du Web qui ont les premières et en priorité eu recours à cette notion et à ce terme.

Ce qui définit aussi essentiellement une métadonnée (par rapport à toute donnée documentaire ou bibliographique traditionnelle) c'est qu'elle est disponible conjointement et simultanément (consubstanciellement) à la donnée qu'elle trace.

Avec l'adoption de ce terme, on observe une diversification des entités documentaires traitées (qui du document sont passé à la ressource) et la redéfinition (transgression) progressive des frontières entre des notions qui font converger les logiques, jusque là liées mais autonomes, de la transmission , du stockage et de la signification des données

Domaines

Les principaux domaines concernés par les métadonnées sont :

- le domaine "classique" des informations bibliographiques : signalement, description et analyse des documents du point de vue de leurs contenus (ressource discovery)

- les caractéristiques techniques de codage, stockage, transmission, consultation et conservation de l'information

- les identifications juridiques et propriétés d'usage (asset management)

Intersection de ces ensembles de métadonnées, le domaine de l'identification, de la numérotation et du marquage des ressources devient un enjeu particulièrement stratégique. (auditing)

Ces différents domaines constituent différentes classes de métadonnées.

Pour une ressource, les métadonnées doivent permettre:

- la gestion même de son cycle de vie : création, mise à jour, archivage

- l'information sur son contenu : identification, localisation, description, analyse

- le suivi de son usage : droits attachés, conditions financières

Propriétés

Liées à la diversité de leurs domaines d'application ainsi qu'à leur intégration technique aux données elles-mêmes, les métadonnées se définissent aussi par ces propriétés :

- la globalité et la généricité des notions ou objets qu'elles traitent
Tout ce qui peut être identifié sur le Web partage le même statut de donnée : site, page, illustration, texte, son, image...

- la souplesse des relations logiques qu'elles manient
Une même donnée peut appartenir à plusieurs contextes répondant à divers usages.

- la généralité des outils et techniques qui les gèrent
La ressource et sa métadonnée sont disponibles simultanément selon des procédures communes

Concepts

Quoique diverses, les métadonnées sont représentées selon une logique d'ensemble qui se manifeste à travers une terminologie propre (à l'origine et parfois encore exclusivement anglophone). On y distingue les niveaux suivants du plus générique eu plus particulier :

- l'architecture générale d'organisation (framework) :

Warwick Framework "container architecture for aggregating metadata objects for interchange" à l'œuvre dans le Dublin Core.
Meta Content Framework (MCF) à l'œuvre dans XML
Ressource Description Framework (RDF) pour le Web
CORBA (Common Object Request Broker Architecture)

- le modèle (model) :
Functional requirements for bibliographic information
CIMI
Dublin Core

- la syntaxe (language) :

SGML (Standard Generalised Mark-Up Language)
TEI (Text encoding initiative)
Encoding Archival Description (EAD)
Machine readable catalog (MARC)
ROADS (Ressource organisation and discovery in subjecyt based services)
Summary Object Interchange Format (SOIF)

Acteurs

Des mondes très divers concourent à la définition et au développement des métadonnées.

- Le monde de la gestion traditionnelle de l'information qui lui-même fait coexister des acteurs distincts :

ceux, eux-mêmes multiples (auteurs, interprètes, producteurs, éditeurs) qui produisent l'information primaire ou en contrôlent la diffusion.
La production de données secondaires étaient jusque là essentiellement liée à des nécessités de gestion interne et ont d'abord donné lieu à des systèmes particuliers. Le développement de la numérisation a conduit ces milieux à progressivement "habiller" leurs produits de structure analysable automatiquement.

ceux, eux-mêmes divers (bibliothèques, archives, centres de documentation), qui produisent l'information documentaire traditionnelle.
La production des données secondaires et leur normalisation avaient jusque là été autonomes de celles des informations primaires. L'effort de normalisation a donc d'abord visé une extension des concepts et des modèles mis au point pour la gestion documentaire des supports analogiques.

Dans ce monde de la documentation "traditionnelle" continuant de concevoir distinctement l'information secondaire et le document primaire ont d'abord été élaborés des standards propres à chaque catégorie de donnée secondaire d'une part , chaque type de document primaire d'autre part (chaque média notamment). Se sont toutefois développés des outils pour générer et utiliser des liens fonctionnels entre données secondaires et document primaire.

- Le monde des technologies de l'information : de son codage, de son stockage et de sa transmission
Lui-même fait cohabiter les spécialistes des techniques de l'informatique, des réseaux et télécommunications, du codage des information.
Déterminés avant tout par le Web, ce sont les besoins pour la diffusion en ligne de ressources numériques qui ont vite dominés. Ils imposent une stratégie globale pour établir des standards communs aux ressources et aux métadonnées.

TABLEAU DES ACTEURS DE LA NORMALISATION DES MÉTADONNÉES

Type d'organisme	Organisme	Groupe de travail	Document	Type	Lien
Organisme de normalisation internationale					
	ISO				
		TC 46 SC 4 Computer applications	Z 3950		
			PICS		Cf 3W consortium
			CIMI		Cf CIMI
		TC 46 SC 9 Présentation, identification et description des documents			

Type d'organisme	Organisme	Groupe de travail	Document	Type	Lien
		TC 154 Documents et éléments d'information dans l'administration, le commerce et l'industrie	Basic Semantic Repository		
	ISO-IEC				
		JTC 1 Joint technical committee on information technology. SC 29 WG 11 Coding of moving pictures and audio	MPEG11		
		JTC 1. SC 32 Gestion et échanges des données.	Specification and Standardization of Data Elements (ISO 11179)		
		JTC 1. SC 32 Gestion et échanges des données. WG 4 Métadonnées	SQL (Structured query language)		
		JTC 1. SC 34 Document description and processing languages	*SGML* (ISO 8879, 1986)		
	CEE	MMRCS (Multimedia rights clearance systems)	*Indecs*	Modèle pour la gestion des droits	
	CEE	OII (Open Interchange standards)	*Metadata Interchange standards*	Répertoire des standards de métadonnées	
	CEE DG XIII	Nedlib	DSEP (data model for a deposit system for electronic publication)	Modéle	Fondé sur OASIS
	CEN	ISSS (Information Society Srandardization	MMI (Modèle conceptuel de métadonnées d'information multimédia) Workshop (depuis février 1998)		
			MMI-Dublin core Workshop		
Organismes de normalisation du Web	**W3C (World Wide Web Consorsium)**		XML (eXtended Markup Language) (1996)		
			RDF (Ressource description framework) (1997)		
			PICS (Platform for Internet Content Selection)		

Type d'organisme	Organisme	Groupe de travail	Document	Type	Lien
	IANA Internet Assigned Numbers Authority		URI (Uniform Resource identifier) : URL (locator) URN (name) URC (characteristic)		
Organismes professionnels Bibliothèques, archives, documentation	IFLA		MARC		
			Functional requirements for bibliographic information		
	CIMI Consortium for the computer Interchange of Museum Informations		CIMI (ComputerInterchange of museum information):	DTD pour les objets muséaux	Présenté à l'ISO TC 46. SC 4 en mai 1999
	UKOLN (UK office for library and information networking)		Cedars (CURL- Consortium of University Research Libraries- exemplars in digital archives)	Répertoire de modèles	Soutenu par l'IEC
	JISC (Joint information systems committee)		*Roads (Ressource organisation and discovery in subject-based services)*		
	Library of Congress, Society of American Archivists		*DTD EAD (Encoding archival description)*		
	OCLC (On-line Computer Library Center)		Dublin Core(Dublin Core Metadata for Simple Ressource Discovery)		
	TEI Consortium		TEI (Text encoding initiative) (1994)		Soutenu par la CEE DG XIII
Organismes professionnels Editeurs, producteurs	DOI Fundation		DOI (Digital object identifier)		
	INDECS Group		INDECS (Interoperabilitybof data in e-commerce systems)(1999)	Modèle pour la gestion des droits	Soutenu par la CEE Info 2000
Organismes professionnels Informatique, télécommunication, industrie	NASA	CCSDS (Consultative Committee for space data systems)	OAIS (Open archival information system) (1998)	Modèle pour la gestion des données numériques	Agrément ISO

Type d'organisme	Organisme	Groupe de travail	Document	Type	Lien
	Meta data Consortium		MDIS (Meta Data Interchange Specification)(1996)		
	OMG (Object Management Group)		CORBA (Common Object Request Broker Architecture) (1991)	Architecture pour l'interopérabilité des matériels et logiciels informatiques	
Organismes professionnels Audiovisuel	SMPTE (Society of motion picture and television engineers)-EBU (European Broadcasting Union)	Task Force for harmonized standards for the exchange of program material as bit stream	Request for technology : metadata and file wrappers (1997)		

Tendances

Un mouvement de convergence (correspondant à la convergence des données elles-mêmes dans le contexte numérique) se dessine propice au développement d'une démarche de standardisation.
Il se manifeste notamment par :

- l'adoption de RDF (Ressource description framework) comme structuration commune qui associe ressource et métadonnées selon plusieurs statuts :
- métadonnées encapsulées dans la ressource (embedded) exemple Dublin core
- métadonnées externes accompagnant la ressource (along-with)
- métadonnées indépendantes utilisables seules (service bureau) : exemple champ 856 des formats US et UNIMARC qui contient un lien actif à une ressource en ligne
- métadonnées contenant aussi la ressource (wrapped) exemple EAD

et construit des schémas d'association de classes de règles à des descriptions

- la présentation de répertoires de métadonnées : DTD (Definition de type de document) décrivant la structure logique d'une classe de documents et les balisant en éléments (éléments logiques qui composent le document = Titre) attributs (qualificatif des éléments = langue) entités (chaîne de caractères ou document externe dans un autre codage attaché à un endroit précis = image, son)

- le développement des systèmes d'identifiants de ressources qui en fiabilise l'accès ainsi qu'à une amorce de concertation entre les entreprises d'identification (réunion ISO des 1 et 2 février 2000)

- le rapprochement des méthodes et standards mis en place pour les différents types de ressources et différentes catégories de métadonnées : élaboration de syntaxes d'encodage fondées sur la famille SGML (Standard generalized markup language) ISO 8879 pour la production de documents, HTML (Hypertext markup language) pour la production des pages Web sur Internet

- la réalisation de projets européens fédérateurs : Biblink, Nedlib

- l'adoption de fait du Dublin Core dans les travaux de MPEG7, MMI

- l'utilisation des métadonnées et des contenus des ressources elles-mêmes par les moteurs de recherche : standardisation des structures logiques et développement de liens "intelligents".

L'évolution manifeste et impose à la fois, un décloisonnement des instances et des champs de la normalisation et un effort de mise en cohérence avec des schémas de pensée et à travers des structures de travail renouvelés. Les outils et méthodes sont non seulement désormais multimédias (c'est-à-dire "a" media) mais aussi multifonctionnels intégrant production, description et accès aux métadonnées d'un côté, aux données primaires elles-mêmes de l'autre. Par ailleurs à la "dématérialisation" l'information électronique ajoute l'instabilité permanente et la nécessité d'identifier un "état" du document avant même de l'indexer. La hiérarchie tend à (tente encore de ?) s'inverser au profit du document logique sur le document physique (l'édition et le support, ces fondement des formats bibliographiques traditionnels), une stratégie des liens (qui eux-mêmes de hiérarchiques deviennent hypermedia) à remplacer la seule indexation.

Discussion

George BROCK-NANNESTAD

Vous avez dit qu'il y avait des problèmes de langage. Par exemple, vous avez presque uniquement utilisé des mots français pour désigner les concepts. Où se situent les problèmes de langage ?

Elizabeth GIULIANI

En fait, il y a plusieurs niveaux. J'ai dû employer le terme de " langage " de façon impropre comme synonyme de " langue " mais en fait, au niveau des métadonnées, c'est de " langage " qu'il convient de parler. Le langage est une articulation entre un sens et une forme, ou plus exactement entre un contenu signifiant et une modalité d'organisation des éléments qui rendent ce sens. Il est vrai que, dans la production en cours sur les métadonnées, qui est très abondante, on s'aperçoit que l'on passe de la rationalité systématique classique à la logique formelle, laquelle est aussi à l'œuvre dans la logique informatique.

Kurt DEGELLER

A quel niveau est pris en compte le multilinguisme dans cette réflexion ?

Elizabeth GIULIANI

Il y a des groupes au niveau de la Communauté européenne qui ont le souci immédiat d'inscrire les travaux sur la structuration des données dans un contexte multilingue. Là encore, je crois que toute la réflexion sur les répertoires de concepts (données mais aussi relations entre ces données) est très intéressante dans ce domaine. La prise en compte du multilinguisme doit se faire à deux niveaux. Les systèmes appliqués de métadonnées doivent songer au contexte multilingue ; en même temps, une réflexion doit être menée sur une articulation de langages, qui peut être appliquée ensuite à toutes les langues, ou du moins aux langues indo-européennes classiquement reproduites dans des ressources électroniques.

Adam LEE

Sean Davies is an independent consultant on electro-acoustics and helps to keep the disc-cutting industry working. He began his career in 1958 as a studio engineer. Today, he works in standards and calibration of archival performance.

TECHNICAL DEMANDS ON THE ARCHIVE OF THE FUTURE.

Sean Davies
S.W. Davies Ltd., U.K.

Initialement prévue dans le cadre des présentations par affiches, M. Sean Davies a bien voulu faire cette conférence à la place de celle de M. Horst Schachlbauer. Par son sujet elle peut être considérée comme faisant partie de la série de présentations ouverte par Klaus Heinz ci-dessus (note de l'éditeur).

Formerly programmed in the course of posters presentations, Mr Sean Davies Sean Davies has agreed to speak in the place of Horst Schachlbauer. The subject could be related to the presentations opened by Mr Klaus Heinz above (editor's note).

1. Introduction.

Audio archives can be broadly separated into the following classifications:

1. Institutional e.g. national bodies, universities.

2. Broadcasting bodies.

3. Commercial record companies.

4. Private collectors.

Traditionally the holdings of categories 1 and 4 would consist mainly of publicly issued recordings, hence the formats would be those designed for the domestic market.
Categories 2 and 3 would hold both domestic formats and professional/studio formats.

There are good reasons why these distinctions may not be best for the future of archives in general; we will look at these later.

All archives share two common duties; a) preservation of the recorded information; b) means of access to that information.
In some cases the means of access has been delegated to an associated body (such as the main studios of a record company).

It is a sad fact that most carriers of sound recordings have a very short life expectancy when compared with those of document collections; the most stable long term format is probably the metal master plate of the analogue disc, although even this needs to be protected against chemical attack. A large amount of work has been done on the best methods for preservation of various sound carriers so this will not be discussed further here, except to note that little has been published on the preservation of metal masters.

However, access to the recorded information involves playback, whether for audition, copying for re-issue or transfer from a carrier which is near the end of its useful life.

It is almost certain that the storage medium of the future will be digital: the ever increasing costs of staff coupled with the reducing costs of digital storage will dictate an automatic backup system in which the digital file may be transferred from one carrier to another as needed without any technical input from the staff. The controlling factor for the quality of the digital file will be the initial transfer from the analogue original (assuming that the digital system is itself of adequate quality).
This most vital transfer must be made in the best possible way, as most access to the information will be via the digital copy. However, there will be pressure from financial departments to destroy the analogue original to save storage expenses, with the argument that as the digital system is better than the analogue there is no point in keeping the original. These pressures must be most vigorously resisted, for the assumption is that at no time in the future will anybody be able to extract more information and/or a better quality from the original: the fallacy of this belief should be obvious to any scientifically minded person.

Thus, analogue playback equipment will have to be maintained in good order for the full lifetime of the carrier in question.

We will now examine the divisions listed at the beginning of this paper.

At present Institutional technical staff and private collectors probably constitute the largest pool of knowledge on a) cylinder recordings; b) pressings of acoustic recordings.

To a slightly lesser extent the same holds true for electrically cut discs of the "78" type.

Broadcasting organisations and record companies have the greatest knowledge of analogue tape systems and microgroove analogue pressings, together with the metal master plates for all disc formats.

