ILKAR: Integrated Solutions for Preservation, Archiving and Conservation of Endangered Magnetic Tapes and Cylinders[1]

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1. Introduction

Research and technology for the archiving and conservation of sound carriers often focuses on the needs and possibilities of big audiovisual archives, for instance, on public broadcasting companies. The solutions developed in this context are only partially applicable for research archives, mainly due to the more heterogeneous nature of research collections which require highly specialized answers. As recent studies have shown (Klijn & de Lusenet, January 2008), research archives around the world together dispose of a huge amount of audio and video recordings on magnetic tape. Often the material is highly significant, either as research material in an academic context or as cultural heritage with relevance to a broad public. Since audiovisual recordings are stored on relatively unstable material, digitization and continued copying of the digital files is necessary to ensure the long-time survival of the recordings (Schüller, 2005, Bradley, 2009, p. 6). Currently, most archives are at some stage of the process of digitizing their holdings to ensure long-term preservation of the collections, but digitization brings costs additional to everyday routines and therefore often proceeds slowly (Fuhrhop, Mengel, & Heinen, February 2007). Presently, very few archives are financially, technologically and personally equipped to handle this extra task professionally.

Today, reliable estimates of the life expectancy of phonographic cylinders and magnetic tape are not available. Most estimates agree that institutions have only a small window of time in which to complete high-quality digitization of reel tapes, depending on storage conditions, the storage media and other factors (Hess, 2008). In view of the rapidly-progressing degradation of sound carriers, many research archives are confronted with an existential challenge. Without huge increases in the speed and productivity of digitization, many archives will not be able to digitize their complete holdings before the information can no longer be retrieved. This is the starting point for the ILKAR project, which puts its main focus on the development of criteria, technologies and methods which will enable a more efficient use of the available timeframe. In order to achieve this objective, ILKAR focuses on three main targets:

- Improvement of methods to identify and treat especially endangered cylinders and tapes;
- Improvement of methods to retard the decay process of storage media; and
- Integration of these developments into the workflows of audiovisual research collections.

The project deals exclusively with two types of storage media: cylinders and magnetic tapes. Wax cylinders are comparatively rare today, being a relatively little-known medium from the early days of recording technology. Small collections of wax cylinders can, however, be found in a fair number of libraries or smaller archives. Nevertheless, these institutions rarely

[1] The project acronym is derived from the German name of the project: "Integrierte Lösungen zur Konservierung, Archivierung und Restaurierung gefährdeter Magnetbänder und Wachswalzen". The ILKAR project is carried out by two institutions of the National Museums in Berlin: the Rathgen Research Laboratory and the Department for Ethnomusicology, Media Technology and the Berlin Phonogramm-Archiv at the Ethnological Museum. The project is funded by the German Federal Cultural Foundation through the KUR Programme to Preserve and Conserve Mobile Cultural Assets. ILKAR runs from May 2008 to August 2011. For more information see http://www.ilkar.de.

have sufficient expertise, equipment and funding to deal with conservation, preservation and digitization of such collections. ILKAR plans on making information available to fill this gap.

Today, magnetic tapes in different forms and formats (cassette or open reel, analog or digital, audio or video) make up by far the biggest part of most audiovisual collections in research archives. The decay process of magnetic tape depends on a complex set of factors (storage conditions, tape type, age, etc.) and is generally not well understood (Thiebaut Benoît, Vilmont, & Lavedrine, 2006). ILKAR attempts to improve existing risk assessment strategies such as those developed in the Sound Directions project[2].

2. Roles of Project Partners

The Rathgen Research Laboratory

First founded by Friedrich Rathgen (1862-1942) in 1888, the Rathgen Research Laboratory carries forward the tradition of the world's first scientific museum laboratory. Since then, it has refined its expertise in the preservation and conservation of movable and immovable cultural heritage, contributing to international institutions and organizations such as the International Council on Monuments and Sites (ICOMOS), the International Council of Museums – Committee for Conservation (ICOM-CC) and the International Centre for the Study and Preservation of Cultural Property (ICCROM). It carries out investigations on a broad variety of materials within the museum environment and focuses its research on scientific issues concerning the care of monuments and archaeological sites.

