# TECHNOLOGY AND OUR AUDIO-VISUAL HERITAGE

*Technology's Role in Preserving the Memory of the World*




**FOURTH JOINT TECHNICAL SYMPOSIUM**

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JTS95

# Technology and Our Audio-Visual Heritage

## Technology's Role in Preserving the Memory of the World

January 27-29 1995

National Film Theatre

South Bank, London, United Kingdom

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JTS95

# Technology and Our Audio-Visual Heritage

## Technology's Role in Preserving the Memory of the World

*Editor: George Boston*

**A Joint Technical Symposium**

Discussing Technical Aspects of the Storage, Preservation and Restoration of Sounds and Moving Images

Organised by the Technical Co-ordinating Committee on behalf of the:

- *Fédération Internationale des Archives du Film*
- *Fédération Internationale des Archives de Télévision*
- *International Association of Sound Archives*
- *International Council of Archives*

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Where available, a summary of the papers and biographical details of the speakers immediately precedes the text. An edited version of the debate that followed a number of the presentations is also given at the end of papers.

# Preface

This Joint Technical Symposium was the fourth in an occasional series of technical symposia organised jointly by the *Fédération International des Archives de Film*, the *Fédération International des Archives du Télévision*, the *International Association of Sound Archives* and the *International Council of Archives*. The Symposium was held in January 1995 at the National Film Theatre in London.

That rather terse statement conceals what was, in fact, an exciting, wide ranging event that examined many aspects of the fight to preserve the world's heritage of sounds and moving images and make them accessible to as many people as possible. Around two hundred people met in a typically grey and wet January in London to hear some thirty speakers present papers and, more importantly, to discuss with other practioners in the field the best ways of achieving the common aim of passing on to our descendants the rich variety of material in the world's collections.

Since the first attempts to record sounds and moving images at the end of the 19th Century, the public has been entertained, informed, educated and amused by the fleeting images and sounds captured by phonograph cylinders, films, gramophone records, sound and video tapes. These provide a continuing source of inspiration for the general public and, increasingly, researchers and academics. Times change, however, and technology changes with it. The tide of digitisation is sweeping in fast. Many of the machines that we rely on to replay the analogue recordings are vanishing. There are also problems arising with the decay of the carriers of the information. We have to face the need to transfer the recorded sounds and images to new formats to preserve them. The question that we have to answer is how?

Some people advocate the preservation at all costs of the original carrier. This carries with it the need to maintain the machinery in working order. This may be difficult if the manufacturers are unwilling to provide an economic supply of spare parts.

Others advocate the transfer of the recordings to digital formats that employ discrete carriers eg. the CD or one of the many digital video tape formats. This may give rise to similar transfer problems in the future as formats change and carrier decay sets in.

A third view is that we should embrace computer technology and move our collections into mass data storage systems. This offers the possibility of client controlled access to the material, automated checking of the fidelity of the recordings in store and automated copying. The problem for many collections is the cost. In practice, the solution will be all of these and others yet to be

invented. The storage of sounds and moving images has a dynamic that is dependent on many factors. Despite the popular conception of an archive being a dusty room covered with cobwebs and serviced by equally dusty custodians, the truth is that the preservation of sounds and moving images depends on technology. Technology is not static and neither, therefore, is the preservation of the collections.

The Fourth Joint Technical Symposium gave an opportunity to researchers and technicians working with sounds and images the opportunity to present their ideas to an audience of their peers and to have the ideas discussed in formal session and informal meetings. Each of the three days of the JTS found enthusiastic people debating, at times quite heatedly, in small groups during the coffee and meal breaks at the conference site and late into the evening at the hotels. On several occasions, rather bemused Londoners on the red double decker buses were entertained by spirited discussions in a variety of forms of English and other languages.

The one thing that shone through was the sheer enthusiasm for the work - even though today's custodians will not solve the problems but will have to pass the work on to succeeding generations. The custodians are akin to gardeners who plant trees in the full knowledge that they will not be present to see their work come into full fruition in one hundred years time. We are sowing the seeds of a new future every day with the decisions that we make about the storage conditions, the handling methods, the treatment of decaying carriers etc. The correctness, or otherwise, of a decision made today may not become apparent in our lifetime. We may be blessed, or cursed, by those that follow us. What we cannot do in many cases is to do nothing. Meeting and discussing problems with colleagues in the field is one important way of helping to make the correct decisions.

I would like to take this opportunity to thank the various people and organisations who assisted with the organisation and running of the JTS. As with any event, it is impossible to name everyone who helped. I name, therefore, those people that I was particularly aware of. Firstly, my colleagues on the Technical Co-ordinating Committee. The members based in the UK - Anne Fleming, Brian Jenkinson and Henning Schou (National Film and Television Archive) - bore the brunt of the administrative work. The other members of the TCC - Harald Brandes, (Bundesarchiv Film Archive, Koblenz, Germany), Jean-Marc Fontaine (Bibliothèque Nationale de France, Paris), Tedd Johanson (NRK, Oslo, Norway) and Dietrich Schüller (Phonogrammarchive, Austrian Academy of Sciences, Vienna) assisted as much as geography permitted.

Assistance with the running of the event from UK colleagues Helen Harrison, Catherine Pinion, Lloyd Stickells and Mark

Jones was also greatly appreciated. The staff of the National Film Theatre were also unfailingly welcoming and supportive.

There were two last minute changes of Session Chairs due to ill-health. Brian Jenkinson was to have Chaired the Fourth Session but was recovering from a heart operation at the time. Philippe Poncin agreed to replace Brian. Crispin Jewitt was unable to undertake the second part of Session Three and William Storm stepped in at the last moment. Thanks are due to these gentlemen and also to the Chairs of the first two sessions - Henning Schou and Dietrich Schüller - for their work.

Thanks are also due to the British Film Institute for their generous help in providing the National Film Theatre without charge. Without this help the JTS would have been far more expensive to attend. Only the generosity of institutions such as the BFI make it possible to hold small specialist events such as the JTS. We owe them a great deal.

None of the work undertaken by the above people would have been of any use without the speakers. They came from many countries to present and to discuss their ideas with an audience of their peers. On your behalf, I warmly thank them for all their work.

George Boston

Chair of the Technical Co-ordinating Committee

# Symposium Programme

## Thursday January 26th

**Opening Reception**

The Museum of the Moving Image, South Bank Centre.

## Friday January 27th

**Welcome and Opening of Symposium**

**Wilf Stevenson** - Director of the British Film Institute
**Clyde Jeavons** - Curator of the National Film and Television Archive

**Keynote Address**

**The Meaning of Memory**
*Professor Hans Fredrik Dahl*
President of the Department of Media and Communications, University of Oslo, Norway

**Introductory Remarks**

**Ethical Questions Relating to Preservation and the Uses of New Technologies in AV Archives**
*George Boston*
Chair of the Technical Co-ordinating Committee, Milton Keynes, United Kingdom

**First Papers Session**

### The Breakdown of the Components of Signal Carriers with Age

**Session Chairman: Henning Schou**
Head of Conservation, National Film and Television Archive, Berkhamsted, United Kingdom.

**The Decay of the Polymers Used for Information Carriers**
*Michele Edge*, assisted by *Joan Whitehead*
Centre for Archival Polymeric Materials, Manchester Metropolitan University, United Kingdom

**Status Report on the Worldwide Molecular Sieve Trade Test Results**
*Tulsi Ram, Diane Carroll-Yacoby, Paige Miller* and *Harry D. Haber*
Eastman Kodak Company, Rochester, New York, USA

**Anomalies in the Treatment of Hydrolysed Tapes: Including Non-Chemical Methods of Determining the Decay of Signals**
*Kevin Bradley*
National Library of Australia, Canberra, Australia

**Wet and Mouldy: The Deterioration and Treatment of Water Damaged Films**
*Mark Nizette*
National Film and Sound Archive, Canberra, Australia

**Microspectrophotometric Analyses of Changes in the Organic Materials Used in Optical Discs**

*Jacques Lemaire**, *Nicholas Pichon** and *Jean-Marc Fontaine***
*Centre National d'Evaluation de Photoprotection
Université Blaise Pascal (Clermont-Ferrand 11), France.
**Bibliothèque Nationale de France, Université Paris 6, Villepreux, France

**Relevance of the Parameters Defining the Quality of CD's**

*Jean-Marc Fontaine*
Bibliothèque Nationale de France, Université Paris 6, Villepreux, France.

**Second Papers Session**

## Signal and Carrier Restoration

**Session Chairman: Dietrich Schüller**
Director, Phonogrammarchiv of the Austrian Academy of Sciences, Vienna, Austria

**An Audio Pre-Amplifier Designed for the Transfer of Historical Sound Recordings**

*Franz Lechleitner*
Phonogrammarchiv, Austrian Academy of Sciences, Vienna, Austria

**The Restoration of Audio Recordings Using Frequency Domain DSP Techniques Running Under Windows**

*Hong Zeng*
Bibliothèque Nationale de France, Université Paris 6, Villepreux, France

**Psychoacoustical Models in Signal Restoration and Noise Reduction**

*Werner A. Deutsch*
Austrian Academy of Sciences, Vienna, Austria.

**Videotape Handling Practices 30 Years Later: Did The Recommended Techniques Work?**

*James Lindner*
VidiPax, New York, United States of America

**Friday Evening**

## Manufacturers Reception and Exhibition

Held in the Galleon Suite at the Royal National Hotel, Woburn Place, Russell Square and hosted by the following companies:

**Conservation by Design**

**CTM-Debrie**

**Image Permanence Institute**

**Media Equipment International**

**RTI/Lipsner-Smith**

**Sony Broadcast and Professional, Europe**

## Saturday January 28th

**Second Papers Session** (Continued)

### Signal and Carrier Restoration

**Session Chairman: Dietrich Schüller**
Director, Phonogrammarchiv of the Austrian Academy of Sciences, Vienna, Austria

**Digital Film Image Restoration: First Practical Experiences and Results**
*Jürgen Ristow*
Optronik GmbH, Potsdam, Germany

**Digital Restoration of Film: The Kodak Cineon Digital Film System**
*Paul Watkins*
Kodak Ltd. Cineon Sales (Europe), London, United Kingdom

**Digital Techniques in Film Image Restoration**
*David Scammell*
Quantel, Newbury, United Kingdom

**HDVS as a Digital Motion Picture Archival Medium**
*Milan Krsljanin*
Sony Broadcast and Professional, Europe, Basingstoke, United Kingdom

**Experiments with Optical Scanning of Negatives of Edison Cylinders**
*Susanne Ziegler*, Gerd Stanke**, Michael Bottlinger**** and *Reinhard Kohius****
*Museum für Völkerkunde, Berlin
**Gesellschaft zur Förderung angewandter Informatik, Berlin
***Deutsches Institut für Lebensmitteltechnik

**Guest Speakers**

**The UNESCO Memory of the World Programme**
*Joie Springer*
UNESCO General Information Programme, Paris, France

**The European Community and Multimedia Technology**
*Yves René de Cotret*
European Commission, Directorate III, Brussels, Belgium

**Third Papers Session**

### Access to Sounds and Moving Images

**Session Chairman: Crispin Jewitt**
Director, National Sound Archive, British Library, London, United Kingdom

**Access to Moving Image Collections**
*John Abbott*
The Image Bank Inc, London, United Kingdom

**The Experience of Six Years of Automatic Access to the Audio-Visual Collection of the Centre Audiovisuel de Paris**
*Philippe Boulanger*
Centre Audiovisuel de Paris, France

**VideoScribe: Combined Image and Text Store to Describe Moving Image Documents**
*Philippe Poncin* and *Vincent Prost*
Institut Nationale de l'Audiovisuel (INA), Bry-sur-Marne, France

**Project JUKEBOX: Remote Access to Sounds**
*Birte Christensen-Dalsgaard*
Computing Centre for Research and Education, Aarhus, Denmark

**Saturday Evening**

**Restoration Lecture**

A special public presentation of restored copies of "lost" episodes of episodes of the television series *Steptoe and Son* and *Dr. Who* with a short introduction by members of the restoration teams from the BBC and the National Film and Television Archive explaining the work undertaken.

## Sunday January 29th

**Third Papers Session** (Continued)

### Access to Sounds and Moving Images
**Session Chairman: William D. Storm**
President, Media Equipment International, Syracuse, New York, U.S.A.