The move to digital technology will eliminate analogue recording systems from all but a few specialised studios or users. This has important implications for archives, particularly a) there will be no new analogue equipment available; b) there will be few or no parts to maintain the existing equipment; c) the pool of analogue expertise within the recording community will gradually disappear.

Some broadcasters have already started to donate or hand over analogue tape holdings to regional archives; so far most record companies are keeping their analogue masters in house but there may well come a time when these are handed over to an appropriate body, along with metal master plates (as has already happened in some countries).

So what of the requirements?

1) All archives should ensure that they have the best possible playback equipment for all the formats which they are holding; if the have not then the items should be purchased now, as even today it may be too late to acquire new machinery.
2) All equipment should be overhauled either by the manufacturer or by an acknowledged expert.
3) An adequate inventory of spares should be purchased, based on recommendations of the manufacturer. Never mind what they cost now, it will cost many times more to have them specially made later.

These three requirements interact with the fourth, Training and Location of Staff.
As mentioned the analogue engineer will become a rare specialist: it is vital that he or she should have a full understanding of the formats he/she will encounter.
Today's archival engineer will probably know about the different stylii needed for various types of 78 pressings, and most of the equalisation curves used on electric 78's from 1926 until the 1960's.
A studio engineer of 50 years old or more would know about Dolby A noise reduction with its two reference points (IEC and NAB) and might remember the difference between a recording made at "Elevated Dolby Level" and "Dolby with Elevated Level ".
Other noise reduction systems such as "dbx" (professional, not domestic) and equalisations (AME; "Ampex Master Equalisation") would at least be recognised, even perhaps tapes from the Telefunken 24 track which had different track spacings to everyone else.

This list is not just to frighten people but to emphasise the range of knowledge required of the archival engineer of the future, because the studio people will all be gone.

But is it so important?

If we don't have or understand the curve, or if the Dolby level is a bit out, well we can clean it up on the computer, after all it's only an old recording.
At this point I hope to hear a shocked intake of breath; if not I'll believe I'm surrounded by record company executives.

Two golden rules must apply to all transfers; I) yesterday's engineers, from 1900 onwards were neither deaf nor stupid; II) today's hi-fi wonder (e.g. 24/96) becomes tomorrow's amusing retro curio.
This means that there is good quality to be had off every original and we should respect the care that went into it and we must offer that care on to the next listeners.

So we are now demanding a person well versed in the whole range of recording from the beginning until, say 1990, not just theoretically but with practical ability. Is this unrealistic? One thing is certain; such a person will not emerge from the usual training courses available to audio engineering students. This is not to criticise those courses, but even if they cover the basics of analogue techniques they cannot be expected to cover the depths which the archive requires.

The technical requirements of the archive of the very near future and beyond can only be met by staff who have undergone specialised training.
Bodies such as this JTS or other are best suited to organise the kind of courses required.
However, it could be argued that as each archive tends to be more or less specialised then appropriate training can take place "in-house" at less expense.
I believe this is wrong because it assumes a more or less static situation in each archive.
However, it is true that few archives would need the full range of knowledge mentioned, so two options exist; 1) archives cooperate to exchange staff /apparatus for rare transfers, or 2) the original carriers are taken to the appropriate speciality. Both have advantages and disadvantages but the third option of making an inferior transfer (knowingly or otherwise) must be avoided.

When the broadcasters and record companies decide they no longer want the trouble of looking after their obsolete format collections they may either a) destroy them; b) hand them over to an organisation they can trust to preserve them and allow continued access.
An institutional archive may suit but many are encumbered by rules restricting access so that a completely new organisation might be better. This would also allow the sharing of costs on high-tech systems such as the digital mass storage already in use by at least one major company.
But the time for action is now! In the last twenty years tens of thousands of metal master plates and analogue tapes have been destroyed. Sadly this is not just a generalised statement; I could tell you most of the numbers.

Where metal masters are held a proper policy of inspection and preservation must be employed; simply closing the door until "posterity" arrives (can someone please give me that date ?) will ensure the destruction by time and corrosion of the supposedly valuable holdings. As facilities for vinyl pressing reduce world-wide it would be sensible to get an agreement to set up a specialised plant for archival use. It is even now difficult as modern LP presses are highly automated and the pressing cycle is not ideal for 78 rpm work. Perhaps someone is already doing this?

All statements up to now have been based on analogue recordings: the last quarter of the 20th. century has seen the proliferation of digital formats some of comparatively short lives. The trend looks set to continue.
For the archive the technical difficulty is much greater: four competent technicians could make an acceptable 1/4" tape machine or a very good playback turntable but what about a PCM F1 system with Betamax player?
Even allowing that a set has been kept in good condition knowledge is again the prime requirement: a whole month of transfers could be made with small ticks disturbing the signal until someone found out that you must have the record lead plugged in even for playback (it gives a clock signal).

There are many valuable recordings on the 32 track digital system of 3M.

Most of us have been led to believe that a digital transfer from a digital original is identical with the original: this is not so but it may come as a surprise that certain quality improvements may only be possible with access to the original. The theoretical background together with practical examples were given in a paper [1] at the 104th. AES Convention; this paper has not yet received the attention it deserves.

The study of technical history relating to obsolete carriers is a valuable activity which should be encouraged both within an archive and by conjunction with other bodies [2]. The co-operation between the British National Sound Archive and the Cedar Company is a good example of this.

In summary then:

1). The audio archive of the future will have to be much more self-reliant in terms of technical facilities than hitherto; the entire range of analogue and some early digital formats will have to be catered for in-house.

2). Facilities for maintenance and repair of playback systems will have to be provided either within the archive or by reference to an accredited organisation.

3). Technical documentation in the form of service manuals, modification reports etc. must be sought and kept with the relevant machines for future reference.

4). The hitherto common division between institutional and commercial archives must be broken down if only in order to prevent further destruction of irreplaceable original recordings.

5). Training of specialised technical staff in all formats, but especially obsolete studio systems must be undertaken whilst the veteran engineers are still available.

6). Playback equipment of a difficult type should be actively sought and preserved now.

7) All archives should institute an exchange of information showing who has capabilities of handling which formats.

8). A common digital file format (for instance "broadcast.wav") should be agreed world-wide for archival exchange.

9). All archival administrations must be dissuaded from using digital formats which involve data reduction.

10). An investigation should be undertaken by a technical committee representing archives with metals into the possibility of establishing a specialised pressing facility.

References:

[1]. Tsukamot, Saito *et. al.* "Correction of Nonlinearity Errors Contained in the Digital Audio Signals". Pre-print 4698 AES 104th. Convention, 1998

[2]. Davies, S.W. " Technical History as an aid to Archiving and Restoration". Pre-print 4887 AES 106th. Convention, 1999.

Discussion

Adam LEE

Some of those statements were quite provocative.

George BOSTON

I would like to thank Sean for setting forth many of the points which I have been trying to communicate to UNESCO and similar organisations for a number of years. On the topic of training, for example, I wrote a paper for UNESCO, explaining the issues around the training of archive administrators, documentalists, etc., not only in sound, but also in video. It was based on my experience teaching bright young technicians, who wanted to work with the new equipment immediately. I tried to help them understand how important it was that they be familiar with the old equipment and methods.
In the video world, I know of only one person alive who is fully familiar with the first electronic videotape system, the BBC VERA: Brian Jenkinson. He has recently retired from the British National Film and Television Archive. Luckily, no tapes of that format currently exist and we do not have to worry about preserving them. However, we must take a historical interest in that equipment. Brian Jenkinson is the only person who can explain that one had to put the record plug in the back of the amplifier in order to provide the clock pulses. I thoroughly endorse your points. This interest in our history is long overdue. The quicker we can start, the better.
Finally, one of the issues that has been discussed quietly here is the next event. We all agree that JTS must also take up non-technical matters, such as training, documentation, co-operation between associations and, lastly, copyright. The latter issue is capable of undermining all of the work that we are currently performing.

Adam LEE

You may be interested to learn that we have a wonderful film recording of VERA working!

George BROCK-NANNESTAD

Yesterday, I asked who will buy the AES calibration discs. Today, I would like to know who will pay me to teach younger generations! I know beforehand that no one will pay! All of the archives complain that they lack money and look to limit expenses as much as possible. That is not satisfactory. It is degrading to the profession that we do not pay for the services we need. My work should not be a handout. It should be remunerated, just as all services.
Secondly, I would like to touch on the topic of coarse-groove records. They have not developed since 1950, when the LP record first appeared on the market. Fortunately, a form of "backward compatibility" appeared spontaneously, allowing the deadline to be "extended" to 1985. Now, LPs and most analogue media are quickly going out of fashion. Unless coordinated efforts are undertaken, we will have no way to play analogue records, barring the "needle and teacup" method.

From the floor

Although I agree with everything you have stated, there are hardly any archives that are not short of cash. There are examples of archives which have managed to prove to their accountants that they are a resource. In another record company, an internal memorandum circulated, announcing piteously: "The archives are the company's assets. If it does not preserve the archives, it will have no assets".
In effect, we must blame ourselves for expecting dogs (or lions or cats) to understand human language. Accountants are simple animals and can only understand columns of figures. They understand these and feel quite at ease. If we try to explain expenditures on the basis of expertise, they glaze over and tend to refuse. This justifies their existence. If, on the other hand, you compare the restoring your recording of the London Symphony Orchestra or the Berlin Symphony Orchestra with that of employing those ensembles today, they will understand far better the advantages of what you are advocating.
Institutionalised archives have grown into implicitly non-profit organisations. We should not assume that every archive is restricted in the same way and to the same extent. Archives can be a possible source of income. Those potential profits can be used to convince accountants that money must be spent on training or equipment. They will understand if you present your projects as a means to preserve an asset and ensure later profits.

Modérateur/Moderator : George Boston, Consultant - Secretary of the Sub-Committee on Technology for the International Advisory Committee of the UNESCO Memory of the World Programme.

George BOSTON

We are entering the last session, which deals with the future: ideas, thoughts about our future technological developments and their implications. Our first speaker, David MacCarn, is the Chief Technologists for the WBGH Educational Foundation and is currently responsible for its long-term planning. He is also member of the Public Broadcasting Society's Engineering Committee and Chair of the SMPTE Study Group on universal preservation format requirements. He holds a Bachelor's of Science in Computer Science and did graduate work on Computing Architecture. In addition to his membership at the SMPTE, he is also a member of the Institute of Electrical and Electronic Engineers and the Association for Computing Machinery.

The Universal Preservation Format
A Recommended Practice for Archiving Media and Electronic Records.

Thom Shepard, Dave MacCarn
WGBH Educational Foundation

Part 1: User Requirements

1. Purpose of this Document

This report attempts to provide a context for the **Universal Preservation Format** by documenting how the UPF initiative builds upon other standards and technologies, how it serves the specific needs of the WGBH Educational Foundation, and how it fulfills broader archival requirements expressed by other institutions and organizations. In a sense, this document functions as metadata to the essence of the companion document, **Technical Requirements of the UPF.**

2. Definition

The **Universal Preservation Format** is a data file mechanism that utilizes a container or wrapper structure. Its framework incorporates metadata that identifies its contents within a registry of standard data types and serves as the source code for mapping or translating binary composition into accessible or useable forms. The **UPF** is designed to be independent of the computer applications used to create content, independent of the operating system from which these applications originated and independent of the physical media upon which that content is stored. The UPF is characterized as "self-described" because it includes, within its metadata, all the technical specifications required to build and rebuild appropriate media browsers to access contained materials throughout time. Objects within the **UPF** are branded with a unique identifier that travels with that object throughout time. Any modification made to the content of the object must be reflected in its identifier.

3. Scope

While archivists working with analog materials have traditionally separated issues of preservation and access, the digital age has blurred these lines to such an extent that many prominent writers in the field (Hedstrom, Waters, et al.) use the terms "digital libraries" and "digital archives" almost interchangeably. The **Digital Library Federation (DLF)**, an organization founded in 1995 for the purpose of "creating, maintaining, expanding and preserving a distributed collection of digital materials accessible to scholars, students, and a wider public," has drafted a definition of digital libraries that seems to encompass the functions of both preservation and access:

> Digital libraries are organizations that provide the resources, including the specialized staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily and economically available for use by a defined community or set of communities. (Donald J. Waters, "What Are Digital Libraries," CLIR issues, No. 4, July/August 1998. http://www.clir.org/pubs/issues/issues04.html)

In his analysis of this working definition, Donald J. Waters, director of the **DLF**, acknowledges that preserving the integrity of digital information and ensuring the persistence of digital works are ideals that member organizations achieve on a variety of levels. Nevertheless, he includes these functions as "central to the concept of a digital library."

The **Society of Motion Picture and Television Engineers/European Broadcasting Union (SMPTE/EBU) Task Force for Harmonized Standards for Exchange of Program Material**, which recently fulfilled its stated mission to "implement new technologies [...] to [establish] standards that will support the vision of future systems," acknowledged in its final report that the metadata required for a digital archive is inherently different from the requirements of acquisition file formats.

> Ideally, an archive system needs a superset of the acquisition Template plus production history. Sufficient Metadata needs to exist to allow fast and efficient identification of the Content. Additional Metadata may be included to describe detailed characteristics of the Content to allow precise searching of the Content. Extensibility is once again a high requirement in order to allow inclusion of customer-specific data such as links to computer databases or billing systems. Applications may use hierarchical storage to contain such Metadata.
> (SMPTE/EBU Task Force for Harmonized Standards for the Exchange of Program Material as Bit Streams, Copyright (c) 1998 European Broadcasting Union and the Society of Motion Picture and Television Engineers, Inc. , http://www.smpte.org/engr/tfhs_out.pdf)

The **UPF** assumes that a fundamental difference exists between acquisition file formats and a format to serve archival requirements. This difference is not simply between access and preservation, but between malleability and permanence, between clay and stone. In its report on preserving digital information, a task force sponsored by the **Commission on Preservation** and the **Research Library Group** defined digital archives as:

> repositories of digital information that are collectively responsible for the long-term accessibility of the nation's social, economic, cultural and intellectual heritage instantiated in digital form.
> (Task Force on Archiving of Digital Information, "Preserving Digital Information: Executive Summary," May 1, 1996, p.8. URL: http://www.rlg.org/ArchTF/)

While other initiatives work toward making digital materials publicly accessible today, we are investigating technologies that will save them for many tomorrows. Our success depends, in part, upon instilling a new awareness within the computer industry: that future digital storage products must be designed to fulfill the documented requirements of users. Despite some promising storage technologies on the horizon, the computer industry has yet to market affordable digital storage vehicles which will last as long as their analog counterparts, nor have they been convinced that is it in their commercial interest to do so. By concentrating on elemental concepts of how data and information about that data might be stored *through time*, the UPF initiative helps to establish working relationships between those who make and market technical specifications and those who must learn to use the tools of technology to preserve the potentially decaying fruits of our cultural heritage.

4. Background

In 1977, two Voyager spacecrafts left Earth on a mission to explore and send back information about our solar system and beyond. Attached to each vehicle was a gold-plated phonograph record which contained 115 images, a collection of Earth's natural sounds, greetings in 55 languages, and musical samples from the collected works of Bach, Beethoven and Chuck Berry. Each record included a stylus, and inscribed on its protective aluminum jacket were visual instructions on how to play it. The disks were intended by astronomer Carl Sagan and his team of managers and engineers as a kind of packaged time capsule for any aliens or distant cousins who, several centuries from now, might be rocketing along.

Voyager's Interstellar Record is an example of a "self-described" storage mechanism. As an analog product, it has a significant advantage over current digital storage in that an "analogy" exists between how its information was stored and fundamental principles of physics, a relationship that does not exist in products consisting of zeroes and ones. For this binary information to be readable, an intermediary interpreter is required. The UPF's notion of a "self-describing" digital file format provides interpreters with all the technical information required to retrieve its contained materials. In effect, these stored algorithms constitute a standardized blueprint for reconstructing both the data types and the physical mechanism itself, upon which the data are recorded.