Among other analytical techniques, the laboratory is equipped with infrared spectroscopy (FT-IR), Pyrolysis-Gas Chromatography (Py-GC/MS), optical and scanning electron microscopy (ESEM/EDS), as well as further methods for the determination of physico-mechanical parameters of materials. It also has at its disposal artificial ageing chambers for climatic simulation and mobile systems for the monitoring of the physical and chemical environment in the collections and on site.

As the leading institution for conservation science, art technology and archaeometry at the National Museums in Berlin, the Rathgen Research Laboratory offers its state-of-the-art services in material analysis, consulting, improvement of workflows and other areas not only to the National Museums, but also to other clients.

With its participation in ILKAR, the Rathgen Research Laboratory extends the range of its activities to the audiovisual sector. The research that is being carried out in the frame of ILKAR complements the laboratory's existing capabilities in inorganic chemistry.

The Music Archive of the Ethnological Museum[3]

The music archive of the Ethnological Museum houses, among other collections, a large number of recordings on phonograph cylinders and magnetic tapes. The cylinder collections are those originally assembled in Berlin by the Phonogramm-Archiv, a collection established by Carl Stumpf (1848-1936) in September 1900 as one of the first audio archives worldwide. Under his guidance, and that of Erich Moritz von Hornbostel (1877-1935), the archive grew quickly and contributed to the institutionalization of ethnomusicology, then known as

2 http://www.dlib.indiana.edu/projects/sounddirections/.

3 The official name of the ethnomusicological department at the Ethnological Museum was provided above. For simplicity's sake, we speak of the Ethnological Museum's music archive referring to the same institution.

comparative musicology, as an academic discipline. Some recordings were made in Berlin, for example with visiting musicians, but most of the recordings were made by travelers (researchers, missionaries, etc.) in other parts of the world.

The Berlin archive was one of the few archives that produced copper negatives in great numbers to copy the recordings on the original wax cylinders and to preserve them; due to the galvanic production process of the negatives, these are also referred to as *galvanos*. Under favorable conditions, these negatives have proved to be more stable than wax cylinders. Thus, many of the recordings in the Berlin archive are still in comparatively good shape (Koch, Wiedmann, & Ziegler, 2004).

Cylinder recordings for the Phonogramm-Archiv were made until 1954. In 1999, the cylinder collections of the Phonogramm-Archiv were entered into the UNESCO register, "Memory of the World". As of April 2009, the Ethnological Museum houses 354 cylinder collections with approximately 16,800 recordings on slightly over 30,000 cylinders (Ziegler, 2006, p. 20).

Since the archive was revived after World War II in 1952, a large and diverse collection on magnetic storage media has been assembled. The archive is constantly growing; in 2008, for example, several new tape collections were added, including recordings by Kurt and Ursula Reinhard, Rüdiger Schumacher and the collections of the International Institute for Traditional Music: approximately 3,500 tapes altogether. The total length of all original audiovisual recordings is now estimated at more than 12,700 hours[4].

Whenever possible, the archive kept the original storage media provided by the collectors. Therefore, over time the collection accumulated a wide range of different tape types, forms and formats, including more recent media like digital audio tapes and various video formats. Due to the diversity of different recording media stored in the music archive of the Ethnological Museum, their varying age and relatively controlled storage histories, the collection serves as an excellent test bed for analyzing typical conservation problems with phonograph cylinders and magnetic tape in various forms and formats.

3. ILKAR's Research Foci

ILKAR's two main aims, i.e. risk assessment and retardation of decay processes, are put into effect for the study of the archive's materials under the following workflows. The starting point for these workflows was a set of questions and problems concerning the state of the materials provided following the launch of ILKAR, with regard to both main research focuses. A thorough condition survey of the collections at the Ethnological Museum was then carried out.