**Software Tools for Moving Image Archives. Access, Indexing and User Interfaces**
*Philippe Aigrain, Philippe Joly, Philippe Lepain and Hae-Kwang Kim*
Institut de Recherche en Informatique de Toulouse, University Paul Sabatier, Toulouse, France

**Tools for Sound Data Acquisition, Transfer, Segmentation and Storage**
*Werner A. Deutsch*
Austrian Academy of Sciences, Vienna, Austria

**Fourth Papers Session**

### Digital and Computer Technology in A-V Archiving
**Session Chair: Philippe Poncin**
Deputy Director, Institut Nationale de l'Audiovisuel, Bry-sur-Marne, France

**Digital Instead of Analogue: Experiences with Modernisation of the *Deutches Spracharchiv***
*Peter Wagener*
Deutsches Spracharchiv, Mannheim, Germany

**Digital Media Management System, Digital Archive Concept**
*Hans-Dieter Queren*
SONOPRESS, Gütersloh, Germany

**A Strategy for the Long- Term Preservation of Data from Space Missions**
*Claude Huc*
French Space Agency, Toulouse, France

**Computers in Archive Storage**
*Michael Alexander*
British Library Computing and Telecomms, Boston Spa, U.K.

**Archive Retrieval**
*Mike Croll*
BBC Research Department, Kingswood Warren, U.K.

**Digital Mass Storage in a Radio Sound Archive: The Customer's Requirements**
*Albrecht Haefner*
Südwestfunk, Baden-Baden, Germany

**Multimedia Mass Data File Server**
*Horst Niederehe*
Sony Broadcast and Professional Deutschland, Köln, Germany

**A Digital VT Server Using MPEG II Compression**
*Denis Frambourt** and *Jean-Luc Morizur***
*Institut National de l'Audiovisuel, Bry-sur-Marne, France
**Société Générale de Téléinformatique, France

**The Final Word**

## Where Next? The Future of A-V Archiving

A panel of speakers from several backgrounds were invited to debate with the JTS Participants the future of sound and moving image collections. The panellists were:

***Michael Croll*** - BBC Research and Development Department
***David Gill*** - Documentary Film Producer
***Clyde Jeavans*** - Curator of the National Film and Television Archive
***William Storm*** - President of Media Equipment International

**Sunday Evening**

**Restoration Lecture**

## Snow White and the Seven Dwarfs

By special permission of the Disney Corporation, a public showing of the recently restored classic animated film. The restoration work employed the latest digital techniques and the film was introduced by members of the restoration team.

# Opening and Welcome to Symposium

## Wilf Stevenson

Director of the British Film Institute

It is my great pleasure to welcome you all to this the Fourth Joint Technical Symposium. I have read the reports of the previous Symposia and it is clear that these conferences are becoming important events. They offer a common meeting ground for those working for the preservation and restoration of our sound and moving image heritage and, if anything, the Symposia are not frequent enough. We at the British Film Institute are delighted that you will be meeting here in London for the next three days. We hope that you will take the opportunity to become acquainted, not only with the National Film Theatre and the Museum of the Moving Image here on the South Bank, but also with our headquarters at Stephen Street and our Conservation Centre at Berkhamsted.

Indeed, in some senses, the BFI itself represents the challenges that you will be addressing over the next few days. We are a producer of film and television programmes. Our film and television archive and our stills, library and museum collections are there to hold as much as we are able of our audio-visual heritage in all its different forms. We preserve and conserve as much of this material as our scarce resources allow and we try to make our collections accessible to as many people and in as many formats as our funds and rights allow. Because about a third of our income is spent on this work, our Governors and our political masters expect us to constantly review what we do and to try to do it better in the future (which really means, cheaper). So as well as a general interest in the papers as a one-time physical chemist and practitioner, you will understand if I also wear a "value for money hat" as I listen to your debates. I hope that you all find the following three days both useful and enjoyable and I wish you well.

*Wilf Stevenson has been the Director of the British Film Institute since October 1988 having joined the BFI in April 1987 as Deputy Director. He is a member of the British Screen Advisory Council, the British Council Film and Television Advisory Committee, acts as Secretary to the All party Parliamentary Group on the Film Industry and is a member of the Council of Europe's Committee of Government Experts on Cinema.*

*Mr Stevenson regularly comments in the media on many aspects of film and broadcasting and has published a number of books and articles on film and broadcasting topics.*

## Clyde Jeavons

Curator of the National Film and Television Archive

I have little to add to the cogent words of welcome from Wilf. I would simply like to endorse Wilf's words of welcome and say on behalf of the National Film and Television Archive how pleased and honoured we are to have been able to collaborate with the members of the Technical Co-ordinating Committee in the organisation of this Joint Technical Symposium here at the National Film Theatre in the Centenary Year of the Cinema. By the time we finish, we will have heard around 40 expert speakers and panellists who will lead us through the technological labyrinth - provocatively and challengingly I trust - for the next three days.

*Clyde Jeavons joined the National Film and Television Archive in 1969 and became Curator in 1990. He is currently the Treasurer of FIAF and a Committee Member of the Lumiere (Media 95) project. He is an Honorary Fellow of the British Kinematograph, Sound and Television Society and a Fellow of the Royal Society of Arts.*

I would like to take this opportunity to congratulate and thank in advance if I may (a perilous thing to do, of course) the Organising Committee led by George Boston, who has borne the brunt of the very complicated administration and logistics of bringing together over 200 delegates from the different sectors of our international family of archives. I would also like to express my personal thanks and appreciation to my archive colleagues, Anne Fleming and Henning Schou, who, together with their staff from the NFTVA, have handled the organisation of the London end with great skill, patience and attention to detail at a time of considerable pressure in their normal duties.

As your hosts here in London, we would like to invite you to visit our Conservation Centre at Berkhamsted if you are staying on in London next week. If you contact Anne Fleming, Henning Schou or myself or better still, our colleague David Peterson, we will try to arrange a visit. You are also invited to visit the Museum of the Moving Image here on the South Bank.

Finally, I would like to thank Adrian Wooton and his team here at the BFI National Film Theatre for agreeing to host this event on these very busy premises.

# Keynote Address:

# The Meaning of Memory

**Hans Fredrik Dahl**

*George Boston:*

*It is now my pleasure to introduce Professor Hans Fredrik Dahl, President of the Institute of Media and Communications at the University of Oslo in Norway. Professor Dahl has agreed to present the Keynote Address. He has taken as the title of his paper* **The Meaning of Memory**. *I am sure that it will contain some very pertinent comments about the role of sound and moving image archives. May I, therefore, without any further delay invite Professor Dahl to present his Address.*

What I have to say in my opening address will certainly strike a chord of friendship and understanding. Being a historian I'm talking on behalf of a profession that is entirely dependant on the work and skills of archivists, and I cannot, therefore, be expected to say anything but niceties in a setting like this. You archivists are quite obviously indispensable for our understanding of the past. You preserve the very memory of society - the huge, silent memory bank that teachers, researchers, writers bring to life in their works. To decide who is the more important in this process is a futile strife. No history can be written without sources; indeed, sources are quite often more important than the actual writer's personal ideas or even his vocational talents. Time and again one is reminded that the quality of the documentary evidence underlying the research work, the richness of the material on which the argument is constructed, is in fact decisive in determining the value of the work.

You may know that, in all languages, the material that the historian uses for reconstructing the past, the historian's data, are called "sources". Yet the very word "source", poetic as it may be, is deeply misleading as to what is going on in our profession. A source is something which springs to the surface in abundance, like fresh water from the ground - pure and clear, endless and with no limitations; there to take as much as you want. This, of course, is not normally the case with the material left to us by the past. Rather, it has to be handled with meticulous care, so as to be preserved, recorded and stored in a proper way. Neither does it pour out endlessly. Scarcity, absence of material, is more common, quite often because, in the past, the traces of yesterday have been carelessly thrown away. And with no material left behind, there will by no story to tell, no history - its as simple as that. For this reason you may imagine that for a historian to address a conference of professional archivists gives one the feeling of being a chimpanzee in front of the banana grocers' annual meeting.

So much for the general feeling. Let me now turn to the study of media matters - the audio-visual media. It is long since that academic researchers in general and historians in particular have come to recognise the importance of audio-visual sources, as a distinct category of material to be handed differently from paper sources and oral evidence. International conferences are frequently held on the topic "history and the new media" or "history and non-written sources" nowadays.[1] There even is an International Association for Audio-visual Media in Historical

Research and Education, which has run many a symposium on the subject. Mass media, moving images, audio-visual sources on the whole are nowadays enjoying a rather high-level esteem among historians. Of all the media, film has captured the imagination of historians in a peculiar way, perhaps more than - say - radio or television. The study of film and history is today a well-established academic industry. The reason for this is quite obvious: film constitutes the oldest, full-blooded mass entertainment medium, having poured into the market for exactly a hundred years, longer than any other medium except the press (permit me to pass over the phonograph as well in this connection). For this reason, the national film archives of even small countries like Denmark, Belgium or Israel contain huge collections, of some 20.000 films - whereas in big countries like France, Germany, UK and the USA, the number of items in film archives must be counted in hundreds of thousands.[2]

The sheer abundance gives the movies their central position. Historians use the moving images in at least three ways: First, these images from the past offer an interpretation or representation of history, interesting enough in its own right; secondly, films - feature films and documentaries alike - provide evidence for social and cultural history whether they report about it or not; and finally, films, both historical and contemporary ones, both from the past and about the past, offer invaluable material in the teaching of history.[3]

The same goes for all the other media, of course. They are important as historic material in more than one sense. Consequently any archivist can feel comfortable with the role of providing material for the researchers and teachers that they serve in their profession, and stay content with the grateful thanks that they receive.

Some of you might, however, be a little uneasy about merely providing bananas for others. You might wish to see your profession as something in its own right, not only as a tool in the hands of others. And indeed, I agree with you. There is something about preserving the signs and signals from yesterday which reaches beyond this role, and there are aspects of the trade outside the mere instrumentality of being useful for others. As I see it, to serve the function of preserving the audio-visual memory of the world touches the cultural meaning of the media themselves and tends to deepen the understanding of these media in general.

Let me approach this theme from my own experience with the history of broadcasting, where for some years I've been dealing with the radio and television of the past, and with how to relate it to the present.

As we all know the broadcast media are contemporary in a very special sense. Programmes last as long as they last - and then

they fade out with the electromagnetic waves passing into the universe. Aerial transmissions being what they are, these media provide strictly momentary events. Broadcasts are not recordings - a distinction which is of course the salient point in dealing with artists and performers rights in the field of radio and television. Broadcasting is different from the reproduction of item copies.

Legally, this was settled as far back as in the 1920s when it was decided that the broadcast of an event or a work was not tantamount to the technical reproduction of a recorded item of the work, analogous with the gramophone disc or the printed book, but rather a non-durable performance analogous to - say - the reading of poetry or the playing of brass music at large popular assemblies like sport events.[4]

As we all very well know also, the result of this definition of broadcasting as a momentary event, is that a very small proportion of what went out on the air over the years has been stored as sound or vision tapes or recorded in the broadcasting institutions. No public library has wanted to demand a record of what went on the air, at par with the copyright libraries of the world which for centuries have been instructed to store copies of all printed items. This deplorable state of affairs has improved since the 1970s, though. Today, electronic signals carrying audio-visual information are defined as part of the cultural heritage as much as print culture is, and most countries have some system of official archives for sound and vision, including broadcast programmes even if the question of legal rights are not yet definitely solved for such recordings.

This means that we now have routines for audio-visual archiving, established - say - around 1980, whereas the sound and vision broadcasts prior to that time are preserved to a much lesser degree and in no systematic fashion. Because of this, society has lost an important part of its memory. Media historians miss their sources, of course, which is sad for them. Much more serious however, we now lack certain aspects of the past which might help us to explain the present.

Let me give you but one example: the origins and meanings of television news.

The daily television news broadcast is one of the pivotal institutions of modern life, structuring leisure time and family routines and providing the very window to the world for a great part of the planet's peoples. I need say nothing more on that subject; one instantly recognises the significance of the phenomenon from one's own experience.

For such an important aspect of modern life it seems evident - at least it is evident for me - to ask questions about the history of that very institution. From where does the TV newscast come -

formally, as a programme format with its particular modes and solutions; or culturally, as a communication genre designed to create credibility, trust, news worthiness? One might ask about the history of the TV news with at least as much legitimacy as you would ask about the history of - say - the TV drama, the newspaper editorial, or the radio feature. This is particularly important since the TV news themselves seem to resist the idea that they have a "history" in an ordinary sense at all. Televised news are certainly momentary; endlessly present as ubiquitous realities, they seem to resist historical explanation by their sheer and monotonous insistence on dealing mainly with contemporary moment - today's news, the situation now. How could there be a history of this unending noisy stream of events, moments, snapshots, presence's? All the same: even if they seem to evade a proper "historical" character, the TV news certainly deserve interest as phenomena with a past, because in dealing with the past you might discover a development, an extension in time which might explain why they are how they are today.[5]

Historically speaking, the TV news as a genre is a merger of the two earlier forms, the radio news bulletin and the film newsreel. The merger can be studied in great detail at the level of persons, jobs, functions, as the coming of the TV news in the 1950s relied heavily on both its predecessors. The newscaster, the anchorman, was usually picked from the experienced radio news bulletin readers; he was close at hand, since in most European countries television developed within the existing radio broadcasting systems. The film photographers, on the other hand, usually came from the various private film news companies, extending their contracts and their modes of operation into the new television medium. After some years of TV news, the weekly newsreel that had formed part of the regular cinema repertoire since the 1920s, passed away and disappeared from the screen; at about the same time the TV news replaced the radio news bulletins as the nation's main news source.