Awareness of the need for a universal preservation standard grew out of meetings between leaders of two departments within the **WGBH Educational Foundation**: Chief Technologist Dave MacCarn and the Director of the Media Archives and Preservation Center, Mary Ide. Concerns were expressed not only for moving image material, but also for the many other data types that the broadcast facility generates: audio, text, database files, captioning, descriptive video information and the whole gamut of original digital content produced for the World Wide Web. Though it was clear that a storage standard could have an enormous impact on the broadcasting industry, it remained to be seen whether UPF's ability to store all data types would appeal to other archival and library communities.

As a major public broadcasting station and content producer, WGBH has developed one of the more important media archives in the industry. Our unique collection not only has obvious production and historical value, but serves as a continuing source of revenue. Unfortunately, these very fragile possessions come in a variety of formats, many requiring antiquated machines to access their contents. Despite new media's promise of easy access and portability, digital technologies are compounding the problem of long-term storage by flooding the marketplace with new file formats and proprietary storage devices.

Two years ago, the WGBH Educational Foundation was awarded a grant (97-029) from the **National Historical Publications and Records Commission of the National Archives** to produce a Recommended Practice. At that time, Thom Shepard was hired as project archivist. Since then, we have presented UPF to a variety of engineering, computer, and archival groups. We have established an impressive Review Board, a formidable Web site (http://info.wgbh.org/upf) and a rapidly growing listserv. We have also collected a large volume of material from those working in the trenches of digital preservation. Among these documents are our user survey and minutes from UPF Study Group sessions within the **Society of Motion Picture and Television Engineers.** These quarterly meetings, described elsewhere in this document, bring together engineers and archivists to exchange ideas, voice concerns and help untangle the semantics that have hindered effective dialogue in the past.

5. Glossaries

The need for a **cross-domain glossary** was recognized in **UPF Study Group** meetings between engineers and archivists. While many archivists could not define technical terms such as "data stream" or "file format," engineers did not understand basic tenets and terminology of cataloguing and collection description as practiced by professional archivists and librarians. It became evident that the underlying concepts of many terms could be mapped for better communication. Several terms were seen to describe the same concept, and other terms had different meanings for different groups. What was needed, the group agreed, was a glossary that mapped the languages of the library to the languages of the computer. Though several specialized glossaries and dictionaries exist both in print and online, little effort has gone into correlating concepts across domains. We have taken the first rudimentary steps in addressing this need through our cross-domain online dictionary, available through our web site (http://info.wgbh.org/upf/glossary.html). Through hundreds of hypertext links, we have attempted to identify relationships among key concepts.

In keeping with the spirit of the cross-domain glossary, we will examine how the words that make up our name can have many different meanings for different groups of people.

The **Universal Preservation Format** is composed of three highly charged concepts. In a way, our name "self-describes" one of **UPF**'s key characteristics: it serves as a container for individual concepts stored within it.

Our use of the term **universal** carries two meanings. First, it relates to a specific philosophical approach. Problems of long-term digital storage cannot be solved or even addressed intelligently without initiating a universal collaborative effort. The responsibility for preserving our cultural heritage supercedes that of any single special interest group.

The second level of "**universal**" applies to the technological component of the **UPF**. We propose the creation of a system for universal storage that will serve as a safe haven for electronic media created in the past, present and future: for current digital materials, for migrated analog materials and for hybrid materials that may be developed in the future. And though we initially focused on technologies and standards recognized by the broadcasting industry, we speak of the **UPF** as possessing a universal application, meaning the same **UPF** system will work with equal success on text, image, and sound. The **UPF** also addresses the concern that basic requirements for any digital systems vary among disciplines and types of repositories.

When we first presented our ideas for a universal preservation format to various archival and library communities, we quickly learned that the meaning of the very term "**preservation**" differed depending upon which group we were addressing.

Paul Conway, head of the Preservation Department at Yale University, writes:

> At one time, advocates for the protection of cultural artifacts, including books, primary source documents, and museum objects, used the terms "conservation" and "preservation" interchangeably. Today, preservation is an umbrella term for the many policies and options for action, including conservation treatments. Preservation is the acquisition, organization, and distribution of resources to prevent further deterioration or renew the usability of selected groups of materials.
> (Paul Conway, "Preservation in the Digital World," January, 1998. URL: www.clir.org/cpa/reports/conway2/)

Arguably, the so-called digital revolution has corrupted the terminology of the archivist by coining new meanings from old lexicons. The computer industry in general is notorious for stealing terms from the "analog" world to label, describe and explain its products. The very term "archive" carries an entirely different meaning in the world of personal computers than in the world of the traditional archivist. When we find our hard drives filling up, we often "archive" them into compressed "zip" or "sit" files.

For some media archivists, "digital" and "preservation" do not belong in the same sentence. Digital information is too easily damaged, too easily manipulated. The highly controversial colorizing of classic black-and-white movies comes immediately to mind. Entire movies can be digitally constructed from the "bits" and pieces of classic films. One need only watch Forest Gump stumbling through historical footage or the recent television commercial that displays Fred Astaire dancing with a vacuum cleaner to witness the power and threat of digital technology. Simon Pockley writes:

> In spite of Marshall McLuhan's book-bound insights ('the medium is the message') **the process of digitization now allows us to separate content from the medium which carries it**. This loosening of the bonds imposed by medium, allows data in almost any form (text, sound, image) to be reused and recombined with a facility which we have yet to learn how to exploit. (Simon Pockley, "Killing the Duck to Keep the Quack," updated January 19, 1998
> http://www.cinemedia.net/FOD/FOD0055.html)

What may be lost on some analog archivists is that "digital" has its own innate integrity. Technically, a digital object is a primary source the moment it is first generated, whether it is authored or composed through a computer or whether it functions as a **digital surrogate**; that is, it has been scanned or migrated through some other method from analog. It is a given that a data file consisting of a facsimile of *A Tale of Two Cities* can never fully equate to a first edition of the original book. We must understand, however, that the data file itself can be considered a digital primary source and that any versions made from it should be referenced in metadata.

THE UNIVERSAL PRESERVATION FORMAT AS A FILE FORMAT.

What do we mean by the term "file format?" In the early days of home and office computers, file formats were associated with a single data type: a text file, a picture file or a sound file. These data types can be broken down further into software specific formats; for example, a text file can be ASCII, Rich Text Format or a proprietary word processing format, such as Word, WordPerfect or AmiPro. A complete definition of file format must include the concept of a **specification**, itself defined as a file's organizational requirements. A file format, then, may be defined as the

> ...specification for holding computer data that dictates what information is present in the file and how it is organized within it.
> (Northern Micrographics: Imaging Dictionary: http://www.normicro.com/glossary.htm)

As stated above, file formats stemming from the early years of computing tended toward a single data type. The **UPF** is based on the model of a **compound document** which is a file format that contains more than one data type.

Related to compound document are the concepts, **essence** and **metadata**. **Essence** is data that represents pictures, sound or text. In the broadcast industry, **essence** is also described metaphorically as a "stream." In a digital environment, this **essence** "flows" as binary code to some processing pool. **Metadata** is defined simply as "data about data." A thorough definition of **metadata** would incorporate its functionality as described in detail by the "Pittsburgh Project." For our purposes, **metadata** is defined as having four functional characteristics: **format**, **description**, **association** and **composition**. Metadata informs us about the **format** or binary code of data types. It also serves as **description** or cataloguing information. In addition, it may relate information about how one component **associates** or links to another. Finally, metadata can consist of **compositional** information, needed to combine data components into a structured sequence, such as a strip of video or staff of music.

Essence and **metadata**, as described above, may be bonded together within the same file format. The generic term is the **container**, but definitions used to describe this relationship vary from one initiative to another. For example, the **Committee on the Preservation of Electronic Documents**, a Task Force affiliated with **the Public Record Office & British Standards Institute**, calls its **bundles** "self-supporting" collections of electronic objects and their associated software.

> Bundling is an electronic transit envelope that contains not only the electronic document files of whatever type, it contains a viewer and other navigation software to be completely self-contained. This envelope or Bundle of documents takes with it the correct version of viewer or browser that can display the documents in it, and to navigate around those documents.
> (Public Record Office & British Standards Institute (UK), "A Mechanism for the Perpetual Preservation of Electronic Records of Value," IDT/1/4 (A Working Group transferring to a Committee Status)TECHNICAL REPORT (Version 0.6))

The **Reference Model for an Open Archival Information System (OAIS)**, which is maintained by the **Council of the Consultative Committee for Space Data Systems (CCSDS)**, describes a similar framework for the archiving of digital information. **OAIS** introduces the term, "**Archival Information Package (AIP)**," defined as:

> An information packaging concept that requires the presence of **Content Information** and all the associated **Preservation Description Information** that is needed to preserve the **Content Information** over the long term. It has associated Packaging Information.
> (Consultative Committee for Space Data Systems, "Reference Model for an Open Archival Information System (OAIS)," White Book (**CCSDS 650.0-W-4.0**), September, 1998. Available at http://ssdoo.gsfc.nasa.gov/nost/isoas/ref_model.html)

This "**package**" consists of data required to "bind and identify" the **Content Information** (the "primary target of preservation") to the **Preservation Description Information** (information required to make long-term sense of the content). The **OAIS** model corresponds to the notion of **Wrappers** as prescribed by the **Society of Motion Picture and Television Engineers/European Broadcasting Union (SMPTE/EBU) Task Force for Harmonized Standards for Exchange of Program Material**. A Wrapper gathers together program material and related information. Though the term "program material" may suggest broadcast content, wrappers in actuality apply to a range of materials, including stationary data types, such as a virtual strip of still images, frames containing scanned documents, and even a series of electronic records. Information within a wrapper may include pointers to materials stored outside the wrapper, a notion that corresponds to the **Warwick Framework**, which is described below.
(SMPTE/EBU Task Force for Harmonized Standards for the Exchange of Program Material as Bit Streams, Copyright (c) 1998 European Broadcasting Union and the Society of Motion Picture and Television Engineers, Inc., http://www.smpte.org/engr/tfhs_out.pdf)

IDENTIFIERS

The idea of a **unique identifier** for electronic media stems from the domain of relational databases, but there is a key difference between records in a relational database and objects stored in **UPF**. If you edit a record's content in a relational database, you do not necessarily change the unique identification of that record. But when speaking of archival content, we should assume that the record is locked. Changes are made to a copy or clone of that record, which takes on a new identifier that associates itself or references the original. To state this another way, when content is duplicated, it keeps the same unique identifier; however, if the copy is changed in any way, the changed file is considered a subset of the original, and a new unique identifier must be assigned. This concept is called **versioning**.

The **Bento Specification**, using the term **globally unique names** to mean unique identifier, provides a naming mechanism "that can be used by large numbers of developers without registration," and still provide reliably unique names. Bento objects also utilize a unique identifier called **a persistent ID**, which is "unique within the scope of its container." Though it is not a Bento requirement, objects may have "additional IDs and/or names that are unique in larger scopes."

The **(SMPTE/EBU) Task Force for Harmonized Standards for Exchange of Program Material** calls for the establishment of the **Unique Material Identifier (UMID)** as a component of its Wrapper. These identifiers would track content as it passed through a production system. Materials originating from the same source would be uniquely identified, whether they were source materials or "intermediate content elements." **UMIDs** would also contain information "to trace copyright information and ownership of both finished and programs."
("SMPTE/EBU Task Force for Harmonized Standards for the Exchange of Program Material as Bit Streams," Copyright (c) 1998 European Broadcasting Union and the Society of Motion Picture and Television Engineers, Inc., http://www.smpte.org/engr/tfhs_out.pdf, p.75.)

Another concept for uniquely identifying material is a **digital signature**, which was proposed by the Department of Defense in the document, "Automated Interchange of Technical Information." This digital signature is "a digital data file that authenticates the identity of the approving authority or sending agent by the use of a computationally unique string of numbers, and that enables the detection of unauthorized modifications to the contents of a signed data file." (**MIL-STD-1840C**, "Automated Interchange of Technical Information," http://www-cals.itsi.disa.mil/core/formal/1840.html) An example of a digital signature for image files is the **digital watermark**, a method of encoding images to create a hidden and traceable pattern which indicates proof of ownership but is invisible to the naked eye.

Of the many standard initiatives concerned with identifying digital documents, perhaps the best known is the **Digital Object Identifier**. A **DOI** is a permanent Web document identifier. If the internet address of a document changes, users are automatically redirected to its new location. The **DOI** system was conceived by the **Association of American Publishers**, in partnership with the **Corporation for National Research Initiatives,** and is now administered by the **International DOI Foundation**. Though the numbering system proposed by the **UPF** is local, similar principles are at work.

Among other initiatives for unique identification are ISO's **International Audiovisual Number** (ISAN), **Sony's Unique Material Identifier**, **Microsoft's Advanced Streaming Format** and US Government's proposed **Digital Signature Standard** (DSS).

Although these numbering systems may be inadequate for identifying the stored contents of a universal preservation format, much can be learned by studying their respective structure.

Lessons could also be gleamed from systems that have worked in the past. The most persevering classification scheme is the **Dewey Decimal System**. Dewey is a hierarchical classification scheme. Numbers represent concepts. The longer the number, the more specific the information. For example, to catalog information about "batting," a pyramid from general to specific could be constructed:

700	The arts. Fine and decorative arts
790	Recreational and performing arts
796	Athletic and outdoor sports and games
796.3	Ball games
796.35	Ball driven by club, mallet, bat
796.357	Baseball
796.3572	Strategy and tactics
796.35726	Batting

Dewey has already been applied to digital objects on the World Wide Web. The "Scorpion Project," sponsored by the **Online Computer Library Center (OCLC)**, is building a tool to automate the indexing and cataloguing of Web materials using the principles of the **Dewey Decimal System**.
(Keith Shafer, "A Brief Introduction to Scorpion," http://orc.rsch.oclc.org:6109/bintro.html)

If we substitute subject content with other kinds of metadata, we might see how a Dewey-like system could be constructed to describe complex relationships, including versioning and levels or degrees of dependency. For example, segments might refer to specific hardware, operating systems, software data types and source programs.

Traceability is a concept related to unique identifiers. It means that versions of objects should be traceable to the original through some quality within the unique identifier. In other words, the unique identifier would be an **intelligent number** that would establish a relationship with other numbers, much in the same way that **Dewey Decimal** numbers provide specific information about the subject matter of published materials. A controversial implementation of identifiers is the recent revelation that **Microsoft** uses a "digital fingerprint" in its Windows 98 software. This code, which is generated when the Windows 98 operating system is installed, represents specific information about a user's hardware configuration. When the system software is registered over the Web, the number decodes and the information enters Microsoft's customer database. Identifiers are also embedded in documents generated by other Microsoft products, such as Word. Microsoft has claimed that it never intended to violate the privacy of its consumers and has vowed to remove it in the future. (Hiawatha Bray, "Privacy advocates decry digital 'fingerprints'", Boston Globe, March 9, 1999.) One might argue that a revised and less nefarious version of Microsoft's traceable **digital fingerprint** might have a positive practical application for a system serving long-term storage needs.

The term **"self-describing"** is often used in connection with storage and file formats. The term appears in the book "Essential Distributed Objects Survival Guide," where authors Orfali, Harkey and Edwards conclude their chapter on Bento with the words:

> So what do you think of these self-describing files within files? We [...] believe that these new compound document file systems -- OpenDoc's Bento and OLE's compound files -- offer tremendous opportunities for developers and system integrators. Just imagine all the good things you can do with files filled with self-describing data.
> (Orfali, Roberd, Dan Harkey, Jeri Edwards. The Essential Distributed Objects Survival Guide. New York: John Wiley and Sons, 1996. p. 385)

Many agree that among these "good things" is the **Warwick Framework**. Developed through the **Dublin Core** workshops, the **Warwick Framework** is a "container architecture" that describes how digital objects might either be embedded in a source file or referenced to external files or other storage areas. This information might include domain specific descriptions, terms and conditions for document use, pointers to all manifestations of document or archival responsibility. The **Warwick Framework** recommends that bit streams within this architecture be self-describing.
(http://cs-tr.cs.cornell.edu:80/Dienst/Repository/2.0/Body/ncstrl.cornell/TR96-1593/html)

Tagging **ASCII** or plain text with bracketed codes is another method for self-describing documents. In this context, the **Standard Generalized Markup Language** or **SGML** might be considered one of the first tools for self-description. An **ISO** standard "metalanguage" since 1986, **SGML** is used to create data files that are platform- and application-independent.