Wax cylinders

Regarding the wax cylinders, the priorities are, on one hand, their conservation, and secondly the definition of the conditions for the correct storage of these materials. Although mould infestation and breakages (Exner, 1997) are known to be among the most important factors preventing correct digitization, a thorough survey to assess the current state of the collection was also considered necessary. With these purposes in mind, the following plan has been put into practice, starting with the diagnosis of the state of the collection.

[4] This estimate is from April 2009 and does not include commercial recordings.

Already extant relevant information from different origins, such as paper collection documents, has been summarized into a central database. Essentially, this step concerns the format information about the collection as well as information about their size.

In order to assess the state of the collection, a condition survey, starting with a sampling procedure, was then designed. A correctly-performed sampling procedure allows one to reach a compromise between the need to arrive at a precise and correct idea of the state of conservation and the impossibility of checking every single object for this purpose. A fully systematic sampling procedure was thus developed which should guarantee representative and valid survey results.

Criteria were then defined that enable identification of damage types and risk groups between the different collections. Within the scope of ILKAR, we intend to compile a set of criteria referring to the identification of aging processes of affected cylinders in the future.

Further steps will include the development of conservation procedures for the most common and most urgent degradation processes, as drawn from the previous assessment study, and the definition of ideal storage conditions for these materials, with regards to the risk of certain types of damage (e.g. mould). In this regard, existing ideas on the adequate storage of wax cylinder will be reworked if necessary.

Finally, a permanent workflow for the regular monitoring of the state of the collection will be elaborated and implemented.

Galvanos

Besides the vast amount of wax cylinders, the Berlin Phonogramm-Archiv houses a singular collection of galvanized copies. These copies were made from 1905 on following interest in utilizing a longer-lasting material (von Hornbostel, 1920-1939) that could preserve information more permanently than could the original wax cylinders. This practice has provided us with a unique collection of 'negative' copies or galvanos, from which virtually unlimited new copies can be cast. The present procedure for the casting of these new copies was developed in 1996.

Just as in the case of wax cylinders, ILKAR is attempting to assess the state of the galvano collection. These criteria are based on preliminary work within the scope of a diploma thesis, currently being completed by Dana Freyberg in the Fachhochschule für Technik und Wirtschaft Berlin, the first survey being carried out on several thousand galvanos. So far, deformation and/or cracks of galvanos, as well as insufficient cleaning of deposits left by earlier cast attempts, are the main occurrences that prevent the smooth casting of new copies and further digitization of the information.

The next step is the revision of the workflow for the casting of new copies. The casting procedure of new wax copies has already been described and analyzed. The critical points of the cylinder casting procedure have been identified as the following:

- Galvanos coming in touch with a casting wax of unknown formulation. Copper is usually the main component of galvanos, while a thin layer of other metals such as silver or nickel may appear in its inner surface. Given the high temperatures used to heat the wax in the 1996 workflow, the question arose as to whether these conditions could damage the inner galvano surface, i.e. that which contains the information (West,

1982). Although proprietary information, the precise composition of the casting wax was provided by the supplier in recognition of the value of the historical copies. This allowed for evaluation of the reactivity of these components on the metallic surface of galvanos.

- Uncontrolled and multiple heating-cooling cycles of the wax through recycling, which may force a change in the properties of the wax and subsequent undesired effects, such as the complication of later cleaning of the galvano. Experiments are being designed and carried out that should provide information on this account. The final workflow will be designed to run under milder, more controlled conditions.
- Uncontrolled heating of the galvanos to clean them from wax. Preliminary solubility experiments on wax were carried out in order to dissolve the wax from the metallic surface, thus avoiding heat. We hope to identify a convenient solvent for use in this respect. An easy-to-use device for the cleaning of galvanos with wax deposits is being designed in order to comply with health and safety procedures in museum environments.

As a result of these analyses, ILKAR is designing a new, milder workflow. Further experiments are also taking place which aim to optimize the present working routine for the production of new wax positives from galvanos.