All this can be studied as I said in detail on the institutional level - where we have written documentary evidence upon which to build our investigations.

But how did the news proper, the TV broadcasts, develop from day to day, gradually establishing its own formal rules and developing its news criteria? Unfortunately, this is a much more difficult question to answer. And I hardly need give you the reasons. We have no complete collection of records of the TV news broadcasts, not in any country as far as I know. For technical reasons of course - videotapes had yet to be invented or were scarce in those days, and nobody really thought it worthwhile to produce a record of it. Well, the items shot on film do exists in the TV station's film archive. But the presentation as such, in an integrated news performance complete with anchorman, weatherman, music and all, does not exist.

Consequently the history of the TV news is very hard to write.

Imagine that - an extraordinary important institution so scantily represented in the memory bank. For example, for many years the TV news were normally presented with music played off screen, like on newsreels. What sort of music? When? With what effect? We simply don't know. At least this is the situation in the research project of early television in Norway where I'm involved.[6]

So - the reasons for treating audio-visual signals as integral parts of the cultural heritage are many. Proper archiving helps the historian and other researchers - very well. The recently imposed rules and routines for taking care of this heritage reflect the improved status of audio-visual culture in society at large - very well, that too. But the need to take care of such material even carries a deeper, cultural meaning: I'm thinking of the increasingly dominant position that visual, or visual-cum-sound images play in sharpening people's memory of the past. Surely, there is much about the audio-visual media that we yet do not know or understand. But the sheer amount of time and attention occupied by these media - several hours per person every day, in most countries - will necessarily influence the basis of social memory, affect people's reminiscence of the past - that which forms part of the collective experience of one's own times.

Any person is of course to some extent made up of her or his memory of the past, which tends to concentrate into patterns of experience that in its turn determine how we evaluate phenomena of the present. People's memories of a war, for instance, concentrate into defined experiences, to be exchanged and affected by other peoples experiences, and from there influence our judgements of today's ideas and events. Needless to say the communication media take an active part in exchanging and affecting such collective experiences - if they do not downright create them sometimes. Some people today may remember the Second World War or in the States, the Vietnam War. More probably however their experiences are shaped by the media versions of the war memories - and of the memory of the war memories, and the memory of the memory of the war, in an indefinite backward chain. Great events in a nation's life will of course be recycled again and again by the cultural media working in that society - textbooks, popular songs, television, whatever.[7]

In the post-1945 western society, however, and in an increasing number of national communities around the world, not only your memory of actual events, but your sense of the past in general, the very substance of your memory, will be determined of what you experience from audio-visual media, and particularly (but not solely) from television. What was on in those days increasingly tend to shape the memory of those days; this is evident from the media consumption statistics alone, and it is confirmed in studies of how and what we remember from the past. When our lives are

filled with audio-visual inputs to the extent that they are today, then certainly the impressions taken from them will form a vital part of our remembering the past. Life experience will increasingly be media experience - and this is novel to most peoples on the Earth.

So as you meet here in London for the next three days to discuss the technical and professional aspects of your trade, I think it appropriate that you should bear in mind the great and growing importance attached to your profession of conserving our audio-visual heritage. Not only as a necessary service to people in teaching, writing, research, who need the source material you can provide; not even only as a means of preserving traces of certain cultural forms which all to easily has slipped into the wastebaskets in the years past and made all of us in some respects poor of historical material. but simply as a service to people's memory, the stuff their minds are made of, the impulses that increasingly shape us all as social beings.

The real and full importance of modern media may still be hidden for us. All the same we should do our utmost to preserve their heritage: One day that may turn out to be necessary - for staying human.

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*3. Pierre Sorlin: The Film in History - Restaging the Past.* Totowa, NJ: Barnes & Noble Books 1980; O'Connor, op.cit.

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# Ethical Questions Relating to the Uses of New Technology in Audio-Visual Archives

**George Boston**

Ethics: your first reaction may well be "What have ethics to do with me - I'm an archive technician". In this brief presentation, I will try to explain why ethics are of rightful concern to all working with historic information including the media that concern us here today. This is also, to some extent, the equivalent of the "Government Health Warning" that is now printed on packets of cigarettes in most countries. It is a warning that what you are buying may have hidden drawbacks that you should be beware of.

Why ethics? Increasingly we are finding that we have to copy the carriers in our collections to new formats in order to preserve the information. This need will be underlined by the speakers that follow me; in particular those that will be speaking about the decay of carriers and obsolescence of equipment. We are being forced to copy material in order to preserve it.

We must remember, however, that when making preservation copies we are reproducing the original or master version. This must not be altered for any reason - least of all for aesthetic reasons. The sound or the images may not be pleasing to the person making the copy and they may desire to alter it to improve it. They must resist this temptation. As the one English Dictator - Oliver Cromwell - said when sitting for his portrait " Paint me warts and all".

In parallel with the making of preservation copies, we are also being asked to provide copies that will improve access to the material. Making access copies has a lower fidelity requirement. Modern aesthetics can play a part. We can add reverberation to music, colourise black and white films, edit the video. None of these activities affects the fidelity of the master copy which must remain unaltered - "Warts and all".

Why is this subject brought up now? You will be hearing later from some of the speakers about the power of modern electronics to change things in a way that may be undetectable when the copy is listened to or viewed in isolation but which becomes apparent when when comparing the pictures or the sound with the original. The danger is of well-meaning but misguided enthusiasm.

To give an example from another field of what can be done by well-intentioned but misguided enthusiasm. The caves at Lascaux in France contain some of the earliest paintings known to man.

*George Boston worked and trained as a sound technician and Manager for BBC Radio and Television in London, Manchester and Milton Keynes for more than 30 years. On appointment as Sound Manager at the BBC Open University Production Centre in Milton Keynes in 1982, he found that one of his responsibilities was the tape and film library. His concerns about the storage of these materials led to him joining IASA in 1985. He is also a member of the AES.*

*He is the current Chair of the Technical Co-ordinating Committee which is formed of technical members of FIAF, FIAT, IASA and ICA. The TCC organised the JTS held in Ottawa in 1990 as well as the current Symposium. One of the major activities of the Committee is the provision of information to their non-technical colleagues and several books have been written for this purpose.*

The paintings were created some 17,000 years ago. They survived with all the freshness and vigour that their creators had intended until they were rediscovered in 1940 and the caves opened to public view. After less than 25 years, the caves had to be sealed up again to protect the paintings which were starting to decay. The final disaster in this story occured when a group of well-meaning environmentalists decided to enter the cave one night and clean some of the graffiti from the walls. In doing so they also removed some wall paintings that had survived for thousands of years.

A more successful project was that funded by Sony to clean the ceiling of the Sistine Chapel in the Vatican. This removed the dirt and grime but left Michelangelo's paint intact. The project took, however, many years of patient work.

The equivalent action in our field is the electronic removal of dirt and grime from a film or disc. It is permissable to remove the dirt and grime but, if there is any danger of touching the underlying information, it is better to leave the original alone. Copy it with all the clicks, bangs and scratches. Leave the cleaning to a later generation with even more sensitive tools. Restrict the use of dirt and grime removal processes to the minimum or apply them only to access copies.

Another area that is causing concern is that of digitisation. Here the problem is the use of data compression or reduction. The Technical Co-ordinating Committee - the organisers of this Symposium - use these two terms - data compression and data reduction - to mean two different things. We use data compression to mean a completely reversible action. In other words, after data compression and expansion, the digital copy that results is identical to the original digital copy with no loss of information at all.

After the process of data reduction and expansion, however, there is a loss of information. The copy is no longer digitally identical to the digital original. Clearly, for an archive master preservation copy only data compression can be used if a reduction in storage space is necessary. Better still, no data compression at all.

This brief presentation does not claim to include all of the answers to these questions. It is merely a short "Government Health Warning" to remind you to consider deeply when undertaking the apparently simple task of copying an original to a new preservation format. The power offered by modern systems can be very tempting. But remember the old adage "All power corrupts; absolute power corrupts absolutely". Do not corrupt the information in your care by misusing the powers given to you by modern technology.

## Session 1:

# The Breakdown of the Components of Signal Carriers with Age

### Chairman: Henning Schou

You will see from the Programme that we have divided the Symposium into four main sessions. The first, which I will be Chairing, is on the stability of the carriers of sounds and images. The second session covers the restoration of carriers and signals. The third session is on access to sounds and images; and the final session will look at some of the latest technologies being applied to the storage of sounds and images.

*Henning Schou is currently the Head of Preservation at the National Film and Television Archive at the British Film Institute's Preservation Centre at Berkhamsted. Previously he was the Head of Film, Sound and Television Preservation and Technical Services at the National Film and Sound Archive in Canberra, Australia.*

*He is President of the FIAF Preservation Commission which carries out research and publishes guidelines and recommendations on all aspects of motion picture preservation. He has undertaken research on deterioration colour dyes in film stocks and on the decomposition of nitrate film - two of the major problems facing film archives world-wide. He represents FIAF on the Technical Co-ordinating Committee.*

# The Decay of Polymers in Information Storage Carriers

**Michele Edge**
assisted by
**Joan Whitehead**

Centre for Archival Polymeric Materials,
Manchester Metropolitan University, United Kingdom

## *Michele Edge*

*Dr Edge gained her Degree and PhD from Manchester Polytechnic (now Manchester Metropolitan University). She is currently Lecturer in Physical Chemistry and is also involved in the supervision of 12 PhDs in Applied Polymer Chemistry, Polymer Photochemistry and Conservation of Polymers. The work of the researchers is sponsored by the National Film and Television Archive, the Tate Gallery, the Science Museum, ICI, Courtaulds Coatings, Du-Pont, Tioxide and Unilever.*

*Dr Edge is the Co-Director of the Centre for Archival Polymers and undertakes research and consultancies for polymers used in long-term applications including information carriers. She is a member of the committee of the Makro group of the Royal Society of Chemistry for discussion of polymer degradation.*

## Summary of Paper

This paper provides a summary of the progress made to date in our understanding of the stability of information carriers. Each of the following problems will be addressed:

**How do the polymers that make up information carriers breakdown.** What is special about the structure of the materials used as information carriers which make them susceptible to the environment.

**How to identify breakdown.** What is the final point at which a material that is degrading but the information can be recovered. At what point does the breakdown become irretrievable. What happens in the "grey area" between these two points. Here simple observation of materials, together with an evaluation of "chemical" test methods, will be covered. Emphasis will be placed on the value of identifying which materials are at risk of deterioration.

**How is breakdown influenced by archival storage conditions.** Temperature, humidity and storage containers will be discussed.

**How can the life expectancy of such materials be extended.** Information carrier materials do not last forever but we can double, or even triple, their life by careful control of environmental conditions.

# The Decay of Polymers in Information Storage Materials


## Michele Edge

assisted by Joan Whitehead


***Henning Schou:***

*Those of you who were in Ottawa in 1990 will recall Michele Edge's presentation which dealt with the deterioration of polymers in audiovisual materials. Today, five years on from Ottawa, Dr. Edge will summarise the progress made in our understanding of the stability of information carriers.*

*Michele was, with her colleagues, Professor Norman Allan and Dr. Jewitt, and Velsom Horrie of Manchester Museum, one of the founders of the Centre for Archival Polymeric Materials at Manchester Metropolitan University (formerly Manchester Polytechnic).*

This paper provides a summary of the progress made to date in our understanding of the stability of information carriers. It is not comprehensive but provides "snapshots" of key issues. Accordingly it addresses problems such as how information carriers break down, how to identify breakdown, how breakdown is influenced by archival storage and how we can extend the lifetime of carriers. With these questions in mind .....

***.....How do the polymers which make up information carriers degrade?***

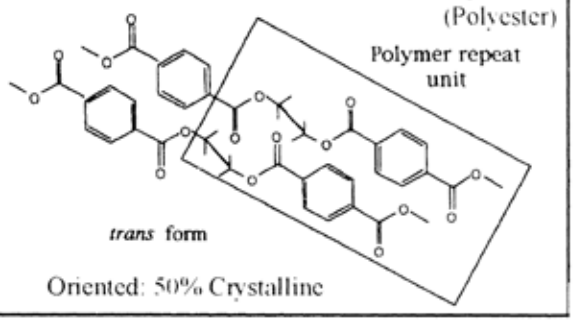
### Photographic Film

Table 1 illustrates the characteristics of the breakdown of photographic film materials as a function of the plastic base which supports the emulsion. The plastic is made up of a polymer mixed with various additives. Polymers are sensitive to their environment and degrade by both hydrolysis and oxidation: They consist of small structural units which are linked together and continuously repeated to form chains. This is illustrated in Figure 1, which shows the chemical structure of two polyester chains, lying side-by-side with the repeat unit within each chain highlighted.