The **University of Illinois Pablo Research Group** has designed a meta-language called the **Self-Defining Data Format (SDDF)**. This "performance data file format" specifies a "data record structure" or "packet" to describe the layout of records, as well as the "data record instances" or actual data to be processed.
(http://www.pablo.cs.uiuc.edu/Project/SDDF/SDDFOverview.htm)

Self-description is central to one of the most exciting Web developments to emerge in the past few years: the **eXtensible Markup Language** or **XML**. Most World Wide Web developers are familiar with **HTML**, the system of tagging format and linking used on the World Wide Web. Like **HTML**, **XML** has roots in **SGML**. Also like **HTML**, documents tagged with **XML** are intended to be understood by cross-platform browsers. Unlike **HTML**, however, **XML** was devised to enable content creators to create their own sets of markup tags. These more robust tags could specify complex relationships among elements within a page, among many documents within a site and across sites. Though the **XML 1.0 Specification** has only recently been published as a **World Wide Web Consortium (W3) Recommendation** (http://www.w3.org), **XML** has been used to create several "vocabularies," including **the Astronomical Markup Language (AML)**, the **Bioinformatic Sequence Markup Language (BSML)** and **Microsoft's Channel Definition Format (CDF)**. One **XML**-based language with enormous potential for the broadcasting industry is the **Synchronized Multimedia Integration Language (SMIL)**, which is currently supported by AT&T/Bell Labs, Microsoft, Netscape, Philips, RealNetworks, and Sun Microsystems.

The impact of **XML** on Web development is likely to be enormous. Its impact on digital preservation remains to be explored. Michael Day, metadata research officer at the **UK Office for Library and Information Networking**, writes, "Text-only 'bootstrap standard' metadata [might be] attached to the data which would provide contextual information and an explanation of how to decode the record itself." (Michael Day, "Extending Metadata for Digital Preservation," Ariadne: the Web Version, May 19 1997 issue 9. http://www.ariadne.ac.uk/issue9/metadata/) The **Research Library Group's Working Group on Preservation Issues of Metadata** has demonstrated how its recommended list of "preservation metadata elements" might be incorporated into an **XML** record. ("RLG Working Group on Preservation Issues of Metadata," Appendix 3: XML Implementation, http://www.rlg.org/preserv/metaapp3.html)

Utilizing **XML** for the **Universal Preservation Format** could involve the creation of new tools to assist in the binding of **essence** to **metadata** and to access stored materials through next generation versions of popular browsers. **XML**, through its related standards, **Xlink** and **XPointer**, might also be used in the creation of the **UPF's digital Rosetta stone**.

The **World Wide Web Consortium** recently announced an initiative to reformat **HTML** as an application of **XML**. This W3 project shares at least one source of inspiration with **UPF**; its code name is "Voyager."

6. Assessing User Requirements

As we investigated the user requirements for a digital archiving system, we gathered and processed information from many different sources, including academic papers, recommended practices, technical specifications, working and study group documents. These documents have been supplemented with fieldwork: soliciting input through user surveys, conferences and meetings.

In keeping with our cross-departmental origins, we sought the participation of organizations from a wide range of domains: the **Association of Moving Image Archivists**, the **Society of American Archivists**, the **Music Library Associations**, **Boston Art Conservation** and **Conservation On-line**. We continue to exchange ideas with individuals who may not be members of these groups but who are actively involved in preservation issues. In addition to our own **UPF listserv**, which currently has close to 80 members, we routinely post updates about this project to the **AMIA listserv**, the **Archivist & Archives listserv**, and the **Electronic Records listserv**. We also send mailings to archivists who do not have email addresses.

6.1 Review of the Literature

There are many initiatives concerned with accessing digital materials, but few deal with long-term digital storage. In his essay, "Archiving and Authenticity," David Bearman, editor of **Archives and Museum Informatics**, points out that digital preservation initiatives have focused on one of four areas: the digital signal, intellectual content, software independence and social and legal standards. Bearman is well known for his pioneering work in network standards, including the "**Business Acceptable Communications (BAC)**," a reference model published in 1995 "to facilitate implementation of environments in which electronic evidence can be created." The BAC reference model was an early proponent of encapsulation as a method to promote software independence and interoperability.

> We envisage transactions taking place as metadata encapsulated objects, although records might not be physically stored in this manner. When transmitted, the contents of the transaction would be preceded by information identifying the record, the terms for access, the way to open and read it, and the business meaning of the communication much as a train of baggage cars is preceded by an engine.
> (David Bearman and Ken Sochats, "Metadata Requirements for Evidence,"
> URL:http://www.lis.pitt.edu/~nhprc/BACartic.html)

One important paper concerned with the signal level of digital preservation level is Jeff Rothenberg's highly influential **"Ensuring the Longevity of Digital Documents,"** published in the January 1995 issue of ***Scientific American***. Rothenberg argues that present technology is not sophisticated enough to mimic software behavior. "To replicate the behavior of a program," he writes, "there is currently little choice but to run it." (Rothenberg, p47) In his paper, "Metadata to Support Data Quality and Longevity," he asserts that current data files are both more complex and depend more upon the applications that created them. His conclusion is that one must access digital records through the original application or through emulators.

> ...there may be no inherent way to know whether to interpret a given sequence of bits as text, number, pointer, image, sound, video, program or new formats...
> (Jeff Rothenberg, "Metadata to Support Data Quality and Longevity," para 1 under section "The Assault on the Longevity of Digital Data" URL:: http://www.computer.org/conferen/meta96/rothenberg_paper/ieee.data-quality.html)

Both Rothenberg and the **UPF** initiative promote the concept of the container, which Rothenberg calls "virtual envelopes." These would contain the bit streams along with descriptions of contents and "transformation history."

> [...] contents would be preserved verbatim, and contextual information associated with each envelope would describe those contents and their transformation history. This information must itself be stored digitally (to ensure its survival), but it must be encoded in a form that humans can read more simply than they can the bit stream itself, so that it can serve as a bootstrap. Therefore, we must adopt bootstrap standards for encoding contextual information; a simple, text-only standard would suffice. Whenever a bit stream is copied to new media, its associated context may be translated into an updated bootstrap standard. [...] These standards can also be used to encode the hardware specifications needed to construct emulators.
> (Jeff Rothenberg, "Ensuring the Longevity of Digital Documents," Scientific American, January 1995, v272 n1, p. 47)

For data to be readable through time, Rothenberg says one must save the hardware specifications in a platform-independent environment. This idea corresponds to the **UPF**'s implementation of a digital **Rosetta stone**, a term Rothenberg uses generically. The **UPF Rosetta stone** would get at the stored data types through platform-independent algorithms. These instructions, saved in a standard plain text format to the storage media, would contain the registry of the data types stored on the media and include their mathematical definitions. The **UPF Technical Requirements** suggests storing this "blueprint" information in analog format at a marked segment within a hybrid storage medium.

The phrase "digital Rosetta stone" appears in a number of other preservation initiatives. Massachusetts Institute of Technology's **Time Capsule File System (TCFS)**, discussed more fully later in this document, uses the phrase to describe its "ideal archival format," which would be "portable across media and platforms and would be easy to reverse-engineer." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/index.html) The phrase is central to Alan R. Heminger and Steven B. Robertson's paper on their process to assure long-term access to digital documents. Their **Digital Rosetta Stone (DRS)** model would contain:

> multiple levels of knowledge about specifications and processes by which information is stored on various types of storage media. It would also contain archives of knowledge about how to meaningfully interpret that information so that the original meaning can be recovered.
> (Heminger & Robertson, "Digital Rosetta Stone: Conceptual Model for Maintaining Long-term Access to Digital Documents," published in *European Research Consortium for Informatics and Mathematics*, Sixth DELOS Workshop, Preservation of Digital Information, June 1998, 35-43.)

Heminger and Robertson call the storing of format information, "knowledge preservation." This **metaknowledge**, which resides in a database, defines how data is stored on specific media and how specific software applications format their digital documents.

The authors describe their **Digital Rosetta Stone (DRS)** as a three step process: **knowledge preservation,** the process of gathering and storing the metadata about storage media techniques and file formats; **data recovery**, the process of migrating data from an obsolete medium; and **file reconstruction**, the process of "interpreting digital documents" through knowledge about how specific software formats its information.

The **UPF**'s self-described file format and Heminger and Robertson's data reconstruction model contain many similarities. Both models contrast with Rothenberg's emulation proposal. Though today's file formats are more complex than yesterday's, as Rothenberg asserts, hardware emulation may prove to be less feasible than the preservation mechanisms proposed by the **UPF** and **DRS** models. In the past, the more successful emulators have depended upon the installation of special hardware helpers: cards that contain proprietary chipsets or ROMs that contain the original operating system.

MIT's **Time Capsule File System (TCFS)** was developed in response to this perceived drawback. **TCFS** Project Head Brian K. Zuzga writes, "Emulators increase in complexity as the original hardware increases in complexity, so this problem only would get more difficult with time." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/subsection2_5_2_3.html) Complicating matters are the special configurations that software applications increasingly place on hardware. Even a machine running the correct version of an operating system must be upgraded to run some of today's more demanding COTS products. In short, computer hardware consists of so many components -- RAM, video and sound cards, even analog converters -- that it is not enough to emulate a generic processor.

Adoption of Rothenberg's ideas will unquestionably salvage volumes of material that might otherwise be lost. And however one might criticize emulation as a long-term solution, successful emulators already exist for a wide range of obsolete systems, many available as freeware. It remains to be seen, however, whether emulation addresses the problem of its own perpetual integrity. One can easily envision running one emulation within another emulation to view data in a way that mimics the look and feel of the original application. Why is the emulation approach superior to migrating to new file formats which might also alter in some small way the original? On the surface, it seems a trade-off between system performance and file format fidelity, but if one factors in the costs and inconvenience of continually upgrading emulation software, not to mention the uncertainties of maintaining the interest of future programmers to do this kind of work, versus the potential loss of how data is formatted from one generation to another, then one might lean to the latter solution.

Emulation may be appropriate when it is necessary to preserve not just data but original programming. David Bearman has pointed out that

> the task of continuing to devise methods to read old signals in old media is becoming more complex as the media proliferate, recording and layout methods become more proprietary, and firmware plays a greater role in decoding.
> (David Bearman, "Archiving and Authenticity," The Getty Art History Information Program: Research Agenda for Networked Cultural Heritage, 1995. URL:http://www.ahip.getty.edu/giinew/ranch/archiving/archiving1.html)

Fundamental questions must be raised about the inherent value of software. Are applications merely the means of generating and accessing data, or might a software program be considered an aesthetic experience, an original creative work, as worthy of preservation as a novel or a painting? If software as self-contained experience is machine- or system-dependent, what are the limits to the archivist's responsibility in assuring its accessibility through time?

The **Commission on Preservation** and the **Research Library Group Task Force on Archiving of Digital Information** has grappled with this aspect of preservation through its guidelines for migration:

> Migration is a set of organized tasks designed to achieve the periodic transfer of digital materials from one hardware/software configuration to another, or from one generation of computer technology to a subsequent generation. The purpose of migration is to retain the ability to display, retrieve, manipulate and use digital information in the face of constantly changing technology. Migration includes refreshing as a means of digital preservation but differs from it in the sense that it is not always possible to make an exact digital copy or replica of a database or other information object as hardware and software change and still maintain the compatibility of the object with the new generation of technology.
> (Commission on Preservation and The Research Library Group, Task Force on Archiving of Digital Information, "Preserving Digital Information," May 1, 1996. http:// www.rlg.org/ArchTF/, p4)

Refreshing relies on someone in the future taking on responsibility for the process. Maggie Exon, a medieval historian, states in a paper delivered at the 1996 Second National Preservation Office Conference in Canberra, Australia:

> A task like information transfer or refreshment which needs to be repeated over and over again, will at some point fail to happen. This failure may take place a few years from now or a few hundred years but it will surely take place.
> (Maggie Exon, "Strategies for Long-Term Preservation," Canberra: National Library of Australia 1996

URL: http://www.nla.gov.au/3/npo/conf/npo95me.html, para 5)

Klaus-Dieter Lehman, **National Librarian of Germany,** in an essay published in **Daedalus** points out that the current popularity of Java applets, used to develop both distributed documents and distributed programs, complicates strategies to preserve digital applications.

> It is no longer necessary to install complete programs on a hard drive; instead, small program modules are written for each specific purpose. These so-called objects -- Java refers to them as "**applets**" -- are available on various computers within the network and can be downloaded as needed and combined to perform a particular task. An interpreter simulating a second computer on a PC insures that the different browser programs understand the applets. The interpreter runs the applets as soon as it receives them.
> (Klaus-Dieter Lehman, "Making the Transitory Permanent: the Intellectual Heritage in a Digitized World of Knowledge," Daedalus, Fall 1996 v125 n4 p307)

In theory, at least, Java itself could have a positive impact on long-term digital storage. As a standard machine-independent programming language, Java could be used to build applications or JavaBeans specifically for accessing or reconstructing data types within an archives.

As a blanketed archival solution, emulation arguably goes against the grain of current archival discourse because, while it does address the integrity of data, it does not solve the issue of informational integrity. Emulation is designed as a tool to interact with data, not simply to view it. The point of an archives is to maintain the content of the data object.

Another approach to promoting data longevity is the widespread adoption of **file format interchange**. One hears the term "native format" quite frequently these days, but what constitutes a "native format" is open to debate, especially considering that most applications offer several options for saving files. Exon posits the question: What information from the period 1995 to 2000 will still be around in 3000?

> The information [likely to survive] will be software independent, and standardized formats will be used which are as simple as is possible consistent with the information still being usable. This, of course, poses a problem with much commercial and non-commercial multimedia, in which complex relationships are set up between image, sound and text. However, the move towards **standardized software and hardware formats** has been very strong in recent times and I can see this continuing, leading to the **possibilities of finding ways of translating these formats into relatively simple migratable formats.**
> (Maggie Exon, "Strategies for Long-Term Preservation,"

URL: http://www.nla.gov.au/3/npo/conf/npo95me.html, para 10)

Though the majority of commercial software programs generate their own proprietary file formats, the actual content is rarely glued to these applications. For example, users of the painting program **PhotoShop** can substitute its own proprietary format with a variety of standard formats that can be read by other painting programs, such as **PaintShop Pro**. Word processing documents saved in either ASCII or RTF standards can be loaded into other word processors on a variety of platforms. Other applications, such as FileMaker, allow its proprietary data files to travel seamlessly across platforms.

In addition, open standard formats exist for many individual data types, and their specifications can be easily obtained through the Internet. Standard interchange formats for compound documents are also being developed. The **Advanced Authoring Format,** announced by Microsoft at the 1998 **National Association of Broadcasters,** is described as "an industry-driven, cross-platform, multimedia file format that will allow interchange of media and compositional information between AAF-compliant application." ("AAF Specification") The AAF standard is being developed through a collaboration among several software companies -- Adobe, Avid, Matrox, Microsoft, Pinnacle, Softimage, Sonic Foundry and TrueVision -- as a way to address the shortcomings of currently available digital media file formats.

The Advanced Authoring Format resembles other container formats, which include Sun's **JavaBeans**, Apple's **QuickTime 3.0**, Avid's **Open Media Management** and Microsoft's own **Advanced Streaming Format**. This should come as no surprise since AAF is based on Avid's **Open Media Framework**, which is built upon **Bento**. Like its predecessors, AAF uses encapsulation to allow applications to identify specific, even proprietary data types. Before these container technologies existed, applications generated separate files for each data type. To move these materials into another application, one often had to convert each of these data types into a series of new formats. Relationships among the converted materials had to be re-established, which was often a laborious procedure. Container technologies, on the other hand, allow for these complex relationships to travel with the data types.

