PRESERVATION OF AUDIO RECORDING CARRIERS

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The preservation of audio recordings implies that of carriers. A general panorama of this problem is presented, bringing out the principal points which have to be studied and a sketch of storage conditions. This paper is essentially devoted to carriers, nevertheless it should not minimize the importance of access systems, particularly the question relative to recording formats.

Keywords : Compact Disc - Lifetime - LP Record - Magnetic Tape - Preservation - Sound Recording - Storage

1. TYPOLOGY OF SOUND RECORDING CARRIERS

A general presentation of sound carriers that can be found in important collections shows two recording processes : the analog one and the digital one. In the following table, we can observe that only magnetic recording is used in both modes. Some carriers are reserved to professional uses, These documents may be assigned to large patrimonial collections : in this case, they are mentioned "Studio", as can be seen in the table.

The table above, which is not exhaustive, shows the very large diversity of carriers and suggests the multiplicity of recording formats. It makes evident one of the most important difficulties in the technical management of huge collections.

Mode / Principle	Analog	Digital
Mechanical	Wax Cylinders Acoustical Discs Electrical Discs Long Playing Discs	
Magnetic	Magnetic Wire _ inch Tape Minicassette *Studio* _ -1-2 inches Tapes	PCM F1 *Studio* PCM 1610-1630 *Studio* DASH and ProDigi *Studio* Nagra D R-DAT DCC
Optical		CD-A (12 and 8 cm) CD-R Mini Disc Pre recorded
Magneto-optical		*Studio* D-9000 mastering Mini Disc Re-writable

2. CARRIERS' DEGRADATION AND MEANS OF CONTROL

We have to face problems linked first to initial characteristics of the material employed, secondly to their physico-chemical ageing, generated or accelerated by factors from diverse origins. We have to identify the element or the combination of elements presenting major risks for carriers.

We can quote for instance :

- wax cylinders : mould, oxidation, breaking.
- Magnetic wire : rupture.
- Shellac discs : breaking, wear generated by stylus rubbing.
- "Acetate" or direct cut discs : chemical and physical varnish degradation on metal core.
- Long-play or vinyl discs : scratches, wear generated by stylus rubbing.
- Acetate tape : breaking, binder stick, polyurethane binder deterioration.
- Analogical polyester tape : deformation, binder deterioration.
- Digital polyester tape : deformation, chemical instability of certain metal particles.
- CD-A : varnish oxidation.
- CD-R : possible instability (not yet precisely stated) of certain thermosensitive layers,

The knowledge of carriers chemical and physical characteristics, of their behaviour in nominal storage and use conditions, is essential. It orientates our action in collaboration with specialized laboratories, more particularly in the topics of organical chemistry.

2.1. Agressive external factors

- temperature and humidity.
- Urban and industrial pollutant agents.
- Dust (inert or charged with contaminating agents).
- Micro organisms.
- Magnetic fields in case of magnetic and magneto-optical carriers.
- Fire.
- Flood.
- Man (risks caused by handling, ...).
- Player systems : for example temperature conditions, mechanical stress of tapes due to certain magnetophons).
- Transportation (vibrations, thermal and hygroscopic shocks, ...).

- etc.

We did not quote time : actually, it is an implicit but permanent factor linked to the above mentioned ones which can moreover be submitted to cycle variations.

2.2. Consequences of carriers' degradation on recording

Before being submitted to any kind of degradation, the state of a recording depends on the conditions in which it has been realized. The first difficulty consists in identifying the **origin** of the observed sound defects.

First example : long playing discs

Sound Recording → Mixing → Master Tape → Cutting (...) → Stamper → Moulding → → Packaging.

Second example : compact discs

Sound Recording → Mixing → Digital Master Tape or Magneto-Optical Master Disc → → Laser cutting (...) → Stamper → Pressing → Aluminium coating → Lacquer → → Protective layer → Printing → Packaging.

This very concise recall of the different manufacturing stages of discs brings out the considerable number of operations which concern as well sound as material. In spite of the numerous controls and the care given to each stage of these processes, defects can appear which are integrated into carriers.

Any degradation of the carrier leads to an information deterioration. This can be very simple (for example a perceptive click coming from a scratch on a LP), or very complex, bringing unpredictable consequences (the acoustical effects produced by a scratch on a CD-A will depend on its shape, its orientation, the efficiency of the error rate treatment, the player servomechanisms, ...). The correlation between information and carrier is taken as a whole in order to determine the cause of loss of information and take the most suitable preservation, and eventually restoration measures

2.3. Diagnosis Elements

2.3.1. Appearence faults

A visual observation remains the major way of controlling the state of carriers and of their containers. It may help to detect possible physical degradations, contamination, etc. The part played by the staff who is directly in contact with collections is major as regards observation and detection of visual defaults on media carriers, magnetic tapes and optical discs. Some protecting boxes or cartridges, although being an effective protection, are an obstacle to the visual observation of defaults. That is why other means are necessary, especially concerning digital recording for which automatic analysis is well-suited.