**Table 1**

| Nitrate Film | Acetate Film |
|---|---|
| - acrid colours | - "vinegar" odour |
| - film discolours | - warping |
| - image fades | - shrinkage |
| - sticky emulsion | - white crystals on film surface |
| - film yellows and congeals | - film reel flaccid or crystalline |
| - large volumes of brown powder on film surfaces or in film can | |

**Figure 1**




In some polymers pendent groups are present along the chain at regular intervals (e.g. as in cellulose nitrate and cellulose acetate (Figure 2)). Both the link points in the chains and the pendant groups are sensitive to moisture, heat and light; hence their environment facilitates hydrolysis and oxidation.

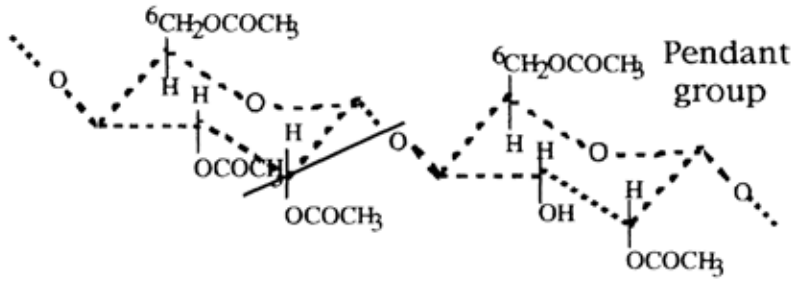
Where pendant groups are present on the polymer chain they may be released: For example, in the presence of moisture the pendant ester group of cellulose esters is released to form an acid (in cellulose nitrate this is nitric acid and in cellulose acetate this is

*The title of Michele's paper is "The Decay of Polymers in Information Storage Materials". She will be assisted with the presentation by her PhD student, Joan Whitehead.*

acetic acid. When the pendant group is released it diffuses through the film reel and out into the film can accounting for the acrid (nitric acid) and vinegar (acetic acid) odours that are all too frequently detected. As the acids diffuse through the film they also come into contact with the film emulsion (silver image + gelatin). Nitrogen dioxide and nitric acid are highly oxidising and fade the silver image to characteristic sepia tones.

Both acids (nitric and acetic) may decompose gelatin causing it to become sticky (nitric acid more so than acetic). In addition, in sufficient quantities these acids may instigate secondary reactions, breaking the links in the polymer chains leading to a reduction in tensile properties and dimensional stability of the film. Since the acid which is initially formed facilitates further breakdown, the degradation reaction is said to be autocatalytic.

**Figure 2**




**Cellulose Triacetate**

- - - cellulosic backbone (polymer repeat unit)

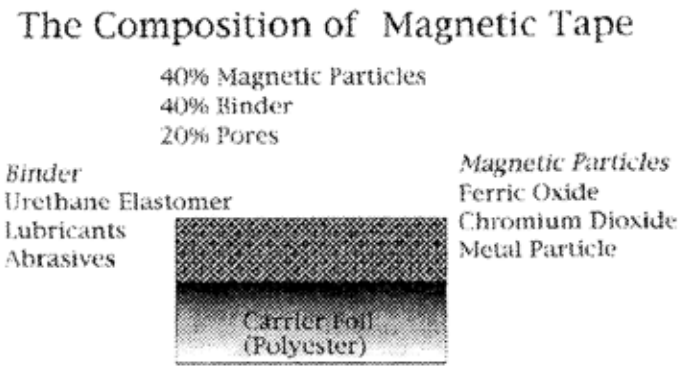
## Magnetic Tape

It is inopportune that more recent audio-visual media are also exhibiting breakdown; though perhaps we should not be surprised since they too are composed of polymers.

Figure 3 illustrates the composition of magnetic tape. This medium consists of 40% (by volume) of magnetic particles ($\gamma Fe_2O_3$, $CrO_2$ or metal particles), 40% polymeric binder (urethane or PVC elastomer, plus lubricants and abrasives) and 20% pores (to reduce friction arising from contact with tape heads on playback) which together constitute the information carrying layer. This layer is the one responsible for instability of the tape, the polyester carrier foil onto which it is coated is considered stable. The characteristics of chemically degraded magnetic tapes include the presence of sticky or particulate deposits on the tape surface and/or binder shedding.

Figure 4 illustrates the weight loss experienced on solvent extraction of three commercial magnetic tapes. The weight loss

**Figure 3**




in unaged tapes is due to extraction of additives, such as lubricants from the binder layer.

Figure 5 shows photographs taken when magnetic tapes were examined at high resolution using a Vanox microscope. Lubricants which have migrated to the film surface and then deposited can be clearly seen in older and aged magnetic tapes. A much greater weight loss is observed (Figure 4) when tapes are aged at 20% RH and 70°C for 100 days. This results in oxidation and hydrolysis of the binder, and it should be noted that the quantity of extractable materials resulting from breakdown varies from tape to tape.

Studies clearly indicate that for urethane elastomers oxidation precedes hydrolysis. Attempts to recover information from degraded magnetic tapes and an examination of signal quality clearly demonstrates that breakdown is not simply hydrolysis but must involve other processes (refer to the work of Kevin Bradley). Table 2 shows the results of an examination of the oxidative breakdown of the three commercial tapes. Two parameters are tabulated: initial peroxide concentration and carbonyl index (time to 0.1 C-O). Peroxides are formed in the binder during and subsequent to manufacture of the tapes. These species may decompose and instigate the degradation of the binder. It can be seen that initial peroxide levels are significantly different since

**Figure 4** % Weight Loss on Solvent Extraction
100 days (20% RH, 70°C)

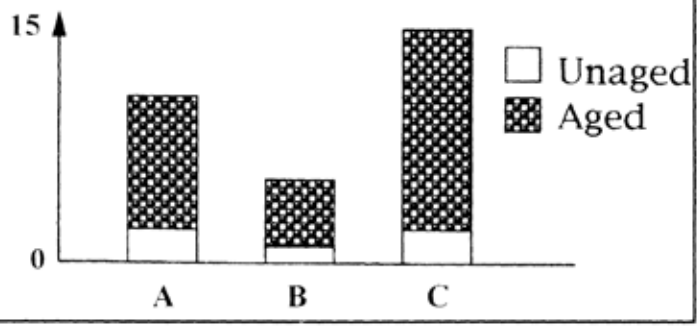
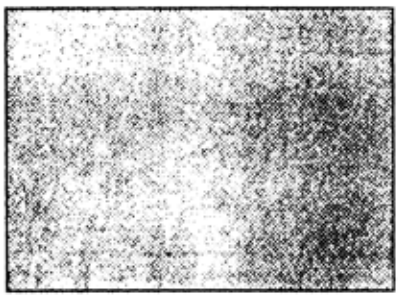
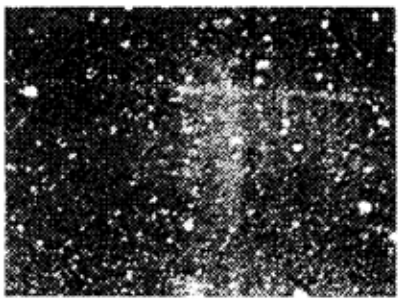


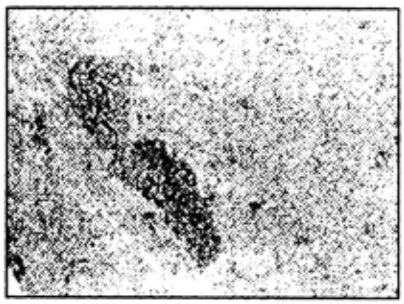

**Figure 5**
Surface analysis photographs of tapes taken by a Vanox microscope at 300X magnification



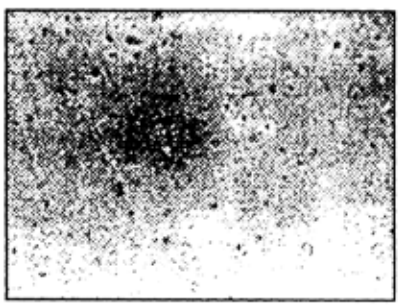
New (1990) 0.5 inch Home Video Tape (Agfa-Gevaert N.V. Belgium)



2 inch Commercial Video Tape (Scotch) made in 1976 (NFTVA, England)



2 inch Commercial Video Tape (Scotch) made in 1968 (NFTVA, England)



0.5 inch Home Video Tape (Agfa-Gevaert N.V. Belgium) aged at 90°C, 100% RH for 63

they depend upon the specific manufacturer formulation. However, this cannot in itself be used as a guide to tape stability because peroxide stability is determined by binder structure and the types of metal ions present (oxidation is in this case exacerbated by the presence and nature of the metal particles embedded in the binder). Breakdown of peroxides results, ultimately, in the production of carbonyl compounds within the binder and measurement of the rate of production of these species correlates to binder shedding.

Table 2 indicates that, though Tape C has the lowest initial peroxide level, it takes the shortest time to develop 0.1 carbonyl. After 140 days the magnetic oxide was easily brushed away from the tape surface. It should be evident by now that significant progress has been made in defining the nature of decomposition in audio-visual materials, but the key question remains .....

**Table 2**

| Manufacturer | Initial Peroxide Concentration (mg/g) | Time to 0.1 C-O (days)* |
|---|---|---|
| A | 19 | 170 |
| B | 5.6 | 210 |
| C | 2.2 | 140 |

*20% RH, 70°C

..... ***"How can the lifetime of such materials be extended?"***

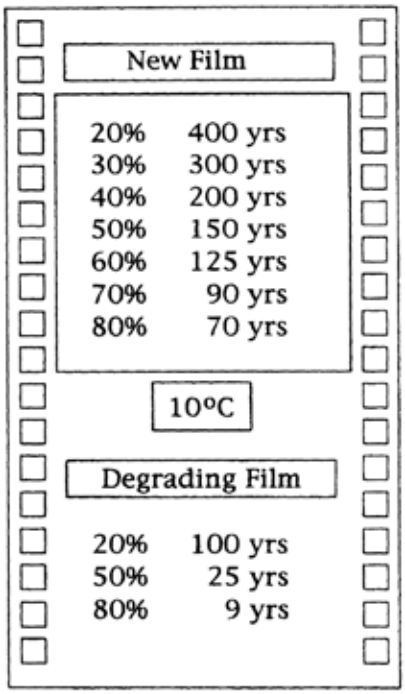
Control of environment is viewed as the primary means of extending the life of audio-visual materials. Because hydrolysis is the principal route to deterioration of a photographic film it is extremely difficult to inhibit by chemical means within the film matrix i.e. inhibition of moisture uptake by films has already been optimised by manufacturers. Since moisture is the species which brings about the hydrolysis reaction a dry atmosphere will prevent degradation.

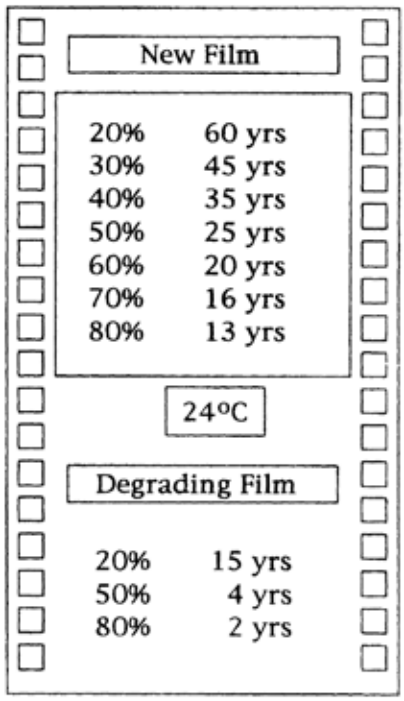
Unfortunately, the gelatin of the film emulsion needs some moisture to prevent its embrittlement. When sufficient moisture is present, an increase in temperature will serve to accelerate the hydrolysis reaction. At higher temperatures, other reactions (free-radical processes) are facilitated which are normally insignificant at ambient temperatures.

Because of this latter feature, care must be exercised when carrying out accelerated ageing tests as a means to predict film lifetime: If the mechanism of degradation changes with increasing temperature then the relationship between time to a given property change and temperature will not be a linear one. Fortunately current standards relating to film storage have been derived from information compiled from accelerated ageing tests and from direct archival experience. This having been said the standards are still subject to debate, probably because they are a compromise between good intention, economics and what is attainable practically.