The **AAF** specification attempts to resolve the difference between an authoring system and a delivery system through "file flattening," a process that strips AAF files of its metadata. Two years ago the **UPF** incorporated this file flattening in the form of a media compiler, an apparatus which would "remove the acquisition format from the archives requirement." (MacCarn, "Toward A Universal Data Format for the Preservation of Media")

Metadata is a crucial component of an archival system, and the **UPF** is designed to incorporate as much metadata as needed. The integrity of digital information is dependent upon the quality of metadata. Peter S.

Graham, associate university librarian for technical and networked information services at Rutgers University, in his paper, "Preserving the Digital Library," has described levels of preservation modes: **medium preservation** (tapes, disks, CD-ROMs, etc.); **technology preservation** (storage formats, operating systems); and **intellectual preservation**, "which addresses the integrity and authenticity of the information as originally recorded."
(Peter Graham, "Preserving the Digital Library," 1995, paper presented at "Long Term Preservation of Electronic Materials," JISC/British Library Workshop, Nov. 1995), http://www.ukoln.ac.uk/services/elib/papers/other/preservation)

Guidelines for all levels or modes of information have been described in great detail by the **Commission on Preservation** and **The Research Library Group Task Force on Archiving of Digital Information** under the section, "Information Objects in the Digital Landscape." The **Open Archival Information System (OAIS)**, discussed above, has adapted these guidelines as components of its **Preservation Description Information**.

Content is defined by **Task Force on Archiving of Digital Information** on several levels, from its very bit stream to its intellectual essence.

> the preservation challenge for digital archives is to migrate [...] **intellectual content** using standard interchange algorithms and other appropriate migration strategies so that the **ideas** available in the end are identical to those contained in the original object. The measure of integrity in the preservation process thus turns, at least in part, on informed and skillful judgments about the appropriate definition of the content of a digital information object -- about the extent to which content depends on its configuration of bits, on the structure and format of its representation, and on the ideas it contains -- and for what purpose.
> (Task Force on Archiving of Digital Information, "Preserving Digital Information: Executive Summary," May 1, 1996, p.13. URL: http://www.rlg.org/ArchTF/)

Margaret Hedstrom, associate professor in the School of Information and Library Studies at the University of Michigan, has examined the complexities of digital content in her seminal paper, "Digital Preservation: a Time Bomb for Digital Libraries." Among her observations is that many librarians and archivists are resorting to transfering digital information to analog formats as a preservation strategy. Hedstrom also points out that some types of digital materials do not lend themselves well to these "print equivalents."
(Margaret Hedstrom, "Digital preservation: a time bomb for Digital Libraries,"
http://www.uky.edu/~kiernan/DL/hedstrom.html)

Fixity refers to digital information as a discrete object or individual thing, unique from other things. The **Task Force on Archiving of Digital Information** offers the publication of books and the broadcasting of radio and television programs as analog examples. Defining fixity for digital objects is more complicated. As Peter S. Graham of Rutgers points out, fixity for printed material is a given:

> The printed journal article I examine because of your footnote is beyond question the same text that you read. Therefore we have confidence that our discussion is based upon a common foundation. With electronic texts we no longer have that confidence.
> (Peter Graham, "Intellectual Preservation: Electronic Preservation of the Third Kind" 1994, http://sul-server-2.stanford.edu/byauth/graham/intpres/)

Graham reports that one way digital fixity might be achieved is through **digital time stamping**, defined as "a means of authenticating not only a particular document, but its existence at a specific time." (Graham, "Intellectual Preservation: Electronic Preservation of the Third Kind")

The **digital watermark**, described above, is another method to help ensure fixity. Still another method might be to incorporate into the digital object a built-in or embedded database that records a kind of chronicle of changes. Donald Waters, Director of the Digital Library Federation, has expanded upon this concept:

> some digital information objects are better modeled as continuously updated databases for which the preservation choice is whether to compile a complete record of changes or to capture snapshots of the database as the means of preserving information integrity.
> (Donald Waters, "The Impact of Electronic Publishing on the Academic Community: Session 5: Digital Libraries and Archiving of Electronic Information: Choices in Digital Archiving: the American Experience," 1997, http://www.portlandpress.co.uk/books/online/tiepac/session5/ch6.htm)

OAIS defines its **Fixity Information** as a "protective shield" to ensure the authentication of its stored contents. A functional example of **fixity** in this sense might be the checksum at the end of an ISBN number, while the ISBN number itself would fall under the category of **Reference Information**.

Reference as an aspect of integrity means that information objects must consistently be findable and identifiable among other objects. The **Task Force on Archiving of Digital Information** cites the new MARC 856 field "to incorporate reference to digital objects." (**Task Force on Archiving of Digital Information**, p15.) The Study also singles out the work being done by the **Internet Engineering Task Force (IETF)** for the unique identification of digital information objects: the **Uniform Resource Name (URN)**, the **Uniform Resource Location (URL)** and a proposed framework called the **Uniform Resource Characteristics (URCs)**, which would include intellectual rights, property rights, context and provenance

Provenance is a term familiar to most archivists. James O'Toole identifies it as the principle by which archives are generally organized, and:

> is based on the deceptively obvious insight that the person or organization producing the records determines their content. A nuclear engineer will produce files and documents that are essentially different from those produced by an impressionist painter, even if both of them talk about a whole range of subjects in their letters
> (O'Toole, James, *Understanding Archives and Manuscripts*, Chicago: Society of American Archivists, 1990, p.55)

Elizabeth Yakel cites provenance as the key difference between how archival records and library materials are organized, a distinction that has clear application to digital realms:

> Books are created to provide information on a specific topic and are physically organized by subject. By their nature, archival records are an organic byproduct of an institution, activity, or person. Therefore, maintaining the context in which archival materials were created is absolutely essential to future historical understanding of an organization, individual, or activity. Archivists have found that the best method of maintaining the context is to organize records according to their "provenance" or creator.
> (Yakel, Elizabeth, Starting an Archives, Chicago: Society of American Archivists, 1994, p.39)

The **Task Force on Archiving of Digital Information** describes provenance as the "assumption [...] that the integrity of an information object is partly embodied in tracing from where it came." (**Task Force on Archiving of Digital Information**, p15) For digital objects, provenance would include tracing migrational history on several levels: through individuals as sources and owners of objects, corporate affiliations and underlying policies, scientific data and instrumentation, and migration activity within one's own organization, called "the chain of custody." (**Task Force on Archiving of Digital Information**, p17)

In a word, provenance is history. **OAIS** defines its **Provenance Information** as information that documents the origin or source of its stored contents, as well as any changes made to it.

Context is defined as how digital information objects "interact with elements in the wider digital environment." (**Task Force on Archiving of Digital Information**, p18) On a technical level, digital information depends on a specific configuration, such as a specific chip or operating system. Another level is the "linkages" of these objects, best illustrated by Web pages. For archives, to maintain integrity, objects and linkages would have to reside within the same storage system. On the communications level, attributes such as bandwidth and security would have to be considered as part of an information object's integrity. The final factor under context is the social environment of digital information. The study cites email as both a personal communication tool and a viable "vehicle for formal communication among academic or business colleagues." (**Task Force on Archiving of Digital Information**, p19) **OAIS** adds to its **Context Information** the requirement to address the question of why the content was created in the first place.

Information integrity has been discussed in several other papers using other terminology. Graham, quoted above, refers to this quality as **Intellectual Preservation**. More recently, the **Society of American Archivists** issued its "Statement on the Preservation of Digitized Reproductions." The document points out that the integrity of digital information "begins with limiting the loss of information that occurs when a file is created originally and then compressed mathematically for storage or transmission across a network." Echoing the recommendations of the **Task Force on Archiving of Digital Information**, SAA urges archivists to "migrate valuable digitized data, indexes and software from one generation of computer technology to a subsequent generation."
(http://www.archivists.org/governance/resolutions/digitize.html)

Perhaps the most practical attempt to ensure the integrity of information is the NHPRC-funded project, "Functional Requirements for Evidence in Recordkeeping" (Grant No. 93-030). Better known as "**The Pittsburgh Project**," this initiative, directed by Richard Cox and James Williams, developed metadata "products" for specific professional domains, including legal, medical, accounting, information and records management. Each of these reference models includes six levels of metadata: **Handle**, **Terms and Conditions**, **Structural**, **Contextual**, **Content** and **Use History**. (http://www.sis.pitt.edu/~nhprc/)

UPF as Tangible Product

> Re-formatting as a means of converting obsolete videotape holdings poses two major dilemmas for the archival world: the lack of an ideal video format and the growing volume of material to be copied. Beyond the need to go to a digital format to avoid generational loss, absent from the archival field is anything remotely approaching what might be called an ideal format or a "preservation copy." Until an ideal or universal preservation format is introduced, video preservation should be viewed not as a tangible product but a continuing process aimed at protecting information that can migrate from one technology to another as the need arises. The current merger of video technology and computers suggests that the ideal format in the future may not be videotape but bitstreams of compressed data recorded on disks.
> ("Television and Video Preservation 1997: A Report on the Current State of American Television and Video Preservation" Report of the Librarian of Congress, October 1997 v1 p41.)

The above passage begs the question, Can an "ideal or universal preservation format" be introduced now? Is the necessary technology available to handle digital media of all types? We believe it to be so, and in a paper published in the **SMPTE Journal**, WGBH's Dave MacCarn cites Apple's **Bento Specification** and

Avid Technology's **Open Media Framework Interchange** Specifications as "both media technologies that approach the UPF concept."

> Bento defines a standard format for storing multiple different types of objects and an application program interface to access these objects... Bento containers are defined by a set of rules for storing multiple objects, so that software that understands the rules can find the objects, figure out what kind of objects they are, and use them correctly.
> (Dave MacCarn, "Toward a Universal Data Format for the Preservation of Media," SMPTE Journal, July 1997 v106 n7 p477-479.)

The **Open Media Framework Interchange (OMFI)** builds upon Bento to establish a standard format for the interchange of digital media data among different platforms. It encapsulates in a single file whatever information it needs to transport digital media across platforms.

In additional to **Bento** and **OMFI**, other file formats and mechanisms have been developed for compound documents, some of which resemble the proposed functions of the UPF.

The **Hierarchical Data Format (HDF)**, for example, is designed for the scientific-visualization market. This standard is maintained by Fortner Software and Research Systems, Inc. and supported by the **National Center for Supercomputing Applications**. **HDF** can import data sets from virtually any format. (http://hdf.ncsa.uiuc.edu/)

> **HDF** data files are "self-describing" in the sense that they include information describing the type, storage structure, and location of the data in the file. They also provide convenient structures for applications to store application-specific metadata. **HDF** files are also "architecture-transparent" in the sense that a file's contents is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers. HDF files also provide structures that facilitate efficient direct access, so that a small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
> (Mike Folk, "HDF as an Archive Format," (A part of the ISO Archiving Workshop Series) http://ssdoo.gsfc.nasa.gov/nost/isoas/dads/DADS16.html)

The **Time Capsule File System**, developed by the Massachusetts Institute of Technology's Artificial Intelligence Lab and Laboratory for Computer Science, is a "universal framework for preserving any archival file in a platform- and medium-independent fashion." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/thesis.html) MIT's decision to develop its own file framework is instructive. As Brian K. Zuzga reports, he and Dr. Alan Bawden considered several options when faced with the challenge of preserving "rooms full of 7-track and 9-track magnetic tapes in various states of decay." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/section2_5_1.html) They rejected preserving only the raw byte stream because they determined that "the knowledge to interpret data is being lost much more quickly than the data on the tapes themselves." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/subsection2_5_2_1.html) They considered maintaining the original hardware, but decided that the expertise required to make repairs is also vanishing. Emulators were also considered and rejected for similar reasons; they necessitated an indeterminate amount of time and money to port the emulator to operating systems of the future. And though they were already maintaining full copies of the original operating systems and applications, they determined that this method inadequately solved the problem "of reducing the number of formats that we need to decode in order to read all of out data." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/subsection2_5_2_4.html) Finally, they considered migrating their files to a small group of standard file formats. Their problem with this approach was the uncertainty as to whether these file formats would still remain standards or would require them to "translate our documents each time a new format comes along." (http://www-swiss.ai.mit.edu/~boogles/papers/tcfs-thesis/subsection2_5_2_5.html)

Mikhail Popov, affiliated with the Centre for Physics and Information Science (Tsentr fizicheskikh issledovanii i informatiki pri OIYaI), has created the **SDF (Self-describing Data Format)** software to assist in "the transfer of binary data between different machines and different architectures," as well as in the "storage and retrieval on a single architecture." (http://unix4.jinr.dubna.sa/sdrintro/sdintro.html)

In 1992 **Adobe** (http://www.adobe.com) introduced its **Portable Document Format (PDF)** as a "universal electronic publishing tool." Though the software driver required to create **PDF** files is a commercial product, the **PDF Reader** is freely available for several platforms. The **PDF** format is generally regarded as the "de facto" standard for publishing professional and technical documents on the World Wide Web. As a measure of **PDF**'s predominance on the Web, Netscape plans to incorporate "direct **PDF** format capability" into its next generation of Web browsers. (http://www.imaging-resource.com/acrobat.html)

6.2 User Survey

Available on the UPF Web site since August 1997, the **UPF User Survey** is intended as a continuous thread of input throughout the UPF project. Though questions are presented in a multiple choice format, the real value of the survey may be found in opportunities for comments and personal anecdotes that follow each question. Many archivists responded with "mini-essays" that illustrate some of the key points expressed in the academic literature. Others raised practical concerns that have not been significantly addressed by theorists.

Underlining most of the comments was the issue of funding. Many archivists reported that their departments couldn't justify the expense of investing in new digital technologies, especially in equipment that may become obsolete after a few years. Some expressed frustration over their inability to control technologies already purchased. The maintenance and replacement of obsolete hardware was cited as a major expense. Several archivists felt that standardizing digital equipment or parts would alleviate this problem dramatically.

Budgets also affected hiring practices. A few managers reported choosing staff with computer skills over those with experience or training in cataloging or records management. As a result, decisions formerly made by long-term strategists are often made by junior-level staffers who may have technical know-how but who also may be implementing short-term fixes.

No one who responded to the survey seriously contemplated replacing analog collections with digital surrogates. In general, archives are experimenting with digital formats to provide selective online public access to their collections. The scope of this phase may broaden, but commentators wrote that their institutions are waiting for open systems before they will consider migration in any serious, systematic fashion. One archivist suggested that until open standards are in place, money would be better spent on developing metadata systems that protect the integrity of media and persevere through time.

The theme of integrity and identification of original works also ran throughout the commentaries. It was imperative, wrote several contributors, that a standard system of digital document identification be developed and administered by a central registry. Any changes to a registered document would result in that document's being given its own unique ID which would reference the original or parent version.

Finally, several archivists who responded to our survey suggested that continuing education should play a stronger role in preparing veteran archivists for new technologies. Archival societies should consider on-line tutorials for members. Archival conferences should include sessions that introduce digital formats and teach specific digital preservation strategies. A universal glossary or thesaurus would also be a greatly appreciated tool, wrote one archivist. A desire for a cross-domain lexicon also was echoed throughout several **SMPTE** sessions.

6.3 SMPTE MEETINGS

The Society of Motion Picture and Television Engineers (SMPTE) is an international technical society, founded in 1916, "devoted to advancing the theory and application of motion-imaging technology including film, television, video, computer imaging, and telecommunications." It has 8,500 members in 72 countries. On September 22, 1997, **SMPTE** assigned the UPF an official **Study Group** (ST13.14). Titled "Requirements for a Universal Preservation Format" and chaired by WGBH's Dave MacCarn, the group first met to establish an agenda and a statement of objectives, which includes gathering input from the archival community through surveys, meetings and conferences. **SMPTE** meetings are held quarterly. Because the engineers who attend our meetings are also deeply involved in other **SMPTE** standard-setting groups, archivists whom we have invited have a unique opportunity to effect the direction of emerging technical standards.

The first meeting of the **SMPTE UPF Study Group** to include archivists was held on December 9, 1997 at the Sony Headquarters in San Jose, California. It was attended by twenty engineers, including the chairs of other related **SMPTE** committees: Stephen Long from the **National Imagery and Mapping Agency**, chairing the **Work Group on Metadata**, and Juergen Heitmann from AV Media Technology, chairing a **Study Group on Automated Storage and Retrieval**. We were joined by Robin Dale, who shared with us some concerns of her organization, the **Research Library Group**, specifically its "Working Group on Preservation Issues of Metadata."