Magnetic tapes

Since the first commercial magnetic tapes were developed in Germany in the 1930s (Clark, 1993, Hess, 2008, p. 240), millions of hours of recordings have been stored in archives all over the world (Schüller, 2001). The recording mechanism relies on a *magnetic layer* capable of 'storing' the sound by retention of the magnetism impressed on them by the recording head. This layer is sustained over a *base film*, which provides structural support. Different materials have been used over time as base films, with acetate, polyvinylchloride and polyethylene being the most widespread in their respective times. A polymeric binder keeps the magnetic layer particles attached to the base film and holds them together. Other typical components of magnetic tape formulation are additives such as lubricants (used to diminish the friction between tape and head in the magnetic layer), plasticizers, stabilising agents, antioxidants, fungicides, dispersants, curing agents and mineral fillers, which are often used to achieve the desired hardness, flexibility or adhesion on the final manufactured magnetic tape.

Given the wide range of materials that take part in the formulation of magnetic tapes, these formulations cannot be expected to have remained constant over the years. Actually, companies used to change tape formulation without notice in order to fine-tune the performance of the products. For instance, the historical changes in materials used in the magnetic layer can be explained by the industry's inclination towards materials with a higher coercivity, a measurement of how efficiently a material stores information (Köster, 1993), and with a higher density of data storage, which requires a small particle size (White, 1990).

However, some of these materials are not stable over time, and information is therefore lost unless certain conditions are provided. Humidity and temperature should be stable and within certain limits, and archive and digitization facilities should be free of avoidable sources of small particulate material such as smoke, food and other sources of dust. If neglected, these environmental agents can rapidly deteriorate the conservation state of the tape (International Standard Organisation (ISO), 2000), (International Standard Organisation (ISO), 2006, pp. 9–11).This, along with the fact that each of these materials may be subject to particular decay mechanisms[5], makes conservation and digitization of all this information a difficult task.

[5] Decay mechanisms have been reviewed and reported elsewhere. See Hess, 2008 for a review, and Bradshaw, Bhushan, Kalthoff, & Warne, 1986 for a specific example of the interaction of different components leading to lower tape performance.

Most of these mechanisms are caused by the degradation of some of the chemical components used in the formulation of the tape, which were not meant to be long-lasting. The best described in the literature [Hess] are those where either the base film or the binding media are the main cause of deterioration, older tapes generally suffering from degradation mechanisms in which the former is involved, being binding media degradation generally responsible for degradation of more recent tape formulations. The difficulty in noticing the behavior of other minor, less spread components makes it very difficult to understand their role in these or other degradation mechanisms.

Some of these degradation processes are noticed only when the tape is played, especially in the cases where the tape is contained in a cassette. Some others are noticeable when it is already too late to act upon.

Supported by scientific facilities at Rathgen Research Laboratory, new tools will be developed within the scope of ILKAR for the identification of materials at higher risk, helping decision-makers to target more endangered materials first.

As with cylinders, the project starts with the diagnosis of the state of the tape collection. A preliminary overview of the collection was achieved thanks to the existing in-house database. This made identification of the most widespread kinds of materials in the collection possible, as well as a more precise definition of the kinds of damage that should be encountered in the survey. These data permit the development of a decision tree which, in turn, should allow for easier training of non-specialized personnel, enabling them to visually identify and report the different kinds of damage appearing in the collection. The lack of specialized personnel and resources, which in turn limits the amount of time available for the assessment of collections, is one of the most common problems encountered nowadays, especially in smaller archives.

The development of a systematic and unbiased sampling procedure that allows for the assessment of the state of the collection in a limited time span and with limited personnel resources was thus one of ILKAR's first considerations. A representative sampling implies taking into account the following characteristics:

- different collections;
- different materials and manufacturers within each collection, meaning different formulations and therefore different decay processes; and
- different life histories: two tapes of the same collection and of the same material and manufacturer may have experienced a very different life history since they were synthesized, and may therefore show different behavior.