A more ingenious way to use the available information pertaining to storage has been provided by the Image Permanence Institute's (IPI) Archival Storage Guides. Data taken from IPI's Archival Storage Wheel is given in Table 3. The data give an indication of the relative lifetime of either a new film (or degrading one) when kept under given conditions of temperature and relative humidity. Information on the effect of time out of storage on film lifetime is also provided by the guides. Even if storage conditions recommended by standards are not within reach, this valuable data provides the archivist with an idea of the limits imposed on film life by the actual conditions implemented.

**Table 3**
Data taken from the IPI Storage Guide for Acetate Film




Standards relating to the keeping of magnetic materials are not as clearly laid down as those for photographic film, ostensibly due to the poorer understanding of relevant factors associated with their breakdown. In the case of magnetic materials because oxidation precedes hydrolysis there are several ways in which breakdown could be inhibited, and current research is concentrating on these.

We have already said that degradation is exacerbated by confinement of the acids evolved. Though the autocatalytic reaction can be prevented by removing acid which is initially formed, it is not sufficient to place holes in film containers through which the acid vapours may escape since they may infect neighbouring films which are in good condition. The acid may be reduced by aerating the film periodically, though rewinding film is a labour intensive process.

What is needed is an inert scavenger of the acid, and this has recently been provided by Kodak's Molecular Sieves. The sieves reduce the build up of acids in the film can preventing secondary reactions taking place (refer to the work of Tulsi Ram) The film can itself also plays an important role in film stability. Recent studies show that aluminium cans are superior to tin-plated metal cans. Tin-plated cans are subject to rusting by evolved acids and may themselves contribute to oxidative breakdown of films, especially for nitrate film. Although peroxides in cellulose acetate film are considered to be stable below 160°C, their decomposition may be catalysed by metal ions at ambient temperatures. Aluminium cans do not appear to facilitate such processes.

Plastic cans commercially produced are either polyethylene or polypropylene or copolymers of these two. These plastics contain inherently greater levels of peroxides than photographic films themselves. The peroxides in plastic cans are frequently less stable than those in photographic film and their decomposition may instigate degradation reactions in the films they are in contact with. The plastic can may absorb some of the acids emanating from the film it holds, but this does not necessarily offer any beneficial effects. More research into suitable film containers is still needed.

Control of environment will never be enough and break down of film is inevitable. It follows that along with appropriate environmental control, a test is needed to identify the end of the useful life of a film. Herein lies the crux of the problem: How do we define the useful life of a film ? It has been proposed that if acidity levels build up so that pH reaches <4, then the film should be copied. So .....

## ..... How can we test for degradation?

From the moment a film is produced it begins to degrade slowly. During the time period prior to autocatalysis there is a gradual build up of acid in a film. It is possible to identify the acidity threshold to autocatalysis by means of an indicator which changes in colour, when the acidity threshold is crossed.

A number of such indicators are currently commercially available. For acetic acid these include IPI's A-D Strips and Dancan's Dancheck. For nitrate film: the Alizarin red-dye test is available. In this test a hole punch of film is placed inside a test-tube. Filter paper soaked in a solution of the Alizarin dye is then placed in the neck of the test-tube. The sample is then heated and the time for the red dye colour to be bleached is noted. A film is considered to be in good condition if little change in colour has taken place after one hour.

Generally, such colour indicators are not stable to light or require long exposure times (24 to 96 hours- or at the best 1 hour) before a colour change is noticeable. Irrespective of these problems, it is envisaged that archivists may require more than one type of indicator.

- On accession of a film by an archive an instant-response indicator is required to give immediate feedback on the condition of the film.
- When the film is shelved in the archive we require an indicator which responds to gradual build-up of acid within the film container. Here it must be appreciated that when a film is taken from the vault and the lid removed acids will escape and it will be necessary to replace the lid and leave for a further period of time when an indicator is put in the can to allow acids to build up again; in any event this will not reproduce the acidity levels which built up over years in the can. The indicator should be in constant contact with the film in the can in the archive and its change of colour should not be reversible.
- A very sensitive on-line sensor placed in the storage area capable of monitoring minute fluctuations in acidity during the course of a day would maintain optimum humidity and temperature corresponding to minimum degradation.

With this in mind indicator tests are being developed for acetate film at the *Centre for Archival Polymeric Materials*. One test uses an indicator dye which changes colour from red to yellow; here a hole-punch film sample does not need to be heated but left for 1-2 hours at room temperature. After this time dyed filter papers which show a linear colour change from their base of 1mm height or more require copying. This test method is rather labour intensive and time consuming so another indicator was developed by absorbing the dye onto a solid support.

A number of trials were carried out on films supplied by the North West Film Archive. A small quantity of the indicator was placed in the film can and examined periodically and the results are given in Table 4. The results provide a graded indication of the presence of various levels of acidity within the film can which apparently correlates with the tested pH of the film samples. A sample with pH<4 is yellow within 4 days of exposure whereas a sample of pH 5.74 remains red even after 14 days; between these two extremes a sample of pH 4.88 takes 14 days for 90% of its area to become yellow whereas a sample of pH 4.44 takes only seven days for the same amount of change. Therefore, the indicator is capable of operating over a long period when a film can is placed in a vault.

**Table 4 Colour Change of Indicator Exposed to Acetate Films**

| Sample | pH | 1 Day | 4 Days | 7 Days | 14 Days |
|---|---|---|---|---|---|
| 3 | <4.00 | 50% Yellow | 100% Yellow | 100% Yellow | 100% Yellow |
| 28 | 4.44 | 10% Yellow | 50% Yellow | 90% Yellow | 100% Yellow |
| 21 | 4.88 | 100% Red | 100% Red | 5% Yellow | 90% Yellow |
| 18 | 5 | 100% Red | 50% Pink | 5% Yellow | 100% Pink |
| 5 | 5.74 | 100% Red | 100% Red | 100% Red | 100% Pink |
| 38 | n/k | 100% Red | 100% Red | 50% Pink | 50% Pink |
| 42 | 5.7 | 100% Pink | 100% Pink | 100% Pink | 100% Pink |

The test is relatively insensitive to nitrate film and the dye used is relatively light and pollutant insensitive: A sample place near a window in Manchester city centre had not changed colour after 6 months. It is possible to modify the response time of the indicator, and this has recently been achieved; on contact with severely degraded films the indicator changed colour irreversibly in less than one minute; so it may also be used as an instant response indicator.

In conclusion, though marked progress has been made towards preserving our audio-visual heritage there is still much to be done. Only by a continued effort on the part of archivists, scientists and manufacturers can we extend these horizons.

***Ian Gilmour:***
*It appears that water is the main factor in degrading magnetic tape, in particular polyester-urethane, and that this is typically a reaction where the hydrogen ions and hydroxyl ions separate to form an alcohol and cartezolic acid which then accelerates the reaction. In order to confirm this a number of tests were conducted in which tapes were artificially aged in both inert gases, such as nitrogen, and in oxygen. The results suggest that, in order of severity, hydrolysis occurs first and then, at higher temperatures, oxidation and then, finally, pyrolysis at well above room temperatures. This has led us to want to store tapes in much lower humidities. I was wondering if you have any comments to make.*

***Michele Edge:***
*It really depends upon the specific structure of the urethane elastomer. There can be great differences between samples from different sources. In some urethane elastomers hydrolysis will dominate the reactions. In our studies, we have found that we can quite easily see the different peroxide levels in different samples and we have observed that the peroxides are decomposing so there must be oxidative degradation taking place as well. We found that the moisture that was present was serving as a plasticizer to actually enhance contact between the urethane elastomer and the pigment particles. This then facilitated the oxidation.*

***Jacques Lemaire:***
*We have been working a lot on the competition of the hydrolysis and the oxidation and in most cases oxidation precedes hydrolysis. For example, in polyester urethane the oxidation process leads to alpha carbonyl rafae which are very sensitive to water. So oxidation precedes hydrolysis.*

***Michele Edge:***
*That is precisely what we found in our results - the initial mechanism was the oxidation.*

***Gerry Gibson:***
*The chart that you showed from the Image Permanence Institute demonstrated, for example, that at 80%RH and at 10°C the tape had a life expectancy of 70 years. At 20%RH and at 24°C it had a life expectancy of 60 years. It would seem to indicate, therefore, that temperature has a major impact. That has not been addressed here. Could you comment?*

***Michele Edge:***
*The principal mechanism of the breakdown is that, to form the acid, you need moisture. All chemical reactions are subject to temperature; the higher the temperature, the faster the process takes place. There is, therefore, an interchange between the temperature and the humidity levels. If you go to very low humidity, there is no agent present to cause the reaction. If there is humidity present, then the lower the temperature the better.*

***Gerry Gibson:***
*Can we conclude, therefore, that cold and dry is best?*

***Michele Edge:***
*It depends upon how dry and how cold, because of other physical property changes. It ceases to be an issue of chemistry and becomes more a problem of physical properties.*

***Henning Schou:***
*One thing that I do not fully understand is that, if you do not know exactly how much acetic acid, which is a catalyst, is present in a film, how can you predict the life expectancy of the film?*

***Michele Edge:***
*This is also a problem. This is why we are working on an indicator. We want to be able to give an indication of how much acid can accumulate before the film is no longer viable. For nitrate film this is easy. You can directly correlate the nitrate acids given off with image fading. With acetate film, the acids create problems with copying, the emulsion becomes sticky and there are physical property changes. A simple correlation is not possible.*

***David Stebbings:***
*I wondered if anyone had studied the possibility of a microbiological activity causing the decay of these polymers.*

***Michele Edge:***
*One major area of polymer research is into biodegradation. The types of polymers that we use for tape and film supports are, in fact, reasonably resistant to bacteria. When breaking these polymers down for recycling, other materials are frequently added to try to accelerate the breakdown. What usually happens, however, is that the bacteria attack the introduced material and leave the polymer alone. So the support polymers seem to be proof against bacterial attack.*

***Tulsi Ram:***
*I want to confirm one point about cellulose nitrate films. We have traditionally thought that it is degrading faster than the acetate materials. The latest data from our tests of films in storage is showing that the pH of the nitrate films is noticeably higher. (ie it is less acid) when kept in the ideal storage conditions than the acetate. Accelerated aging tests are also indicating that the behaviour of nitrate film is better than acetate.*

***Michele Edge:***
*It depends on the parameter that you are measuring. If you are measuring the acidity levels then I agree. If, however, you examine what is given off by nitrate film when its temperature is first raised then you will find nitrogen dioxide which fades the image.*

***Friedrich Engel:***
*May I point out that not all binders of magnetic tape include polyurethanes. Some tape binders, particularly in tapes of German manufacture, are PVC based and these are more stable.*

***Michele Edge:***
*As Prof Lemaire will, I'm sure, confirm, PVC's are notoriously unstable, particularly with regard to oxidation and breakdown. It really depends upon the exact formulation. I have been talking about the work done on urethane elastomers and cannot, therefore, comment greatly about the PVC binders because we have not examined these in detail. The research has involved examining old tape samples which contain urethane elastomers.*

***Dietrich Schüller:***
*A comment about the Vinegar Syndrome and sound tapes. As a result of the Second JTS in Berlin in 1987, we examined the tapes held in the Phonogrammarchiv of the Austrian Academy of Sciences and found a tape that smelt of vinegar. It was removed from the store and placed on my desk in an open box. I have now lost an interesting demonstration item because it does not smell of vinegar any more and it is perfectly playable. I guess that there is a trade off between ventilation and enclosures; between the vinegar syndrome and dust and atmospheric pollutants.*

***Michele Edge:***
*You are right; it is the practicality. On one hand it is enclosure and the vinegar syndrome and on the other good ventilation and dust. If you merely punch holes in the boxes and cans, you run the risk of infecting adjacent films or tapes.*

***Ian Gilmour:***
*The point raised by Dietrich Schüller is timely. The indicators that have been discussed measure the concentration of acetic vapours in the air. There has been a lot of debate recently about whether it is better to aerate cans or whether it is better to keep them sealed so that a decaying film does not infect its neighbours. Could you advise on this please.*

***Michele Edge:***
*I cannot really comment on this dilemma. It is really for you to decide which course of action will be best for your collection. My work is aimed at finding out what is happening to enable you to make informed decisions.*

***Morten Jacobsen:***
*Dr Edge said that she would group indicators into two groups: long-term and short-term. The indicator that my company make, the M-Check, is placed by her in the long-term group. If I put one of my indicators in a can with a film that is only marginally smelling of vinegar, even to the nose at the start of a day when it is fresh, my indicator will show a change within a few days. If a similar test is carried out with a strongly acidic film, the indicator will change within six hours. This I would call a short-term indicator. We must also look at how long the indicator will stay in the can. Will it last for a generation or two or three? The indicator must survive as long as it is necessary for it to turn yellow. The question of ventilation of cans is interesting. There are libraries in the US where they hold the lid of the can above the base by means of small pegs. Others punch holes in the base and sides. Both increase ventilation considerably. There are countries, however, where the fire regulations do not permit this.*