The members of the **RLG** are mostly involved with the migration of static still images. Because there is no standard practice for saving these images in a single file format, digital images are stored on a wide range of formats. Dale expressed the hope that a universal file format will be flexible enough to transport any kind of still image file.

Though the idea of a preservation format appealed to her organization's membership, Dale pointed out that most research librarians would resist the imposition of any given standard. Librarians, Dale said, "prefer their own methods of doing things." For example, several standards exist for cataloguing. Recommended practices are frequently being appended or replaced to accommodate new media. An initiative that is likely to win acceptance in her community will be flexible in incorporating practices already established by research libraries and archives. She added that a "best practice" framework would have greater appeal to her group than a single standard. This framework could define the types of data that might be included in a preservation file format.

The next meeting of the SMPTE Study Group was held on March 12, 1998 in Atlanta, GA at the Turner Entertainment Building. Despite the early morning meeting time, seven representatives of local archival institutions attended.

Should a digital preservation specification consist of a series of standard file formats or would a "preservation mechanism" that ensures lossless migration to new technologies better serve the archival community? While this question was discussed but not resolved, all agreed that obtaining the perspective of the archivist was crucial to developing a standard for digital storage. Some of the engineers admitted that the companies they represented needed to catch up with what the archival communities have known for decades: the realization that materials must be identified.

"There are things that this community takes for granted," said one engineer, "things that other communities have to understand." Solutions that serve the day-to-day needs of those working in video post-production may not be useful "in terms of maintaining this for years, let alone decades."

Specifically, the video data stream should contain the kind of information traditionally found in the title pages of books. This information would remain with the video from the moment it is created or recorded as a primary source, or the point at which authorship begins.

It was pointed out that because **SMPTE** lacks the expertise to define all the classes of metadata, content experts in other domains must actively define their own classes. **SMPTE** can provide standards to enable the transport of these classes of metadata in a way that will make it easier "to migrate content with metadata from one physical carrier to the next one in 15-20 years."

One conservator assured the engineers that domain-specific systems of metadata have already been developed for electronic records. "What we have not done is address the technical issues." The study group was cautioned not to accept all input collected from archival and library communities as "equally valid." Levels of experience and expertise vary, and not all spokespersons recognize the complexity of the problem. The study group pointed out that UPF activities are examined and guided by a review board, whose members are well regarded in the preservation field.

The fourth meeting of the UPF Study Group was held on June 10, 1998 at the Microsoft Headquarters in Redmond, WA, attended by a dozen archivists and 20 engineers.

For the first time we discussed how specific characteristics of the **Universal Preservation Format** might serve the mission of the archivist. Engineers asked if archivists thought digital materials should be stored in the format on which they were created or in formats that increased their chances of survival. One archivist expressed the view that it was important to preserve the "look and feel" of the original media so that future users could recreate "the context in which a particular item was intended to be experienced."

The impact of home computing on emerging storage technologies was another topic raised at this meeting. The issue is relevant to a universal preservation format because consumer needs may eventually define the boundaries between what is considered an acquisition or program format and one designed for platform-independent long-term storage. When video cameras replaced 8mm film, many families rushed to have their old 16- and 8mm home movies "preserved" on video. As equipment to digitize becomes more affordable, families are scanning their family albums and converting their home videos into digital formats in the belief that these materials are being preserved for future generations. The sad truth is that digital devices marketed for consumers may prove to be less adequate for long-term storage than the medium they are replacing. The hope was expressed that public awareness and consumer demand for better computer storage products will help archivists in their quest for more affordable and durable storage tools and devices. At the same time, one engineer emphasized, "archivists must demand that manufacturers provide tools for migration management, that make it easy to migrate from one file format to the next file format technology that may come with the next operating systems."

The most recent meeting was held on September, 1998 at the Avid headquarters in Tewksbury, MA, during which the issues outlined above were further discussed and developed.

6.4 Conferences

From the moment Dave MacCarn introduced the UPF at the 1996 annual meeting of the **Association of Moving Image Archivists,** archival and library conferences have been important vehicles for exchanging ideas and raising public awareness about UPF. To date, our team has presented the UPF at the following:

Aug. 1997	**Society of American Archivists (SAA)**: Electronic Records Section	Mary Ide
Oct. 1997	**Music Library Association,** New England Chapter	Thom Shepard
Nov. 1997	**Association of Moving Image Archivists**	Shepard, MacCarn
Feb. 1998	**Music Library Association**, National Conference	Thom Shepard
June 1998	**European Research Consortium Sixth DELOS Workshop**	Dave MacCarn
June 1998	**American Institute for Conservation 26th Annual Meeting Electronic Media Special Interest Group**	Thom Shepard
June 1998	**American Library Association ALCTS PARS ReformattingDiscussion Group**	Thom Shepard
Sept. 1988	**Museum Computer Network**	Thom Shepard
Dec. 1988	**Association of Moving Image Archivists**	Paul Messier Eddy Zwaneveld Dave MacCarn

In general, our call for collaboration between archivists and engineers in adapting existing technologies for long-term digital storage has been met with both enthusiasm and guarded optimism. Specific qualities of the UPF that audiences seem to understand and support include the **container** structure (metadata and essence stored together) and the **hybrid model** (digital materials stored with analog instructions). Other archivists have expressed their conviction that no storage system that depends upon software to retrieve its contents can ever be considered truly archival.

Coming full circle, the UPF presented its final session at the **AMIA** Conference in Miami, FL on December 9, 1998. This year, we invited speakers from outside the project to discuss how a UPF storage standard would impact upon digital preservation. Dave MacCarn presented an overview and introduced our guest speakers.

Ed Zwaneveld, director of Technical Research and Development for the **National Film Board of Canada** and chair of the **AMIA Preservation Committee,** pointed out that video recording systems were originally conceived to be "interoperable in all production and post-production phases." The trend now is toward "application-specific equipment," each of which has its own proprietary "standard." He spoke about the need for true interoperable standards that will last 50 years or more, and discussed the work of SMPTE and EBU working groups to develop such a standard. He pointed out the UPF's connection to these technical initiatives, particularly the **SMPTE/EBU Task Force for Harmonized Standards for Exchange of Program Material**, and its call for the development of wrapper technology specifically designed for archival use.

Paul Messier, founding member of the **Boston Arts Conservation** and founder of the newly formed **Electronic Media Specialty Group of the American Institute for Conservation**, focused on the role of the UPF in helping to ensure "the integrity of digital cultural materials." He reminded the audience that "a digital work is not only information, but potentially a piece of our shared material culture." He pointed out that becoming custodians of digital information is a new challenge for archivists. "We have difficulty assessing where the value of a particular digital work lies."

Both speakers contrasted UPF with migration. Zwaneveld demonstrated that playback quality can diminish dramatically as moving image material migrates from one digital format to another, while Messier pointed out that if digital materials are determined by conservators to have intrinsic value, then preservation strategies other than migration must be developed. "A migration strategy based on creating a new digital surrogate is not a preservation technique," he said, "since the new digital object was often significantly altered as compared to the original."

7. Summary

At the March 12, 1998 session of the SMPTE UPF Study Group, Juergen Heitmann (AV Media Technology, Seeheim-J, Germany) told us, "I look forward to a very short list of requirements coming out of this group." According to responses from SMPTE UPF SG meetings, our User Survey and other sources described in this document, these requirements may be itemized as follows:

- A digital preservation system should be designed to last at least 100 years.
- Archivists must be able to store their materials in a platform-independent way.
- Instructions must be provided on how to retrieve material if the software application used to create it is no longer available or accessible.
- Digital solutions purchased today must not be obsolete in the future.
- Documents stored in an archival system should be uniquely identified. Changes or versions of these documents must be identified as both separate from and related to the source document.
- Many archivists call for a central registry of identifiers.
- The only "complete" system for long-term digital preservation must incorporate both analog and digital elements.
- A table of contents for a digital storage system should be viewable without the need of special digital devices.
- A storage system should allow for input from a limitless number of sources. For example, one should be able to export from a graphics application, a word processor, or a database program seamlessly onto a long-term digital storage medium.
- Ideally, the system should allow for the various data types to "know about each other"; that is, the user could build associations among the stored objects. In a sense, the storage system itself could become a database with its own search and retrieval mechanism.
- A storage system must include an easy, perpetual, and foolproof method to determine the stability of the storage medium and the integrity of the stored contents. This test may be the equivalent of a standard test pattern.

8. Conclusion

Given the current mindset of the computer industry, which seems to regard digital equipment, storage media and file formats as disposable as paperclips, archival institutions and organizations are struggling courageously with technical obsolescence either by developing in-house tools or by adapting commercial products that are woefully inadequate.

In the early stages of this project, we sought to bring together engineers and archivists because we believed that digital technologies and products have been developed and marketed without direct input from the professionals who use them. We quickly learned that problems of communication were not limited to these two camps. Archival communities are far from reaching a consensus on digital preservation. Though much work is being done to make digital materials accessible and searchable over networks, less effort has gone into developing open standards or shared systems designed specifically for long-term digital storage.

For many years, analog archivists and librarians have grappled with the kinds of issues outlined in this paper. As Margaret Hedstrom has pointed out:

> Preservationists within the library and archival community have been instrumental in developing an array of tools and methodologies to reduce the decay of traditional materials and to restore books and documents that have deteriorated to such an extent that their longevity and usability are threatened.
> (Margaret Hedstrom, "Digital Preservation: a Time Bomb for Digital Libraries," http://www.uky.edu/~kiernan/DL/hedstrom.html)

It is time to study the past accomplishments of librarians and archivists, map their findings and continually solicit their input in the common quest to preserve digital materials. For example, along with "retro-active" solutions mentioned throughout this paper, one would be wise to study "pro-active" strategies used in the past, such as the successful effort to standardize acid-free paper.

Finally, as we advocate a specific set of standards for the long-term storage of electronically generated media, we seek to raise public awareness about the need for universal computer storage standards. The integrity of digital information is a moral issue. It affects both institutions and individuals. The day is here when many of history's primary text and visual sources -- photos, films, letters, and other documents of the human record -- are generated electronically. The authenticity of this "evidence" must be assured. As we have demonstrated, the technological foundation for a universal preservation format has existed for several years, but for any digital preservation model to succeed, we must have storage vehicles that will last at least as long as their analog counterparts. Our hope is that the Universal Preservation Format initiative will be instrumental in creating a self-described mechanism as durable as the Voyager's "long playing" record.

Part 2: Technical Requirements

1. Introduction

The Universal Preservation Format (UPF) is a storage system for electronically generated content. UPF requires a storage technology that is "self-describing." A "self-describing" storage technology is one where the structure of the storage need not be known. The structure is disclosed internally in the storage. Access to the storage system is described. Once access is obtained, all information for the retrieval of stored content is described as well as the structure of the content. This "self-description" protects against technological obsolescence.

> Note: There are two main format concepts used here. First, the physical storage format or media (e.g. a hard disk mechanism or data tape,) and second, the content storage technology (i.e. the file format in which the content is stored.) Using the example of a video tape system, these two formats are bound together within the machine. The content is encoded in some byte order or format (e.g. samples per line, bytes per sample, compressed or uncompressed.) This encoding is stored on a physical medium in a specialized order (decollated blocks of video or audio bytes.) UPF removes this bond by abstracting the encoded content (i.e. setting it free) from the recording system.

The "self-describing" storage technology uses a Wrapper concept (see below) to hold the content (defined as Metadata plus Essence.) Physically connected to the content is a description, in analog form (i.e. human readable blueprint,) of the physical format housing the storage format. This description describes the construction of a "reader" for the physical format, thereby insuring recovery of the content, even in the absence of the original recording mechanism (i.e. physical storage devise.) This requirement is key to UPF and defines UPF as a hybrid technology, one with an analog component and a digital component.

> Note: It is possible to have a subset of the UPF, one that doesn't contain the analog component. This subset is one in which the content is stored in a Wrapper on a known physical format (e.g. DLT tape.) This form would be subject to changes in the technology of the physical format (there will always be another tape or disk format). But as long as the physical format is readable (the specification of the drive mechanism, byte order, etc. is known), the content will be recoverable. This allows for an assumed less expensive storage system but with all the problems of migration. However, this form provides for a common content storage format, allowing other content formats to be merged.

2. Analog Component

The analog component of UPF would be a human readable system that describes the content stored on the physical media. It also contains the information (i.e. text, pictures, specifications) to construct a system to read the physical media in order to retrieve the content. Because the content is stored within a storage structure, the blueprints also must explain how to access the digital storage structure that contains the content. The analog system must be attached to the media to prevent loss of this information.

For example, a system like microfiche would store instructions that can be read simply with the aid of magnification. These instructions would first explain what is contained on the physical media (e.g. the title, producer, etc. of a video program) and that it is stored in a digital form in a storage structure. Then the instructions explain how to read the digital media and would describe such things as the recording mechanism (e.g. DVD-ROM, phase-change optical, DLT etc.) and include full manufacturer specifications for elements such as, transport system, heads, byte coding, etc. Additional information needed to access the content within the retrieved storage structure is also available. The combination of the analog component and the digital storage structure could be stored on a single piece of media that uses one side for the storage of the analog information and the other side for the storage of the digital information. Norsam Technologies, Inc. is developing a technology for such a combine storage system. (http://www.norsam.com/)

3. Digital Component

3.1 WRAPPER

The digital component of UPF would be a content storage technology (also known as a storage structure or Wrapper) that contains information about the content and which is stored as objects. The information in the Wrapper describes not only the location of content within the Wrapper but also all information about the content (i.e. it's type.) The Wrapper could be defined as a "self-describing" database. This Wrapper can contain any type of digital object (Essence or Metadata, e.g. text, still or moving images, sound, etc.) "The fundamental purposes of a Wrapper are (i) to gather together programme materials and related information (both by inclusion and by reference to material stored elsewhere) and (ii) to identify the pieces of information and thus facilitate the placing of information into the Wrapper, the retrieval of information from the Wrapper, and the management of transactions involving the information." (SMPTE and EBU, Task Force for Harmonized Standards for Exchange of Program Material as Bitstreams, Final Report: Analyses ands Results, July 1998. see http://www.ebu.ch/pmc_es_tf.html)

The Wrapper would be capable of describing and defining the content and its structure. This would include the type of the object and all information needed to reconstruct the object. (This information could be referred to as another type of Metadata.)

An example of an object is a Rich Text Format (RTF) file. The structure (algorithm) of a RTF file is defined as:

An RTF file has the following syntax:

<File>
'{' <header> <document> '}'
*This syntax is the standard RTF syntax; any RTF reader must be able to correctly interpret RTF written to this syntax. It is worth mentioning again that RTF readers do not have to use all control words, but they must be able to harmlessly ignore unknown (or unused) control words, and they must correctly skip over destinations marked with the * control symbol. There may, however, be RTF writers that generate RTF that does not conform to this syntax, and as such, RTF readers should be robust enough to handle some minor variations. Nonetheless, if an RTF writer generates RTF conforming to this specification, then any correct RTF reader should be able to interpret it.*

Header

The header has the following syntax:

<header>
***\rtf** <charset> **\deff**? <fonttbl> <filetbl>? <colortbl>? <stylesheet>? <revtbl>?*

RTF Version

*An entire RTF file is considered a group and must be enclosed in braces. The control word **\rtfN** must follow the opening brace. The numeric parameter **N** identifies the major version of the RTF Specification used. The RTF standard described in this Application Note, although titled as version 1.4, continues to correspond syntactically to RTF Specification Version 1. Therefore, the numeric parameter N for the **\rtf** control word should still be emitted as 1.*

Character Set

After specifying the RTF version, you must declare the character set used in this document. The control word for the character set must precede any plain text or any table control words. The RTF Specification currently supports the following character sets.