2.3.2. Physico-chemical analysis

Physico-chemical analyses and studies allow to interpret the degradations that have been visually or auditorily observed and to remedy, reduce, prevent them in the future. Being meant for very diversified products, these analyses must be practised only by highly specialized laboratories, equipped with important analytical means and making use of multiple techniques. The eventual absence of description (the old formula having disappeared, or the recent ones being missing because of the trade secret) generates great difficulties regarding the technical management of the stocks.

Such analyses might be considered of a high cost, but actually the precise knowledge of how to preserve and restore discs allows significant savings. For instance, climate conditions will be chosen according to the concerned kind of products. Preservation in wrong climate conditions could bring about unjustified expenses. New carrier preservation rules must not necessarily follow the ancient ones, but must be adapted to each kind of documents.

2.3.3. Acoustical diagnosis of analogical recordings

In the case of analogical recordings, the global sound information including the "useful signal" mixed with a set of defaults called "harmful signals" is examined. The ear remains (who would complain about it ?) the most effective means to distinguish the two kinds of information, but also the most debated one because it depends on the listener auditory system, on its expectations, on the cultural and psychological listening context. Technical solutions are extremely complex owing to the multiple sound shapes, to the nature of messages (speech, music, sound items). Added to these are another infinity, that of the different degradation modes of sound messages, the consequences of which vary according to each type of recording, each sound identity, the time when the defaults intervene during the sound event. Answers depend on the knowledge in pluridisciplinary fields which have to be shynthetized. As for us, the studies concerning the pathology of sound recording has been oriented towards the following fields :

- identification of perturbations provoqued by carriers;
- development of tools for acoustical analyses (for example spectrographic imagery), thus helping the comprehension of information modes' destruction and, hence, allowing to find a remedy ;
- development of signal data processing, or restoration of degraded messages.

2.3.4. Parametric diagnosis of digital recording

Digital recording of sound events is also concerned by the precedent (above) observations, but consequences are totally different from those of analogical recording. In the case of analogical recording, defaults observed on signal are generally proportional to those observed on carriers. But concerning digital recording, things are quite different. If a default generating a loss of information (error) is corrected by the player, no perturbation can be heard; but if a failure on a CD-A or a DAT is such that the correcting process is overload, information will be suddenly and completely lost. Digital recording is more comfortable (comforting, safe, reliable) but somewhat manichean !

Some players can store all the correcting operations, organize and set them out (display, reveal). Moreover, this simple and particularly efficient non destructive system allows to detect the eventual presence of uncor-

rected defaults which could compromise (alter, disturb) the reading of the following recorded information. They represent thus a precious means, but unfortunately rather expensive, of measuring the initial quality of digital carriers (recorded information) and then following their evolution. Other types of apparatus, still more performing and working like real analyzers, can accede to a great number of parameters, thus allowing to find out the origin of failures. But this last procedure regards more research than routine control operations.

However, when defaults have been detected, we must recognize that we have practically few means to have a direct action on documents. We could think of direct cleaning or polishing operations in order to eliminate certain types of scratching. But the most effective action is to transfer information (in time !) onto another carrier.

3. MODELIZATION OF CARRIER LIFETIME

Some degradation phenomena are instantaneous i.e. accidental. Besides these accidental circumstances, which should be avoided, it is necessary to be able to anticipate the lifetime of the different kinds of carriers due to their long-term storage conditions. Gradually, models are developing, allowing degradation simulations, but on what principles are they based ?

3.1. An experimental approach

It consists in observing the behaviour of carrier samples in more or less severe agressive conditions, so as to deduct the time which would be necessary to obtain similar effects in nominal storage conditions. Samples are submitted to one or several combined factors (stimuli), then, at regular periods, consequences are examined through one or more indicators chosen in relation with their relevance and sensibility. Such a study gives interesting information concerning the gloval behaviour, but it can lead to completely wrong results as long as the basic evolution is not interpreted, thus understood. The material used is always complex: loading components (black discs), different multilayers polymeres, films metal (CD) or powder metal (magnetic tape), additives, ... According to the gravity degree of the applied stress, different processes of evolution can start. But global observations can mislead to wrong lifetime estimation when extrapoling in nominal conditions. Such test methods should be applied most carefully when exploiting the results.