***Michele Edge:***
*The grouping of indicators into long-term and short-term is merely a guide as to how long it will take to change colour. There are several good indicators available, including yours and the one Joan was speaking about, that change colour in a day or in a week or so. What is needed is an indicator that will change colour very quickly, ideally with a graded colour change that permits an estimate of the degree of acid to be made, so that films can be tested as they come into the archive.*

***Henning Schou:***
*May I ask Joan a question. You said that you use non-ionic resins for these tests. As the chemists amongst the audience will know, when you measure the pH it is, in fact, the negative logarithm of the ionised hydrogen. How confident are you that a non-ionic resin will give a realistic result?*

***Joan Whitehead:***
*I am confident because what I have done is to change the pH range of the indicator that I am using by buffering it. Also I am not measuring the pH of the film but the acetic vapour in the can. The results of the tests that I am conducting cannot be expressed in terms of a pH anyway.*

***Henning Schou:***
*An acid is only as strong as its medium and when we measure pH we talk about water as neutral at 10.7 of hydrogen etc. If the water is not present and we use non-ionic resins, presumably without water, how reliable are the results of your work?*

***Joan Whitehead:***
*I will be able to answer that point in three or four months time. The work is still in progress but the signs are that the test is going to be very reliable.*

***Henning Schou:***
*Would it be true to say that, at the moment, these indicators are at an experimental stage?*

***Joan Whitehead:***
*Yes.*

***Terry Watson:***
*The lithium red test that you described showed a colour change after one or two hours. Does this tell us where on the graph of acetate film that particular film is? Has it already passed the point of no return?*

***Joan Whitehead:***
*What I found was that a one millimetre linear colour change on the filter paper corresponded with a pH of about 4.0 or 4.5. I cannot be more specific because the test is carried out at room temperature. Variations in the ambient temperature cause variations in the results. Tests carried out in the higher temperatures of the summer months reacted much faster than tests carried out in the winter. I have carried out tests on over 100 films and I can confidently say that if the filter paper shows a one millimetre colour change then its pH is between 4.0 and 4.5.*

# Status Report on the Worldwide Molecular Sieve Trade Test Results

**Tulsi Ram, Diane Carroll-Yacoby, Paige Miller** and **Harry D. Haber**

Eastman Kodak Company, Rochester, New York, USA

## Summary of Paper Presented by Dr Ram

The Molecular Sieve Trade Test was initiated to verify the results of the accelerated laboratory tests, under the actual storage conditions at various archives worldwide. The acidity levels before and after placing molecular sieves for four months were analysed in our laboratory on paired reels of five title films of several vintages The data were analysed for changes in the level of acetic acid in the vapour phase by 3M monitors and for changes in pH and acidity levels of the film samples, using a paired T-test to predict the statistical significance and the trends in these measurements.

The evidence of the trade test is that placement of molecular sieves inside cans of low-acid chromogenic type colour and B&W motion picture films on cellulose triacetate (CTA) support decreases the acid level. This conclusion is based on the fact that the pH of the film samples was higher when the molecular sieves were used, with a confidence level of 99% or higher. the same conclusion was reached from the potentiometric analysis of acid measurements, at a confidence level of 78%, and from the 3M detector data.

Based on the statistical analysis of the trade test data, further input and comments wore solicited from the participants to verify the suitability and potential benefits, and to identify possible pitfalls, of the use of molecular sieves for film preservation.

# Status Report on the Worldwide Molecular Sieve Trade Test Results*

**A. Tulsi Ram, Diane M. Carroll-Yacoby, Paige Miller and Harry D. Heuer**

* Parts of this paper were also presented at the Association of Moving Image Archivists (AMIA) Conference, Boston, MA during November 15-19, 1994.

*Henning Schou:*

*It gives me great pleasure to welcome Dr Tulsi Ram as our next speaker. Dr Ram is involved with research into material degradation and the properties of photographic film. He is the Secretary of the American National Standards Institute IT9 Committee on Image Permanence and Physical properties and Chairman of the IT9-4 Committee on the Stability of Thermal Process Silver Film.*

*Dr Ram is also very active in research into the stability of archival film and has conceived the idea of a "chemical sponge" - the Molecular Sieve. His paper is entitled "Status Report on the Worldwide Molecular Sieve Trade Test Results".*

## Introduction

The use of molecular sieves for film preservation to combat the "Vinegar syndrome" is a relatively new technology first introduced in 1992. The results of accelerated tests[1] indicate that the addition of molecular sieves in confined storage with processed chromogenic roll films (similar to motion-picture color film) not only reduces the chances of deacetylation of the cellulose triacetate (CTA) support, but also enhances the keeping quality of the yellow and magenta image dyes and to a lesser extent, that of the cyan dye beyond that projected for currently recommended storage conditions. Preliminary data further suggests that the use of molecular sieves also arrests the oxidative attack of the imaged silver (B&W) films, without significantly affecting the physical conditions of the roll films during accelerated keeping tests.

The primary purpose of the Molecular Sieve Trade Test is to verify the results of the accelerated laboratory tests under the actual storage conditions at various archives worldwide. The acidity levels before and after placing molecular sieves for four months were analyzed in our laboratory on paired reels of five title film of several vintages. So far eight institutes, designated "A" through "H" in Table 1, have participated in the trade testing of molecular sieves in full conformance with the recommended test procedures. This joint effort has provided the desired experience with different field storage conditions and has permitted further critical evaluation of the suitability, potential benefits and possible pitfalls of molecular sieves for film preservation.

The acidity level in the vapor phase was characterized using 3M monitors, and the acidity in the film sample was determined by pH measurement and potentiometric titration according to the procedures used in the accelerated tests.[1] The data were analyzed for changes in the level of acetic acid in the vapor phase by 3M monitors and changes in pH and acidity levels of the film samples using a paired T-test to predict the statistical significance and the trends in these measurements. These data are summarized for the specific test sites in the Appendices A-H. They were combined according to film age and to storage temerature and humidity conditions to detect trends in acidity concentration in the presence and absence of molecular sieves during the four month period.

The statistical analysis of the trade test data was shared with all the participants to get additional inputs and comnents to make the necessary recommendations.

## Experimental and Analytical Limitations

Each roll-film sample was sealed in a polyethylene bag together with a 3M detector, with and without molecular sieve, to determine the acetic acid concentration in the vapor phase. These measurements were made at the start and end of the four month test period after enclosure in the sealed bag seven days. Specimens of the films were also provided in sealed glass vials for the precise determination of pH and total acidity.

Although sufficient care was exercised by all the participants in handing the 3M detectors and providing the film samples in sealed glass vials for the analysis, it is imperative that the total acidity of the specimen is precisely quantified by the analytical procedures that were followed. Since the sample population exhibited extreme swings in the acid levels, some of the pertinent limitations in the analytical test methods used, and the data handling are discussed below.

**1. 3M Vapor Detectors:**

This GC procedure provides linearity in the detection of acetic acid concentration only between 0.002 and about 25 mg/sample. However, the acetic acid vapor concentration detected by the 3M monitors ranged from 0.002 to more than 25mg/specimen after the fixed 7 day exposure, as shown in Appendices A-H. The very high values came from severely degraded films. In order to avoid erroneous conclusions, values above 20.000 mg/specimen were not used in the statistical analysis, except as one group of pooled data of all severely degraded films. It should be noted, however, that the 3M detector is well suited to characterize the early stages of film support degradation and for quantification of acidic volatiles under a range of storage temperatures from 2 to 30°C.

**2. pH Determination:**

The total acids present in the film specimen are eluted in distilled water at room temperature similar to cold extraction pH measurements used with ASTM/ANSI standards. In all cases, one gram of the film sample cut into small pieces was immersed in 100 mL of distilled water ancl later stirred using a magnetic stirrer for three hours before measurim the pH. Duplicate analyses were performed, and the average of the two measurements are reported.

## Table 1: Participating Sites

**Test site A:**
National Film Center, Tokyo, Japan.
Dr Harry Iwano, Fuji Ashigara Laboratory and Mr Masatoshi Obba, National Film Center, Tokyo. (Vault built in 1985).
STORAGE CONDITIONS:
Film A1 to A4 kept at 5°C and 40% RH for a maximum of 8 years and film A5 kept at 26°C and 65% RH (ambient).

**Test site B:**
Toho Print Center, Tokyo.
Mr Junichi Kohno, Konica Corporation and Mr Kazunori Nishida, Imagica - both of Tokyo, Japan.
STORAGE CONDITIONS:
Film B1 to B5 are constantly used but kept in a storage area maintained at 22°C and about 60% RH (ambient).

**Test site C:**
Royal Cinemathèque, Brussels, Belgium.
Dr. Karel Brems, Agfa, Mortsel, Belgium.
STORAGE CONDITIONS:
Film Cl to C5 are kept at 15°C and 45% RH, but the actual time spent in the cold vaults is not certain.

**Test site D:**
George Eastman House, Rochester, New York, USA
Dr. Christopher Horak and Mr. Edward Stratman, GEH, Rochester.
STORAGE CONDITIONS:
Films Dl to D10 were evaluated under several different storage conditions, and are not part of the paired reel comparisons used for the trade tests. Data included for completeness.

**Test site E:**
National Archives of Canada, Ottawa, Canada
Dr. Klaus Hendriks and Mr. William O' Farrell, Ottawa.
STORAGE CONDITIONS:
Film E1 to E5 were kept at 20°C and 35% RH for a maximum of 20 years.

**Test site F:**
Library of Congress, Washington, DC, USA.
Mr. David Francis and Mr. Gerry Gibson, Washington.
(Vault built in 1977).
STORAGE CONDITIONS:
Film F1 to F5 were kept at 2°C and 25% RH for a maximum of 16 years. The longest cold and dry storage conditions. Film F6 to F8 are currently repeated due to some doubts whether film F3, F4 and F5 were indeed kept in cold storage for a maximum of 16 years.

**Test site G:**
National Film and Sound Archives, Canberra, Australia
Mr. Mark Nizette, Canberra.
STORAGE CONDITIONS:
Film Gl & G2 were kept at 21°C and 40% RH; film G3 at 9°C and 41% RH; and film G4 & G5 at 7°C and 47% RH but not sure for a maximum of 33 years?

**Test site H:**
Les Archives du Film, Bois d'Arcy, France.
Mr. Daniel Toussaint, Paris, France
STORAGE CONDITIONS:
Film H1 to H5 are kept at 12°C and 44% RH, but not sure for a maximum of 40 years. The four month keeping of the paired reels is now completed.

Similar to the 3M monitors, pH is effective at the initial stages of film degradation, but is limited to the pKa of acetic acid (pH of 1N acetic acid = 2.9). At a measured pH of 6.0 it corresponds to $1.0 \times 10^{-6}$ moles/liter of $H^+$ ion concentration and, assuming it is all acetic acid, is 0.06 mg of acetic acid/gram of the film sample or 0.001 meq of acetic acid/gram of film sample. The latter values are quoted in the potentiometric titrations. similarly, a pH of the film sample of 4.0 in these analyses corresponds to 0.1 meq/g or 6 mg/g of acetic acid. Hence, even in severely degraded films, the pH of the film sample may not reach appreciably below 3.0, if only acetic acid is present. The pH values ranged between 3.0 to 6.0 units per gram of film in 100 mL of distilled water.

**3. Potentiometric Analysis of Acid:**

One gram of the total film (emulsion plus support) was analyzed by dissolving the CTA support in benzyl alcohol and in chlorobenzene by heating to about 100°C and then titrating with hexadecyltrimethylammonium hydroxide (HDTMAH). The potentiometric titration was carried out at about 40°C, with the undissolved gelatin emulsions remaining in the solution. The 95% confidence interval for the titration results is +/- 0.5%. This value has been determined from the analysis of replicates of variety of materials. The actual precision may vary somewhat from this estimate. The acidity values ranged between 0.005 to 1.660 milliequivalents/gram, (meq/g), of film sample. It is recognized that some loss in the total acidity is likely to occur due to evaporation, because of the heating that is required to dissolve the CTA polymer in this method.

## Statistical Analysis

Among the eight sites listed in Table 1, the data from the George Eastman House (Dl to D10) were excluded, as it was not performed as paired reels of the title films both with and without molecular sieves. Such an inclusion would bias the data with higher mean values for reels containing molecular sieves.

The available data from all the seven sites (A, B, C, E, F, G and H) were pooled together (n = 35) for the analysis. The statistical significance of the acid levels was determined using a paired T-test at the end of four months' keeping to study the effects of the molecular sieves at their respective storage conditions and ages. The replicate values at the start of the test (t = 0) were averaged as the 'original' value, although the two replicate reels of the same title film showed some variability in the initial data set. The missing data, mostly in the pH and acidity of the film values, is designated as '.' in the tables, as there were some

difficulties experienced in acquiring adequate film samples. Hence, the data for pH and the acidity of the films is reduced to a sample size of n = 28. Each site analyzed five title films of different vintage. There are many variables present in this data set, which are outlined as follows:

All films were on cellulose triacetate (CTA) supports made by different manufacturers, processed in various chemistries, and of different vintage. The past storage history of these films prior to vault storage is not known for many samples in this study. It is recognized that four-month keeping due to the presence or absence of molecular sieves in these reels is a short period, but is evaluated to study the statistical trends in the data.