Control word
Character set
\ansi
ANSI (the default)
\mac
Apple Macintosh
\pc
IBM PC code page 437
\pca
IBM PC code page 850, used by IBM Personal System/2Æ (not implemented in version 1 of Microsoft Word for OS/2)

Font Table

*The **\fonttbl** control word introduces the font table group. Unique **\fN** control words define each font available in the document, and are used to reference that font throughout the document. This group has the following syntax:*
...

Or the another example of an object is an ITU-R 601, 4:2:2 format video. ITU-R 601 is defined as:

ITU-R BT 601 4:2:2 format:
Video Signal
3 components
Luminance Y
Chrominance Cb, Cr
differentiation for 25 Hz countries and 30Hz countries.

25 frames per second (30 frames per second), that is 50 fields/s (60 fields/s)

625 lines/frame (525 lines/frame)

for luminance: 864 samples/line (858 samples/line), that means for both cases a sampling frequency of 13.5 MHz.

for chrominance: 432 samples/line (429 samples/line), that means for both cases a sampling frequency of 6.75 MHz.

sampling structure: orthogonal.

sample coding: uniform PCM either 8 bits or 10 bits.

quantization levels (for 8 bits samples) and analogical signal:

0 and 255 only for sync.
from 1 to 254 for video.
luminance: 16 = black, 235 = white
chrominance: 128 = no chrominance

(this includes byte order, sample rate, bits per sample, etc.)

The Wrapper could also contain single or multiple objects (Essence or Metadata) of varying size. The Wrapper may point to other Wrappers, thus permitting content to be spaced over multiple storage systems. Metadata in each Wrapper would track and index the content.

[For information on the internal structure (i.e. storage technology) of Wrappers see:
Apple's Bento
(http://info.wgbh.org/upf/bento_design_overview.html),
IronDoc
(http://www.best.com/~mccusker/irondoc/irondoc.htm)
and
Microsoft's Component Object Model.
(http://www.microsoft.com/wpaper/Com_modl.asp)]

3.2 Essence

Essence is any electronically generated data that represents images, sound and text, etc. Essence types could be video, audio and data of many kinds including graphic, still image, captions, text and other data that might be needed by other stored Essence. Certain types of Essence may be treated as Metadata, such as captions, which might be included visually in a program and be used as an index to a program.

Essence may be compressed or non-compressed as dictated by the original source. It is important to note that Essence is to be stored in its native format. The structure of the Essence depends upon its encoding scheme (e.g. a TIFF file.) This scheme would be identified and defined in the Metadata.

Essence would be available by sequential or random access depending on the physical storage mechanism.

3.3 Metadata

Metadata is generally defined as data about data. Metadata would be a stored object type. This object type would have other Metadata describing its type and structure. For example, Metadata might be a MARC record. (http://lcweb.loc.gov/marc/marc.html)

A Metadata object would describe a MARC record and defined it as:

USMARC Concise Bibliographic: Leader and Directory
LEADER

A fixed field that comprises the first 24 character positions (00-23) of each record and provides information for the processing of the record.

Character Positions

00-04 - Logical record length

The computer-generated, five-character numeric string that specifies the length of the entire record. The number is right justified and each unused
position contains a zero.

05 - Record status

A one-character code that indicates the relation of the record to a file.

a - Increase in encoding level

The Encoding level (Leader/17) of the record has been changed to a higher encoding level.

c - Corrected or revised

A change other than in the Encoding level code has been made to the record.

d - Deleted

n - New

p - Increase in encoding level from prepublication

The cataloging level of a prepublication record has changed because of the availability of the published item.

06 - Type of record

A one-character code that indicates the characteristics of and defines the components of the record.

a - Language material

This code is also used for microforms of language material.

c - Printed music

This code is also used for microforms of printed music.

d - Manuscript music

This code is also used for microforms of manuscript music.

e - Printed map

This code is also used for microforms of printed maps.

f - Manuscript map

This code is also used for microforms of manuscript maps.

g - Projected medium

The described item is a motion picture, videorecording, filmstrip, slide, transparency, or material specifically designed for overhead projection.

i - Nonmusical sound recording

j - Musical sound recording

k - Two-dimensional nonprojectable graphic

This code is used for items such as activity cards, charts, collages, computer graphics, drawings, duplication masters, flash cards, paintings, photonegatives, photoprints, pictures, postcards, posters, prints, spirit masters, study prints, technical drawings, transparency masters, photomechanical reproductions, and reproductions of any of these.

m - Computer file

...

Any number of Metadata types would be accommodated. Some types might be keywords or databases, but all are required to be identified and defined.

One essential Metadata type would be a Unique Material Identifier. Unique Material Identifiers should subscribe to a single standard format and be established in a single registry. This Metadata type would also be classed as permanent. If the Essence is modified through versioning, the Unique Material Identifier would reflect the versioning.

[For a discussion of Metadata types and characteristics see SMPTE and EBU, Task Force for Harmonized Standards for Exchange of Program Material as Bitstreams, Final Report: Analyses ands Results, July 1998. http://www.ebu.ch/pmc_es_tf.html.]

Certain types of Metadata might be duplicated elsewhere, e.g. indexes, keywords and other information that is stored in a database external to UPF, which refers to Essence stored in the UPF system.

3.4 Other Object Types.

Other types of stored objects would include Application Programming Interfaces (API) to allow for the creation of any number of content management systems that would have full access to the stored content in the UPF.

4. Open Standards

The UPF would be an open standard. By it's nature UPF requires a complete "self-described" system, the technical specifications of the system would be required to be in the public domain.

5. Media Compiler

A device that might be called a "media compiler" would control the UPF. This media compiler would handle the assembling of the Essence and Metadata objects and prepare them for storage in the UPF. This preparation is required because the sources (i.e. databases, media libraries, tape machine etc.) of the objects may be varied. User interaction may be needed to select the location of the objects (e.g. they could exist somewhere on a network.)

It is desirable to make the compilation process as automated as possible. This automation would use a standard open protocol for interconnection to other automation systems, be they databases or other storage systems.

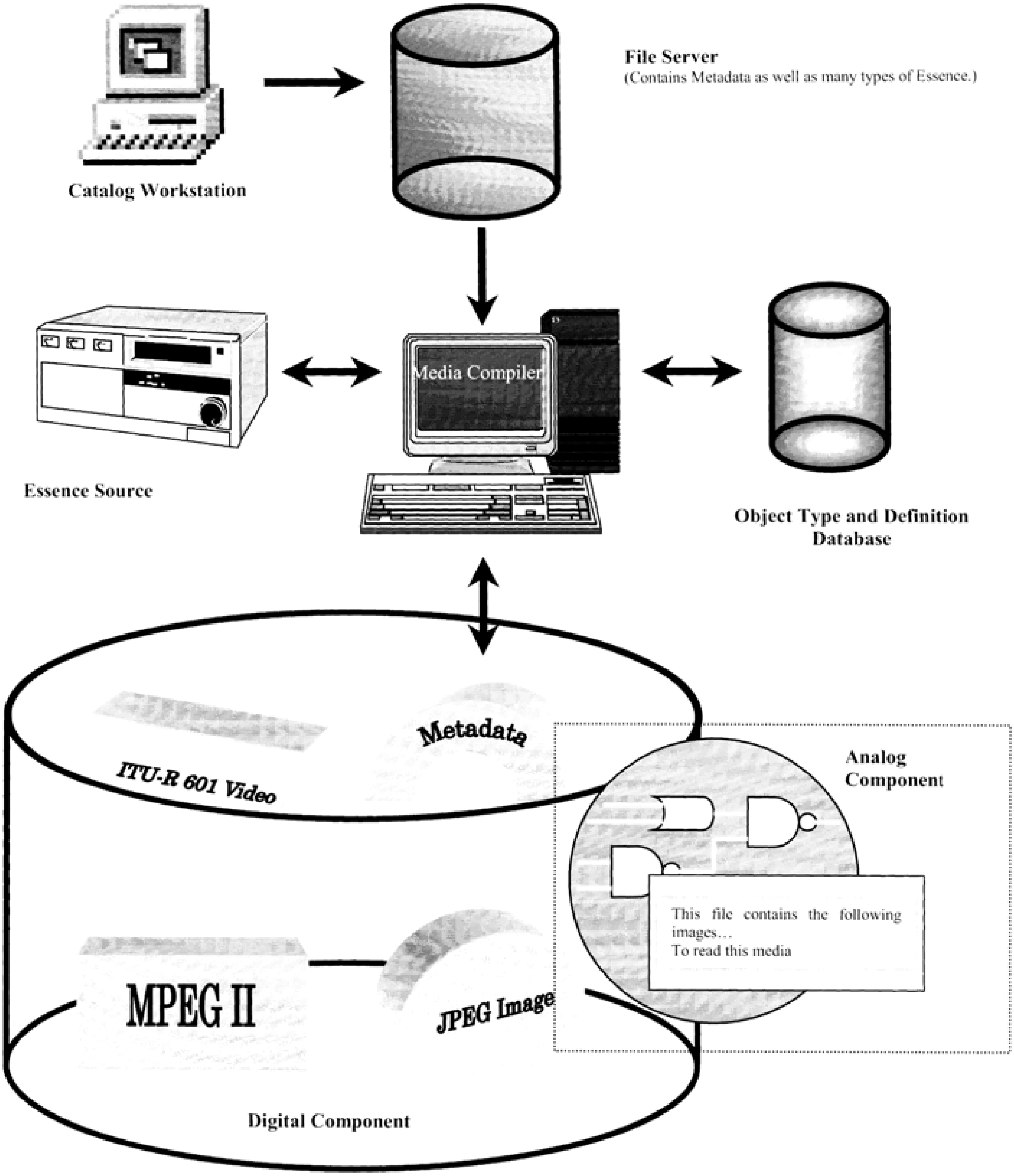
Object typing would be handled automatically where possible. The media compiler would contain a database of known object types and, as much as possible, be able to recognize the supplied objects and write the required Metadata to define and describe the objects.

The media compiler would also handle the retrieval of Essence and Metadata. Standard interfaces would be provided to export the retrieved materials to the requesting systems, be they a database for Metadata or image playback systems for Essence. In some cases it will be necessary to convert objects to contemporary or future systems. For example, videotape recorded in ITU-R 601 format and stored in the UPF might be required to playback to a D-7 videotape machine or to some as yet defined format of the future. Another example is the recovery of a bit-mapped image (BMP) and converted for a JPEG viewer.

6. Other Options and Features

Manufacturers of media compilers could define other options and features for their UPF storage systems to differentiate their products. However, the UPF could not be made proprietary.

Media Compiler and UPF Storage System



George BOSTON

There appear to be no questions for Dave MacCarn. This indicates that he was perfectly clear. Our next speaker is Jim Lindner, President of VidiPax which specialises in the restoration of audio and video material, as well as the migration of material to new formats. The company has restored over 100 000 hours of material for over 2 000 clients, ranging from the Library of Congress and the US National Archives to IBM and Coca-Cola. Jim is a member of both AMIA's and FIAT's Executive Boards. He is a former Chairman of the Anthology of Film Archives. He has written a number of articles, acts as a consultant and is a Forensic Video Expert Witness.

Toward an Immaterial Archive

Jim LINDNER
(Vidipax) - USA

During the question and answer session, I will perform a demonstration of special software using highly advanced materials. I hope that this will help you remain attentive at this late hour.

A Dreary Outlook

SYSTEM FAILURES

Over the past three days, we have heard many horror stories. We were told of film and film elements made of nitrates, acetates, polyesters, discs, cylinder, vinyl, wire and polystyrene. We were told that this material is stored in a mixed environment. In most parts of the world, air conditioning, security and fire protection are only present when one is lucky. In summary, we have learned how fragile media is. Nitrates explode while acetates end up on salad bars. Binder material either falls apart entirely or sticks together with such intensity that it must be pried apart with razor blades. All lamination de-laminates. Chemical deterioration, physical damage and natural disasters all seem to conspire. Man-made disasters, war, personal revenge (theft by unhappy employees), human imperfection (directors who lose material) and economic worries only worsen the situation. Finally, technical evolution and development only serve to confuse us.

I have still said nothing about content: no standards exist in the field of digital management. Since our search tools are primitive, a simple desire, such as viewing all of the films with Ford cars in them, becomes impossible. We still attempt to describe sounds and pictures with words. We do not know how to search for sounds and thus cannot distinguish between "ding" and "dong". We must face reality: our system is not working.

LACK OF STRATEGY

We need to develop a long-term strategy. No single media type, technology, location or format lasts forever. How long should we attempt to store data? Manufacturers would like us to aim for no more than 90 days. Meanwhile, paper documents last hundreds of years and clay tablets have remained in existence for many thousands of years. Most of us are worrying about tomorrow. Can we reformat forever? It makes no sense to do so, considering the costs involved and the fact that we are constantly developing new material. Furthermore, we have no way of knowing how much of today's data will be valuable later.

Thus far, only one solution has been support: the creation of a deep archive, set somewhere in a mountain. It will be managed by a robot, whose duty will be to ensure that reformatting takes place properly. That is convenient, but totally unrealistic. No single place can be safe for any prolonged amount of time. The US government has already spent USD 3 billion simply to design a nuclear waste storage centre in Nevada. As of 1998, it estimates that the total cost (construction of a safe holding unit, its management and its subsequent closing) will amount to USD 18 billion. Our goal is different. We want to have access to our chamber.

Yet even that seems unrealistic. How could we support the cost of reformatting forever? Who will take care of the machines in 10 000 years? New media formats already appear every five years. Is it likely that any media type will last forever? Would any manufacture want to make it? We must be willing to admit that what we have done thus far has not worked well. Let us start thinking differently. This new way of thinking will not change reality tomorrow; it will come into effect in twenty or thirty years. Marcia McCloon, one of the great thinkers in the 1960s and 1970s, stated that "the medium is the message". She was emphasising the importance of the individual experience and pointing out that it is not so much what one sees, but the way in which one sees it. Concretely, television has a greater impact than print for most people.

The Network Solution

ASSUMPTIONS

Perhaps today's medium is the network. This statement is based on a set of assumptions, most of which are beyond what we can do today or in two years. This is only to be expected. As archivists, we should not be focusing on such fleeting technologies as MPEG 420 (8 megabits). We should awaken and realise that a two-year timetable is ridiculous. The following assumptions are part of a philosophy, not a methodology. They are simply food for thought.

- **Unlimited Band-Width**
  Essentially, one can move material from one's computer as quickly as one can move it to any other place. Thus, there is no use in storing it on one's hard drive, as opposed to elsewhere. Why sort locally if we can sort somewhere else?
- **Processing Power**
  Video and film resolution are attractive in that they are based on bit maps and are thus definable. Any number is acceptable and can be used to calculate definition at a later time. Computer animation does not work the same way: a processor that is twice as fast gives rise to scenes that are four times slower to render. The

processing power necessary is that which is mandated by moving streams of data. That need can be distributed over many locations.

Let us assume that errors are unacceptable and that compression is a short-time artefact. I hope that future technicians will look back at our proceedings and wonder why we ever took this path. Today, one can buy 25 gigabytes for USD 250. Moore's Law states that, every year, storage capacity and computer processing power double while price remains the same. That has indeed happened. Why has compression even entered the picture?

ARCHIVES IN CONSTANT MOTION

We can obtain information as quickly as possible. Why keep it locally? The Internet is a network over which we move information from one place to another. I feel that we should move beyond this idea. SETE At Home (the Search for Extra Terrestrials), a phenomenal product, is capitalising on the Internet's characteristics. SETE's designers had access to a radio telescope that captures information from everywhere. However, they needed computing power to make their system work. As a small, impoverished group, they knew they would never obtain grants. Thus, they decided to call upon the world's network of computers. They convinced their members to replace their screen savers with material that performs calculations for SETE and attack this monolithic problem. In just over one year, 100 000 years of computer time processing have already been accomplished. In the US, 600 000 users have joined in, as have users in 224 other countries.

Could this be applied to the archival problem? Could an archive move from being a storage centre to being the actual information that is stored within the network? Information will be in constant movement, bouncing between computers or "mirrors". It will be divided into many sets of redundant streams, thereby making it impossible to "lose" any data. Moreover, since the information will be moved in smaller units, it will be able to move more quickly. In other words, we will create a clog of information on the Internet. Although the system currently cannot handle such dense units, we will be able to change it. Once it is split, the information will be able to bounce back and forth between hundreds of mirrors. The controlling unit, or "demon", will be a traffic policeman with memory. Its duty will be to keep track of the streams and to move them to locations of less cost, higher quality and easier retrieval.