The object of the survey is to gain insight into the state of the archive of the Ethnological Museum, and the most frequent kind of materials in the archive, in order to be able to implement a relevant development study. Given the characteristics of the archive, a preliminary sampling procedure organized in several rounds was proposed. According to this sampling, heterogeneity and size of a given collection are particularly taken into account when determining how many tapes of the collection will be entering the survey.

This assessment of the present state of the collection is based on visual examination of the materials. However, once they are visible, degradation processes are already too widespread and advanced to permit stabilization of the objects. According to ILKAR's main objectives, the development of new methodologies for the identification and handling of sound materials at risk, new tools should be developed that are able to point out the start of deterioration

processes. Although already attempted, this research has often proved fruitless. Some authors (Bigourdan, Reilly, Santoro, & Salesin, 2006) have recently cast doubts on the possibility of a simple diagnostic tool due to the plethora of tape formulations, which lead to different behaviors. However, a timely assessment should allow for the preservation and digitization of the information contained in these materials before it becomes irrecoverable. The same authors pointed at the identification of a key property change as the possible lead to be followed in this respect, change that should be measurable under non-destructive conditions, with easy-to-use equipment and by non-specialized personnel. Previous research has mainly focused on the following trends:

- Invasive mechanical studies such as friction and wear tests;
- Free acidity measurements, which up to the present date have not yet been found to be useful diagnostic tools as indicators of tape decay;
- Acetone extraction, which provided data that failed to indicate a general pattern of behavior in degraded tapes; and
- Analysis of the volatile organic compounds (VOCs) released by degrading materials, still at an early stage of development (Thiébaut, Lattuati-Derieux, Hocevar, & Vilmont, 2007).

Integrated solutions

The experience with previous projects at the music archive of the Ethnological Museum has sometimes shown less-than-optimal results concerning application. In the 1990s valuable research on the digitization of wax cylinders was carried out (e.g. the Berlin Wax Cylinder Project and SpuBiTo[6]), the scientific results were published and disseminated among the scientific community, and yet the practical outcomes for our own as well as other archives were comparatively few. This accounts, for example, for research on optical signal extraction from galvanos (copper negatives, e.g. Wöhrle, 1997).

To ensure that the ILKAR research results have a better chance of application in everyday routines, ILKAR includes a separate work package that accompanies the research and development phase of the project. The core concepts of the integrated solutions are:

- A holistic stance. ILKAR attempts to take a holistic perspective, looking at the whole range of archive activities from collecting, preservation, storage, and documentation to making archival documents accessible, in order to provide solutions which are practical.
- Integration in usual workflows. ILKAR will not just publish its results, but will attempt to provide working solutions (e.g. software) to integrate the results in existing workflows of research archives.
- Optimization of the ILKAR results for the specific requirements and abilities of research archives. Recommendations will take into account factors such as highly diverse collections and limited funding.

To ensure that ILKAR's results will be useful for other archives, the project will work together with approximately ten partner archives. As a first step, conservation requirements of these archives will be determined in 2009. Later the solutions developed by ILKAR will be tested in collaboration with these archives.

[6] See http://www.gfai.de/projekte/spubito/papers/smpk2000.pdf

4. Outlook

As described in this article, ILKAR currently focuses on an analysis of conservational problems of the cylinder and magnetic tape collections at the Ethnological Museum in Berlin. Condition surveys will be completed in fall 2009. ILKAR should then have a good overview of actual problems occurring in archival practice as a basis for the research and development phase of the project. Starting in summer 2009, ILKAR will also contact other archives with cylinder and tape collections to determine the specific needs and abilities of research archives with respect to the conservation of these materials and to ensure that the results are not only applicable to the archive in Berlin alone[7]. As to ILKAR's results so far, workflows are already being examined and modified, particularly for the case of cylinder casting; further research into non-destructive preservation methodologies that allow for timely risk assessment will be reported at the IASA annual meeting in Athens, 2009.

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[7] If you are interested, please contact us through contact@ilkar.de

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