## Results and Discussion

The composite data from all the eight trade test sites is shown in Table II showing the different levels of acidity in the samples at the start and after four months in the presence and absence of molecular sieves. The data are arranged as a function of the processed age of the film (0.2 to 42 years), the storage temperature (2 to 26°C), and the storage relative humidity (25 to >65% RH).

| Variable - | Range |
|---|---|
| Number of years after processing - | 0.2 to 42 years |
| Number of years in cold/dry vaults - | 0.0 to 42 years |
| Temperature of storage - | 2 to 26°C |
| Humidity of storage - | 25 to >65% RH |
| Constant use vs confined storage - | Site B vs the rest |
| Analytical precision of the data - | 3M monitor, pH, acidity |
| Replicate reels at start, t=0 - | 3M monitor, pH, acidity |
| Size of reel and amount of MS used - | 2-3 sites varied |
| Film types used - | B&W, colour, negs & prints |

## I. Observations noted in the paired T-test data:

Only the film samples from the test sites "A" through "H" in Table II with an '*' sign, were used for the paired T-test comparisons. These paired data are further illustrated as a function of the ascending storage temperatures at the above seven sites in Figure 1 for the 3M detector data, in Figure 2 for the acidity by the potentiometric method, and in Figure 3 for the pH changes in the film samples. Both the x and y axis scales in Figures 1-3 were kept constant, with the x-axis ranging from 0 to 50 years, so that the data could be followed as a function of the processed age of the film at any given site with respect to their storage conditions. The original values are designated by the symbol "o", the samples without molecular sieves at the end

of four months by a '+' symbol, and the samples containing the molecular sieves by an '*' in these figures. A best fit linear regression line was also plotted for the three conditions:

'___ ___' - original
'_____' - without MS
'-----' - with MS

which are also shown Figures 1-3. The following observations in the data from Table II and Figures 1-3 are noteworthy.

1. Prior histogram of the available data suggested that it contained a large number of samples (n = 30) with relatively low-acid levels, and a few samples (n = 5) with significant vinegar syndrome detectable in the film and also in the vapor phase.

2. A regression analysis of the data also suggested the age of the film sample, storage time in the vaults, and temperature and humidity of storage as significant variables that might be responsible for the measured acidity in the population.

3. The level of acidity did not appear to increase linearly with the processed age of the film, and/or the time in the vault, but appears to increase abruptly to significantly high levels after thirty years of processing. It is more apparent in certain sites exhibited by the poor fit of the linear regression lines shown in Figures 1-3. In some cases, a quadratic line best fits the data.

4. Deviation from (3) is noted with F5 from the Library of Congress which was kept at 2°C and 25% RH suggesting the benefits of cold and dry storage conditions. Also seen with sites A, C, E through H in Figures 1-3, are the benefits of good storage conditions.

5. However, significant deviation from (3) was also noticed with film samples from test site Bl to B5 which are constantly used although kept at ambient storage of 22°C and 60% RH for films of similar vintage. This implies that as the acids are expelled from the films by ventilation and/or volatile diffusion of acetic acid due to use (winding and unwinding of the roll film), the total acidity in the film even after 39 years under these adverse storage conditions is relatively low compared to the other counterparts mintained under confined storage. This anomaly can be readily seen for the site B in Figures 1-3.

6. An example of the prior storage history of the film before placing in the vault is noted with E4 and E5 films in Table II, which were kept at 20°C and 30% RH for 20

years. The 26-year-old E5 shows significantly higher levels of vinegar syndrome than the 27-year-old E4 film from the National Archives in Canada. Similar behavior is noted in G4 and G5 films after about 30 years of storage.

## II. Paired T-test analysis:

The combined data of all the samples used with the paired T-test analysis is graphically illustrated as a function of number of years after processing in Figure 4 for the 3M data, in Figure 5 for the acid levels, and in Figure 6 for the changes in the pH values. Significant scatter in the data is observed in Figures 4-6, as they encompass a variety of storage conditions. A paired T-test was performed to compare the mean levels for film samples stored with and without molecular sieves. The data was analyzed in the following three possible combinations:

**Method A:**
The combined data from the paired samples was used independent of the storage conditions and age of the film by setting an upper limit of 20.000 mg/sample in the 3M monitor data, which eliminated film A5, C5, G5, and H5 for the analysis of the 3M detector values. This reduced the sample size for this parameter to n = 31, instead of n = 35.

**Method B:**
In this analysis, all the high-acid films (A5, C5, E5, G5, and H5) were eliminated from the combined data set of the paired samples for all three parameters (3M data, pH and acidity). This reduced the sample size for pH and acidity to (n = 23) and for the 3M data to (n = 30). Only the E5 film in the combined data set (Method A) was slightly below 20.000 mg/sample - the upper limit set for the 3M detector values.

**Method C:**
In the third analysis, only the high-acid acid films (A5, C5, E5, G5, and H5) are used. The actual 3M detector values (even beyond the 20.000 mg/sample) are included, but only with a sample size of (n = 5).

The results analyzed by the three combinations above are shown in Table III. With regard to pH measurements, the effect of molecular sieves is statistically significant and in the expected direction (their presence yield higher pH values) with confidence level 99% or greater for both the combined data and also for the low-acid samples.

The potentiometric analysis of acid shows that for the low-acid films, the films with molecular sieves have a lower mean level of acid than the films without molecular sieves, although this would be significant with only 78% confidence. This low confidence level can be attributed to several factors: there is a lot of noise in

| Test Site Code | Years After Processing | Temp° C | % RH | Years in Vault | Type | 3M Detector g/sample | pH | Acid meq/gm |
|---|---|---|---|---|---|---|---|---|
| F1* | 0.2 | 2 | 25 | 0.2 | Original | 0.019 | | |
| | | | | | w/o MS | 0.086 | | |
| | | | | | with MS | 0.073 | | |
| E1* | 0.8 | 20 | 35 | 0.8 | Original | 0.034 | 5.075 | 0.005 |
| | | | | | w/o MS | 0.029 | 5.070 | 0.015 |
| | | | | | with MS | 0.029 | 5.370 | 0.011 |
| C1* | 1.0 | 15 | 45 | 1.0 | Original | 0.032 | 4.960 | 0.047 |
| | | | | | w/o MS | 0.003 | 5.110 | 0.029 |
| | | | | | with MS | 0.004 | 4.960 | 0.047 |
| F6 | 2.0 | 2 | 25 | 1.0 | Original | 0.017 | 5.710 | 0.043 |
| | | | | | w/o MS | | | |
| | | | | | with MS | | | |
| H1* | 2.0 | 12 | 44 | 2.0 | Original | 0.081 | 5.960 | 0.020 |
| | | | | | w/o MS | 0.036 | 4.680 | 0.015 |
| | | | | | with MS | 0.028 | 6.210 | 0.015 |
| D4 | 2.0 | 15 | 50 | 2.0 | Original | 0.062 | 5.490 | 0.039 |
| | | | | | w/o MS | | | |
| | | | | | with MS | | | |
| G1* | 2.0 | 21 | 40 | 2.0 | Original | 0.110 | 5.045 | 0.030 |
| | | | | | w/o MS | 0.090 | 4.660 | 0.031 |
| | | | | | with MS | 0.084 | 4.900 | 0.031 |
| F2* | 10.0 | 2 | 25 | 10.0 | Original | 0.008 | 5.935 | 0.041 |
| | | | | | w/o MS | 0.062 | 4.540 | 0.037 |
| | | | | | with MS | 0.017 | 5.860 | 0.037 |

| Test Site Code | Years After Processing | Temp° C | % RH | Years in Vault | Type | 3M Detector g/sample | pH | Acid meq/gm |
|---|---|---|---|---|---|---|---|---|
| B1* | 2.0 | 22 | 60 | 2.0 | Original | 0.049 | | |
| | | | | | w/o MS | 0.022 | | |
| | | | | | with MS | 0.029 | | |
| A1* | 3.0 | 5 | 40 | 3.0 | Original | 0.063 | 4.880 | 0.005 |
| | | | | | w/o MS | 0.003 | 4.730 | 0.007 |
| | | | | | with MS | 0.006 | 5.230 | 0.008 |
| H2* | 6.0 | 12 | 44 | 6.0 | Original | 0.085 | 5.955 | 0.008 |
| | | | | | w/o MS | 0.051 | 6.060 | 0.016 |
| | | | | | with MS | 0.043 | 6.080 | 0.012 |
| D2 | 7.0 | 10 | 40 | 7.0 | Original | 0.114 | 4.800 | 0.042 |
| | | | | | w/o MS | | | |
| | | | | | with MS | 0.057 | 4.940 | 0.053 |
| E2* | 7.0 | 20 | 35 | 6.0 | Original | 0.062 | 5.300 | 0.005 |
| | | | | | w/o MS | 0.079 | 4.800 | 0.018 |
| | | | | | with MS | 0.071 | 5.170 | 0.018 |
| G2* | 7.0 | 21 | 40 | 7.0 | Original | 3.050 | | |
| | | | | | w/o MS | 1.163 | | |
| | | | | | with MS | 0.968 | | |
| F7 | 8.0 | 2 | 25 | 6.0 | Original | 0.002 | 5.770 | 0.021 |
| | | | | | w/o MS | | | |
| | | | | | with MS | | | |
| E3* | 15.0 | 20 | 35 | 8.0 | Original | 0.124 | 4.240 | 0.031 |
| | | | | | w/o MS | 0.126 | 4.460 | 0.036 |
| | | | | | with MS | 0.127 | 4.350 | 0.028 |

**Table II** Molecular Sieve Trade Test Composite Data With and Without MS after Storage for 4 Months

| Test Site Code | Years After Processing | Temp° C | % RH | Years in Vault | Type | 3M Detector g/sample | pH | Acid meq/gm |
|---|---|---|---|---|---|---|---|---|
| D1 | 10.0 | 10 | 40 | 10.0 | Original | 0.027 | 5.080 | 0.005 |
| | | | | | w/o MS | | | |
| | | | | | with MS | 0.020 | 5.460 | 0.024 |
| A2* | 11.0 | 5 | 40 | 8.0 | Original | 0.033 | 4.585 | 0.015 |
| | | | | | w/o MS | 0.035 | 4.730 | 0.017 |
| | | | | | with MS | 0.009 | 4.420 | 0.015 |
| B2* | 11.0 | 22 | 60 | 11.0 | Original | 0.089 | 5.285 | 0.055 |
| | | | | | w/o MS | 0.069 | 5.520 | 0.040 |
| | | | | | with MS | 0.024 | 5.600 | 0.045 |
| G3* | 13.0 | 9 | 41 | 13.0 | Original | 0.930 | 6.035 | 0.026 |
| | | | | | w/o MS | 0.046 | 4.930 | 0.022 |
| | | | | | with MS | 0.050 | 4.750 | 0.021 |
| C2* | 13.0 | 15 | 45 | 13.0 | Original | 0.093 | 4.800 | 0.042 |
| | | | | | w/o MS | 0.058 | 4.400 | 0.023 |
| | | | | | with MS | 0.076 | 5.320 | 0.034 |
| F8 | 15.0 | 2 | 25 | 14.0 | Original | 0.027 | 5.405 | 0.038 |
| | | | | | w/o MS | | | |
| | | | | | with MS | | | |
| B3* | 23.0 | 22 | 60 | 23.0 | Original | 0.187 | | |
| | | | | | w/o MS | 0.053 | | |
| | | | | | with MS | 0.101 | | |
| D3 | 25.0 | 15 | 50 | 19.0 | Original | 0.074 | 5.620 | 0.015 |
| | | | | | w/o MS | | | |
| | | | | | with MS | 0.003 | 5.180 | 0.027 |
| H3* | 18.0 | 12 | 44 | 18.0 | Original | 0.034 | 5.900 | 0.024 |
| | | | | | w/o MS | 0.055 | 5.800 | 0.042 |
| | | | | | with MS | 0.045 | 6.040 | 0.013 |
| F4* | 20.0 | 2 | 25 | 16.0 | Original | 0.009 | 5.280 | 0.032 |
| | | | | | w/o MS | 0.036 | 4.290 | 0.034 |
| | | | | | with MS | 0.017 | 4.490 | 0.032 |
| A3* | 22.0 | 5 | 40 | 8.0 | Original | 0.096 | 4.495 | 0.019 |
| | | | | | w/o MS | 0.136 | 4.420 | 0.013 |
| | | | | | with MS | 0.080 | 4.590 | 0.020 |
| H4* | 23.0 | 12 | 44 | 23.0 | Original | 0.025 | 5.855 | 0.022 |
| | | | | | w/o MS | 0.032 | 4.710 | 0.011 |
| | | | | | with MS | 0.046 | 5.660 | 0.012 |
| C3* | 23.0 | 15 | 45 | 23.0 | Original | 0.022 | 5.550 | 0.014 |
| | | | | | w/o MS | 0.003 | 4.860 | 0.005 |
| | | | | | with MS | 0.005 | 5.680 | 0.007 |
| D7 | 23.0 | 22 | 50 | 13.0 | Original | 0.002 | 5.640 | 0.005 |
| | | | | | w/o MS | | | |
| | | | | | with MS | 0.002 | 5.490 | 0.017 |
| G4* | 31.0 | 7 | 47 | 31.0 | Original | 1.265 | | |
| | | | | | w/o MS | 0.243 | | |
| | | | | | with MS | 0.410 | | |
| A4* | 32.0 | 5 | 40 | 8.0 | Original | 0.208 | 4.215 | 0.053 |
| | | | | | w/o MS | 0.067 | 3.840 | 0.230 |
| | | | | | with MS | 0.070 | 4.280 | 0.037 |