The process does not necessarily have to be serial; it can also be parallel. One of the major obstacles to this system lies in the fact that the speed of light, at which information is projected off of the radio telescopes, is far too fast. In order to slow down the process, information could be bounced off of a planet. The information is redundant and protected and faces no problems. We can also slow information by performing quality control on it. We might stagger their arrival on the network, creating a temporal delay in the system. In the end, the data will always return.

Conclusion

Media does not last forever. None of the scenarios mentioned thus far could support preservation over a long period of time. Given the rate at which we are generating content, this material will be too cumbersome to store even if we wished to do so. A deep-cave approach raises far more questions than it can answer. We need a medium that survives for a long period of time.

Discussion

Sean DAVIES

This system, in which everything is everywhere, is full of implications. It may take longer for archivists to understand this system than to wear out their current media. The archival attitude consists of saying "look at what we have". You are suggesting that we share our assets with almost everyone. That will be difficult to accept. I see that philosophical barrier as being more significant than the technical barrier.

Jim LINDNER

Naturally, all of the information could and should be encrypted. If a given archive receives one stream, it will have at most one-eighth of the total information.
I have faith in archivists. They are dealing with the conflict between intellectual control and physical control and are doing so quite well. We deal with non-physical material on a daily basis: telephones and ATMs are examples of how much technology has integrated our lives. Provided we can engineer a system that works, I believe that we can convince people to use it. The absence of material assets will be accepted.

Ian GILMOUR

I like your idea. The idea of throwing information is somewhere between the principle of the cell phone and that of datacasting. The load would be removed from archives.

From the floor

What is the storage capacity of such a system? Delay lines are already in use. That is how we know that the distance to the sun can be traveled in 8.5 minutes. Perhaps the round trip would take 30 minutes. The rate at which the information travels would be rather slow.

Jim LINDNER

There is no problem with engineering. We are sitting in information.

From the floor (the same speaker)

I will not enter the psychological problem raised by Sean. I would simply like to know how much storage capacity will be offered to those who make the heavy investments needed to encrypt and develop protocols. The capacity is potentially infinite. However, I would like a precise estimate. The idea itself is beautiful in that it is based on the stability and resistance of holographics. Some figures would convince many people.

Jim LINDNER

I fully agree and hope that a doctoral candidate is present and would like to take up this question. From a philosophical point of view, I can imagine a number of possible methods. You may find ways in the upcoming days. Supposing I covered the left and right walls of this room with laser beam transmitters and receivers, millions of laser beams would fill the room. Information could start at location 0.1 to 0.1, then move on to 1.1, 2.1, 3.1, etc. to create a delay line.

From the floor

You would end up with three seconds per million kilometres of delay line. Please provide us with some calculations.

Sean DAVIES

A delay line is effectively information flying around and alighting no where. In contrast, SETE is information that resides in a computer for a certain period of time. The latter's capacity is thus infinite. Your objective will be to attract as many new users as SETE has managed to do. How will you go about this? How will you distribute the same information between different people in order to safeguard against all potential loss of information?

Jim LINDNER

Your question is twofold. Co-operation is an easy issue to handle: we will pay. Who could refuse USD 10 per month? People will allow us to send them information and have that information sent elsewhere while they are not using their computers. As soon as they touch their computers, the loading will stop. Eventually, as people offer their computers' free time for lower sums, the service will become a commodity. The cost of storage will be whatever the market will bear.
As regards the information split, all of the data will be backed up many times and operate on the principle of redundancy.

Delegate from the Finnish Broadcasting Company

The copyright implications of the system are enormous. Courts have determined that sound samples of a recording are protected. What will happen if bits that are under copyright are put in a million places? Will we charge royalties every time they are moved?

Jim LINDNER

Once again, all of the information will be encrypted and will be as protected as if it were on your hard drive. As a forensics expert, I know that there is often a wide gap between what the courts say and what actually occurs. I am sure the legal system will need time to address these problems.

Conclusions générales du 5ème JTS

Michelle AUBERT

Nous arrivons au terme de ce 5ème JTS. Nous avons demandé à George Boston qui a participé à de nombreux JTS et qui en a co-organisé plusieurs de conclure cette manifestation.
Avant de laisser la parole à George Boston, je voudrais adresser des remerciements. Au début de cette manifestation, Jean-Pierre Hoss a remercié toutes les organisations officielles qui ont participé à ce JTS. Pour ma part, je souhaiterais remercier les personnes qui nous ont apporté leur aide dans l'organisation de cette manifestation. Merci tout d'abord au comité éditorial qui a sélectionné avec une grande pertinence les intervenants de ces trois jours. Ce comité éditorial s'est réuni pendant plus d'un an. Il était composé d'Isabelle Giannattasio, d'Elizabeth Giuliani, de Joëlle Garcia pour la Bibliothèque nationale, de Jean-Marc Fontaine pour le CNRS Bibliothèque nationale, de Dietrich Schüller pour le Phonogram Archiv à Vienne, de Denis Frambourt pour l'INA, de Bernard Lavédrine pour le CRCDG et de Richard Billeaud, conseiller. Je voudrais également remercier Monette Guyard et Magda Wassef de l'IMA qui nous ont soutenu pendant plusieurs mois et qui ont mis à notre disposition cette salle et l'auditorium. Mes remerciements vont aussi à l'équipe technique de l'IMA qui nous a aidé pendant ces trois jours ainsi qu'à l'équipe de la CST. Merci à Sybille Monod de l'ARSAG, à l'équipe des Archives du film et de l'ECPA qui nous ont aidé, à Eric Régis, Nicolas Ricordel, Feridoun Mahboubi, Daron Manuelyan, Corine Lasselin, Jocelyne Cartier-Sterin, Muriel Lecarpentier, Daniel Sandoval et enfin Richard Billeaud à qui revient l'organisation et la logistique de cette manifestation. Enfin, je remercie et félicite les traductrices qui ont fait un travail extraordinaire. Merci à vous tous pour votre participation. J'espère que, pour vous, ces trois jours ont été intéressants et enrichissants.

George BOSTON

I have been asked to look at this event, at past JTS' and future meetings and draw some conclusions. As is often the case in archival matters, I feel somewhat «under-resourced». I am reminded of Charles Dickens' work, A Christmas Carol, in which he uses three ghosts to describe the past, the present and the future. Today, you only have me.

The JTS' are a wonderful meeting place for archive technicians and others interested in archive technologies. The problems that we face are common around the world. When we meet people from other countries who share the same problems, we are reassured since we realise that we have done nothing intrinsically wrong. In that sense, events such as these boost our morale. This particular conference has shown that we aim for permanence of information. In so doing, we must also realise that we are ephemeral. We are the temporary item in this work.
I have now attended four Joint Technical Symposia; I missed the first event, which involved only the moving image Archive Associations - FIAF and FIAT. However, I have read the papers from the Stockholm Conference and would describe it as the last of the Golden Age. Although there were underlying problems regarding the ability to play certain types of material, there were no major worries. They could see that stability had been achieved; no major changes were foreseen. As long as we keep historical material in our vaults, we will be faced with the challenge of being able to play it, even if we have made copies on digital formats or in computer storage. We do not intend to discard the original as long as it is accessible; we never know what future technology will offer.
The «Big Crash» came in 1987, in Berlin. It came in the form of the Vinegar Syndrome. The film world has been abuzz with the problem since that time. The video world was also set afire. It had become used to the two-inch quad format and had to deal with its phasing out. Indeed, for the first time they had to face the problem of format obsolescence. The audio world had already seen the start of the digital revolution (CDs, etc.) and wanted to understand how to use digital technologies.

In 1990 (Ottawa), we were still discussing the same issues: the Vinegar Syndrome, the obsolescence of formats and the implications of digital media. Another issue also appeared: the eternal archive. Instead of preserving the carrier, we wanted to concentrate more on the preservation of the information. At the end of the conference, Bill Storm and David Wickstrom gave their thoughts on how computer techniques could be used to achieve this. Many thought this was science fiction. Today, it is reality. It was also becoming obvious that digitisation was the future.

In 1995, in London, we were still concerned about the new technologies and about our direction. The concept of digitisation had nonetheless been sold to the worlds of video and sound and was slowly being sold to the film world. For the first time, even the most demanding producers expressed their acceptance of the new systems. There was general agreement as to the potential of digital techniques and computer-based technologies. Nonetheless, cost remained a major issue, as were the practicalities of the system. Today, the solutions to those problems appear to have been found.
In Paris, today, we are still working to keep our current material playable. There is no question of giving up

that task; we cannot afford to do so. We have too much work ahead to transfer all of our present material elsewhere. We must work to maintain the material as long as possible, provided the cost and effort required are reasonable. I would not suggest that we put «heroic» efforts into protecting every last disc, tape or film. We can stretch life, but cannot prevent death. In that sense, we are dealing with very human artefacts.

In this conference, it was interesting to see that non-technical matters were also mentioned. We have touched upon problems such as cataloguing, documentation, selection of material (given that storage of everything is impossible) and, finally, the major issue of copyright. That being said, if approached properly, copyright will not pose as significant a problem as we may think. Those who own the rights are not interested in stopping us from gaining access to the material; they are interested in receiving payment. If they can do so reliably and easily, we will not have any problems with copyright. The most difficult aspect will be bringing those people together and reaching an agreement.

We can also see that the sun is beginning to rise again. A new Golden Age may be upon us. Mass-storage systems enable us to move away from constantly worrying about the cost of copying and checking. Those tasks can be left to machines that work 24 hours a day.

Our industry is growing more stable. In 1983, we thought we were in a stable situation. Nearly 20 years later, that may finally be true. As our position stabilises, our place within the world of broadcasting is changing. We are no longer at the end of the line. Archives will be at the heart of programme generation. The production studio, the editing room and the transmission suite will become the peripherals. We are the heart. We will see a major change in the way people think about us.

I think that there may not be any more Joint Technical Symposiums. We will surely meet again, but will hold less technical discussions. Training, copyright and documentation are just a few of the new topics that are rightly entering our joint discussions. When these conferences were first launched, their goal was to bring together users of tape - video and audio - and film to share their technical research. The same principle will apply to people interested in training, documentation etc., especially as we develop common storage platforms.

In recent years, I have been involved with UNESCO's Memory of the World programme. It aims to consider the problems of conserving, preserving and making accessible any material that can be placed on a library shelf. In my work for the Programme, I learned much about the print world. The textual world is riddled with problems that are much more serious than even the Vinegar Syndrome. The breakdown of the paper polymer under the influence of acids has reached amazing dimensions. The British Library, the Bibliothèque nationale de France and the US Library of Congress are struggling against these issues, which we must recognise as being huge in comparison to ours.

UNESCO is trying to draw the various areas that form part of what is now called «information technology» closer together with the aim of «achieving the democratisation of access to information». This typically bureaucratic phrase means giving everyone the right to get hold of information. Digital techniques are the obvious solution: information needs to be stored on digital media and stored in mass-storage systems connected to networks. Once digitised and stored, the difference between video, audio and sound become meaningless. The computer sees them as identical - as binary data. This will have a major effect on the existing archive federations: we will work closer and closer together, until we finally merge. This is another reason why we may not have future JTS: we will all be one organisation.

A few years ago, much of what we now take for granted were dreams. As I stated earlier, ideas expressed by some of our members in 1990 were considered science fiction. Those dreams are now reality. I would suggest that we should keep dreaming. As Jim Lindner said, we must look beyond the next couple of years if we are to establish true long-term goals. Without that long distance view, it is very difficult to plot the path forward. The short-term is only a series of zig-zags. I do not know how the long term will be realised; that will be left to my grandchildren. I will do my duty now, as my father, also a sound technician, did before me. The machines he built and the work he left behind are at the National Sound Archive. My work is in the BBC collections. I do not know what my son will build, nor do I know what my grandchildren will do. That is the beauty of our world. We are like gardeners. We plan for 200 years' time and hope that what we plan is beautiful when it is finished.

Michelle AUBERT

Je me permets de vous rappeler que le site web du JTS va rester ouvert encore plusieurs mois. Nous espérons avoir vos contributions pour les références bibliographiques de sites techniques que vous avez signalés. Les actes de ce symposium seront édités très bientôt, sur papier et peut-être sur CD-ROM. Merci à tous.

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Manifestation scientifique et technique qui s'est tenue pour la première fois à Stockholm en 1983, puis à Berlin en 1987, à Ottawa en 1990 et à Londres en 1995, le JTS rassemble, à l'initiative et avec le soutien de l'UNESCO, les trois organisations internationales audiovisuelles qui ont pour responsabilité première de conserver et restaurer les collections originales dans les domaines de l'image animée et du son : la Fédération Internationale des Archives du Film (FIAF), la Fédération Internationale des Archives de Télévision (FIAT), et l'Association Internationale des Archives Sonores et Audiovisuelles (IASA), ainsi que les sous-comités audiovisuels de l'ICA (International Council of Archives) et de l'IFLA (International Federation of Library Associations and institutions).

Plate-forme d'échange de recherches scientifiques et d'expériences pratiques pour apporter à tous des voies de réflexion et de prise de décision, le 5ème Symposium JTS Paris 2000 a été organisé par le CNC (Centre National de la Cinématographie) avec le concours de la CST (Commission Supérieure Technique de l'Image et du Son), et la collaboration de l'INA (Institut National de l'Audiovisuel) et de la BnF (Bibliothèque nationale de France).

En prenant pour thème :
"Archiver et communiquer l'image et le son : les enjeux du 3ème millénaire"
le JTS Paris 2000 a voulu mettre en lumière les implications et les évolutions que les nouveaux environnements numériques et de l'Internet introduisent dans les activités et les stratégies de l'archivage des images et des sons.

Le JTS Paris 2000 a présenté 30 conférences et 8 présentations par affiches réparties en trois chapitres qui correspondent aux principaux enjeux du présent et du futur :

- l'appréciation des risques dans la conservation des images et des sons
- le transfert et la restauration des originaux images et sons
- les systèmes de gestion de l'information et les stratégies de migration.

Scientific and technical event that was organised for the first time in Stockholm in 1983, then in Berlin (1987), Ottawa (1990) and London (1995), the JTS gathers, at the initiative and with the support of UNESCO, the three international organisations implied in the preservation and restoration of original image and sound materials : Fédération Internationale des Archives de Film (FIAF), International Federation of Television Archives (FIAT/IFTVA), International Association of Sound Archives (IASA), and the audiovisual sub committees of ICA (International Council of Archives) and of IFLA (International Federation of Library Associations and institutions).

It is a platform for specialists of audio-visual, cinema and sound archives to share scientific and technical researches as well as practical experiences, in order to provide guidelines for action for curators, technicians, researchers...
The 5th JTS Paris 2000 has been organised by CNC (Centre National de la Cinématographie) assisted by CST (Commission Supérieure Technique de l'Image et du Son), with the collaboration of INA (Institut National de l'Audiovisuel) and BnF (Bibliothèque nationale de France), and in association with institutions such as AMIA (Association of Moving Image Archivists), the ARCHIMEDIA network, ARSAG (Association pour la Recherche Scientifique sur les Arts Graphiques), BKSTS (British Kinematograph, Sound and Television Society), and the GAMMA group.

The subject of the JTS Paris 2000 "Image and Sound Archiving and Access : the challenges of the 3rd Millennium" clearly focussed on the implications and the evolutions introduced by the new digital and Internet environments for the preservation of moving images and sounds activities and strategies.

The JTS Paris 2000 presented 30 papers and 8 posters organised in three chapters corresponding to the main present and future challenges :

- *Risk assessment in the preservation of image and sound materials*
- *Transfer and restoration of original image and sound*
- *Data management systems and migration strategies.*

Les traductions en français et en anglais des conférences existent sur la version CD-ROM des Actes.
The French and English translations of the papers are on the CD-ROM version of the Proceedings.

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