3.2. A fundamental approach

It is meant to describe and understand the fundamental working mechanisms. The theoretical interpretation of certain phenomena linked to ageing has been successfully realized, for example, concerning magnetic tapes, print through effect (H.N. Bertram), polyurethane binder hydrolisis (E.F. Cuddihy, then N.S. Allen and M. Edge). Adjustment to mathematical ageing patterns can then be elaborated on theoretical bases. Reliable extrapolations, hence anticipations, can thus be established.

To this end, we are working with University of Clermont-Ferrand (CNEP Laboratory), particularly concerning moulded CD-A, CD-ROM and once recordable compact disc (CD-R).

Moulded CDs have been the subject matter of some researches in order to determine the most unstable element as regards natural ageing. An analysis of ageing varnish (protecting layer on the back face) shows the earlier chemical evolutions (J. Lemaire, CNEP). In the same time, the error rate (BLER) evolution, which is the most important parameter and very easy to measure, has been studied in order to determine the quality of the information quality written on the carrier. The relation between varnish deterioration and error rate increase has not yet been deeply explained, but the following assumption can be seriously considered :

Varnish deterioration → penetration of oxygen and damp as far as the metal film → metal oxidation → loss of metal film reflective properties → error increasing.

4. SOME RESULTS : STORAGE CONDITIONS

A synthesis of the gathered information allowed to draw up a summary table of sound documents storage conditions. It can be noticed, among these factors, the absence of pollutant agents (urban and industrial) for which we have not yet enough data.

5. ACCESS SYSTEMS

Sound recording cannot exist without a system, i.e. without a device to provide the transformations necessary on one hand to fix information onto a carrier, on the second hand to diffuse it. These systems (apparatus, devices) can be extremely simple (phonographs) or very complex (CD, R-DAT, ...). They all include the temporal unfolding of sound phenomena and the local modification of the material state, in order to "hold back" information, either permanently (material deformation) or temporarily (reversibility of the magnetic state). The problem of access to information is as ancient as the invention of phonographs. The dimensional comptability between formats was already a difficulty for ancient wax cylinders. Then, a consensus had given the "standard" model.

The growing complexity of systems makes apparatus restoration, or even reconstruction, more and more difficult. Thus, more and more collections become illegible from a lack of playing means. Digitization increases dramatically this kind of difficulty in using many components such as processors, convertors and other integrated circuits which include specific data and digital processing software.

We do not benefit by studies concerning lifetime access systems compared to those concerning carriers. Moreover, we have to take into account the hazards of the commercial lifetime of products, which becomes shorter and shorter... We understand that "de-marketting" has to be surrounded with discretion, that is why we must be very vigilant regarding the destiny of the access systems corresponding to our carriers.

Factors	Tempe-rature	Humi-dity	Climate Varia-tions	Dust	Magne-tic Fields	Fire	Miscel-laneous
Conditions	**18° C**	**40% RH**	**± 2°C ± 5% RH**	**< Class 100 000**	**<400A/m**	**detection extinction**	
Cylinders	**X**	**X**				**X**	**X** chocks
Shellac Discs						**X**	**X** chocks
Direct Cut Discs			**X** critical			**X** varnish	
Long Play Records						**X** critical	
Acetate Magnetic Tapes	**X** critical	**X** critical	**X**		**X**	**X**	
Polyester Magnetic Tapes	**X**	**X**	**X**	**X**	**X**	**X**	
Digital & Video Cassettes	**X**	**X**	**X**	**X** critical	**X**	**X**	
Pre recorded Optical Discs				**X**		**X**	
Optical Discs WORM (CD-R)						**X**	**X** light

Not determinative **X** *To be carefully considered* **X**critical *To be taken into very high consideration*

Standards proliferation

As regards stability, audio compact discs constitute a happy exception among the tremendous number of propositions for digital recording systems. In 1982, they appeared as very high quality products. Due to their sound quality and their error rate efficiency, for some years they have been attacked for purposes that are more commercial than technical (mini-discs, DCC). However, the improvements concerning digital images and data transportation will have considerable effects on digital codage and sound carrier technology. The present information about high density CDs has to be seriously taken into account. On an other hand, magnetic recording must not be neglected for storing very large quantities of digital audio and video data.

Anyway, technological mutation rhythms of digital recording are so fast that it is no longer possible to imagine the lifetime of a patrimonial collection without managing in anticipating future transfers to insure long-term preservation and access to recordings.