**Table II** Molecular Sieve Trade Test Composite Data With and Without MS after Storage for 4 Months

| Test Site Code | Years After Processing | Temp° C | % RH | Years in Vault | Type | 3M Detector g/sample | pH | Acid meq/gm |
|---|---|---|---|---|---|---|---|---|
| E5* | 26.0 | 20 | 35 | 20.0 | Original | 14.300 | 3.750 | 0.325 |
| | | | | | w/o MS | 18.300 | 3.660 | 0.330 |
| | | | | | with MS | 14.700 | 3.770 | 0.270 |
| E4* | 27.0 | 20 | 35 | 20.0 | Original | 0.055 | 4.915 | 0.012 |
| | | | | | w/o MS | 0.058 | 5.090 | 0.016 |
| | | | | | with MS | 0.079 | 4.840 | 0.012 |
| D8 | 30.0 | 22 | 50 | 18.0 | Original | 0.137 | 4.400 | 0.037 |
| | | | | | w/o MS | | | |
| | | | | | with MS | 0.137 | 5.460 | 0.047 |
| B4* | 30.0 | 22 | 60 | 30.0 | Original | 0.386 | | |
| | | | | | w/o MS | 0.113 | | |
| | | | | | with MS | 0.193 | | |
| F3* | 31.0 | 2 | 25 | 16.0 | Original | 0.026 | 5.445 | 0.024 |
| | | | | | w/o MS | 0.081 | 4.380 | 0.016 |
| | | | | | with MS | 0.081 | 4.580 | 0.020 |
| D10 | 40.0 | 25 | 60 | 19.0 | Original | 14.260 | 3.420 | 0.470 |
| | | | | | w/o MS | | | |
| | | | | | with MS | >20.000 | 3.870 | 0.300 |
| D9 | 40.0 | 25 | 60 | 10.0 | Original | 18.360 | 3.300 | 0.480 |
| | | | | | w/o MS | | | |
| | | | | | with MS | >20.000 | 3.500 | 0.340 |

| Test Site Code | Years After Processing | Temp° C | % RH | Years in Vault | Type | 3M Detector g/sample | pH | Acid meq/gm |
|---|---|---|---|---|---|---|---|---|
| C4* | 32.0 | 15 | 45 | 32.0 | Original | 0.055 | 4.820 | 0.012 |
| | | | | | w/o MS | 0.011 | 5.710 | 0.012 |
| | | | | | with MS | 0.006 | 5.530 | 0.015 |
| G5* | 33.0 | 7 | 47 | 33.0 | Original | >20.000 | 3.320 | 1.500 |
| | | | | | w/o MS | >20.000 | 3.200 | 1.100 |
| | | | | | with MS | >20.000 | 3.110 | 1.600 |
| B5* | 39.0 | 22 | 60 | 39.0 | Original | 0.242 | 4.820 | 0.014 |
| | | | | | w/o MS | 0.156 | 5.650 | 0.008 |
| | | | | | with MS | 0.077 | 5.680 | 0.007 |
| F5* | 40.0 | 2 | 25 | 16.0 | Original | 0.051 | | |
| | | | | | w/o MS | 0.248 | | |
| | | | | | with MS | 0.124 | | |
| H5* | 40.0 | 12 | 44 | 21.0 | Original | >20.000 | 3.150 | 1.660 |
| | | | | | w/o MS | >20.000 | 3.030 | 1.690 |
| | | | | | with MS | >20.000 | 3.160 | 1.400 |
| A5* | 40.0 | 26 | 65 | 40.0 | Original | >20.000 | 3.365 | 0.850 |
| | | | | | w/o MS | >20.000 | 3.490 | 0.720 |
| | | | | | with MS | >20.000 | 3.240 | 1.100 |
| C5* | 42.0 | 15 | 45 | 42.0 | Original | >20.000 | 3.305 | 1.250 |
| | | | | | w/o MS | >20.000 | 3.150 | 1.300 |
| | | | | | with MS | >20.000 | 3.210 | 1.400 |

**Table II** Molecular Sieve Trade Test Composite Data With and Without MS after Storage for 4 Months

the data, partly due to varied storage histories of the films, the sample size is small and with larger sample sizes the effect would become more significant, the effect of molecular sieves is not that strong after four months, or there is no effect of molecular sieves. In the high-acid films, the effect of the molecular sieves on the acid level is in the opposite direction but with a similar confidence level (72%). One must be extremely cautious before using a result based upon five samples, particularly when the samples are so varied and the results run counter to previous work on molecular sieves. As there are two populations of acid levels in the data, the results of the entire data set are probably meaningless.

The 3M vapor detector measurements show no difference among the low-acid samples, a large difference among the high-acid samples with (81.8% confidence), and among all the samples used (excluding the values >20.000 mg/sanple, which were above the test capability), the results were pointing in the direction and the means were different with 70.14% confidence. Again, the low confidence levels exist for the same potential reasons listed for the potentiometric analysis of acid.

| **Table III** | Method A - Combined Data | | | Method B - Combined Data with High-Acid Films (A5, C5, E5, G5 and H5) Excluded | | | Method C - Using Only High-Acid Films (A5, C5, E5, G5 and H5) | | |
|---|---|---|---|---|---|---|---|---|---|
| Film Measurement Parameter | pH | Acid eq/gm | 3M Detector g/sampl | pH | Acid eq/gm | 3M Detector g/sample | pH | Acid eq/gm | 3M Detector g/sample |
| Sample Size - N | 28 | 28 | 31 | 23 | 23 | 30 | 5 | 5 | 5 |
| Mean Original | 4.8657 | 0.2192 | 0.7042 | 5.1891 | 0.0240 | 0.2510 | 3.3780 | 1.1170 | 28.5437 |
| Mean without MS | 4.6061 | 0.2083 | 0.6952 | 4.8887 | 0.0301 | 0.1083 | 3.3060 | 1.0280 | 32.5740 |
| Mean with MS | 4.8600 | 0.2238 | 0.5701 | 5.1996 | 0.0216 | 0.0991 | 3.2980 | 1.1540 | 26.5940 |
| Confidence Level for Paired T-Test Due to MS | 9.01 | 5.96 | 70.14% | 9.11 | 8.27 | 11.66% | 0.93 | 1.92 | 81.80% |

**Molecular Sieve Trade Test Data - Paired Reels Only With and Without MS After Four Months Storage**

The mean levels for the original (time = o) measurements are also shown as a reference in Table III. It can be seen, for example, that, among the low-acid films, the original and four-month samples with molecular sieves, the mean pH levels are nearly identical, while the mean pH decreased after four months without molecular sieves. A similar conclusion holds for the acid level among the low-acid samples. The original data was also used to provide additional degrees of freedom to estimate the standard deviation used in the T-test.

## Conclusions

The evidence regarding the effect of molecular sieves on the pH of the filrn samples clearly points to higher pH levels when molecular sieves are present with confidence level 99% or greater. The potentiametric analysis of acid measurements of the same film yield only 78% confidence, but coupled with earlier studies that showed a significant effect of molecular sieves, and the short duration of these practical tests and their varied film storage histories, the logical conclusion is that there is an effect of molecular sieves on the low-acid films, specifically that storage with molecular sieves decreases the acid level. The same can be said for the 3M detector measurements when looking at the combined data and when looking at the high-acid films.

## Acknowledgments

The help rendered by Mr. Joseph Gatas for the pH measurements, Mr. Daniel Linehan for the potentiometric analysis, and Mr. Joseph Winter for the GC analysis of the 3M vapor monitors are gratefully acknowledged.

## Reference

1. A. Tulsi Ram, David F. Kopperl, Richard C. Sehlin, Stephanie Masaryk-Morris, James L. Vincent and Paige Miller, *The Effects and Prevention of the 'Vinegar Syndrome'*, Journal of Imaging Science and Technology, 38: 249-261, May/June 1994.

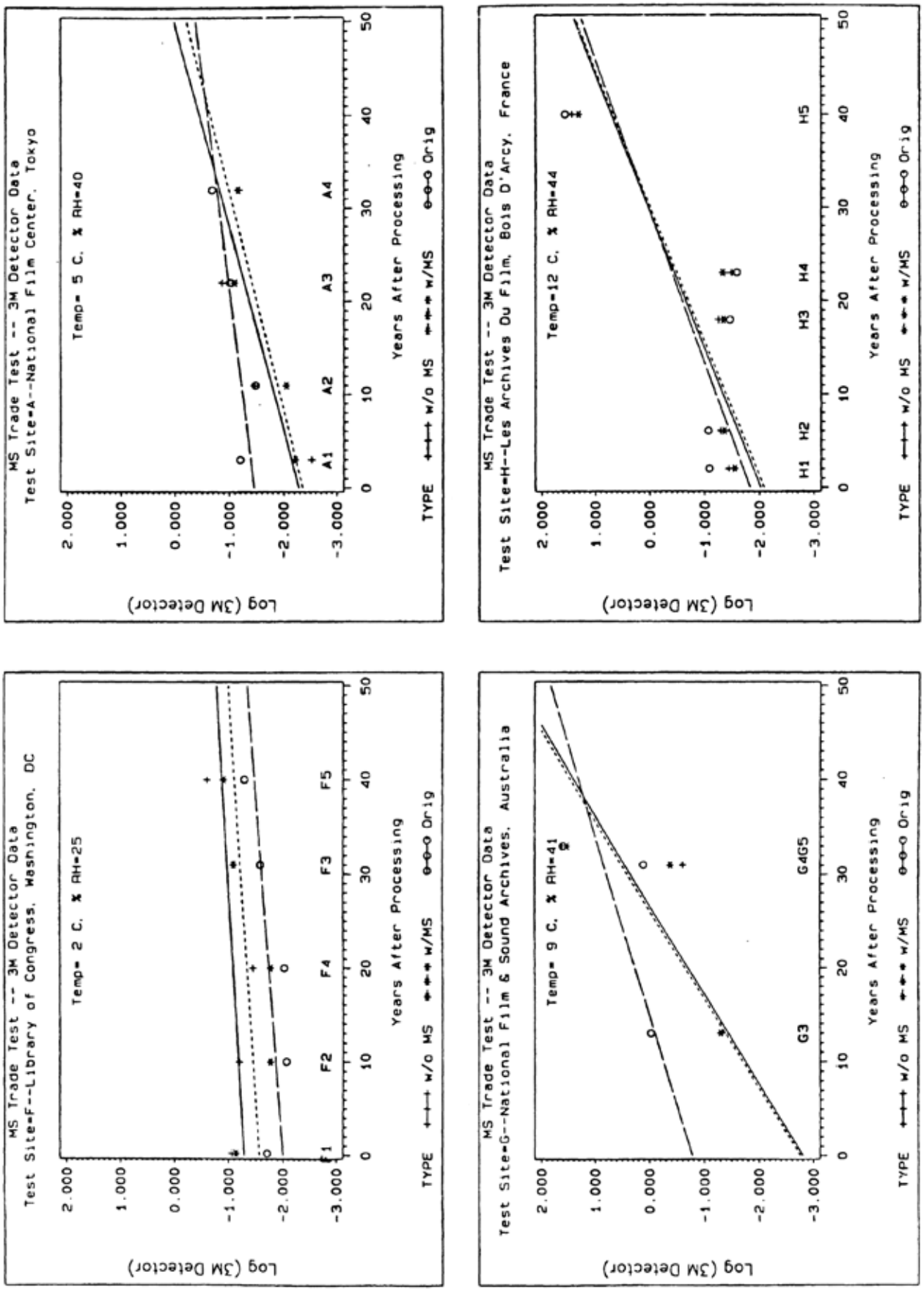



**Figure 1: 3M Detector Data at the Test Sites**

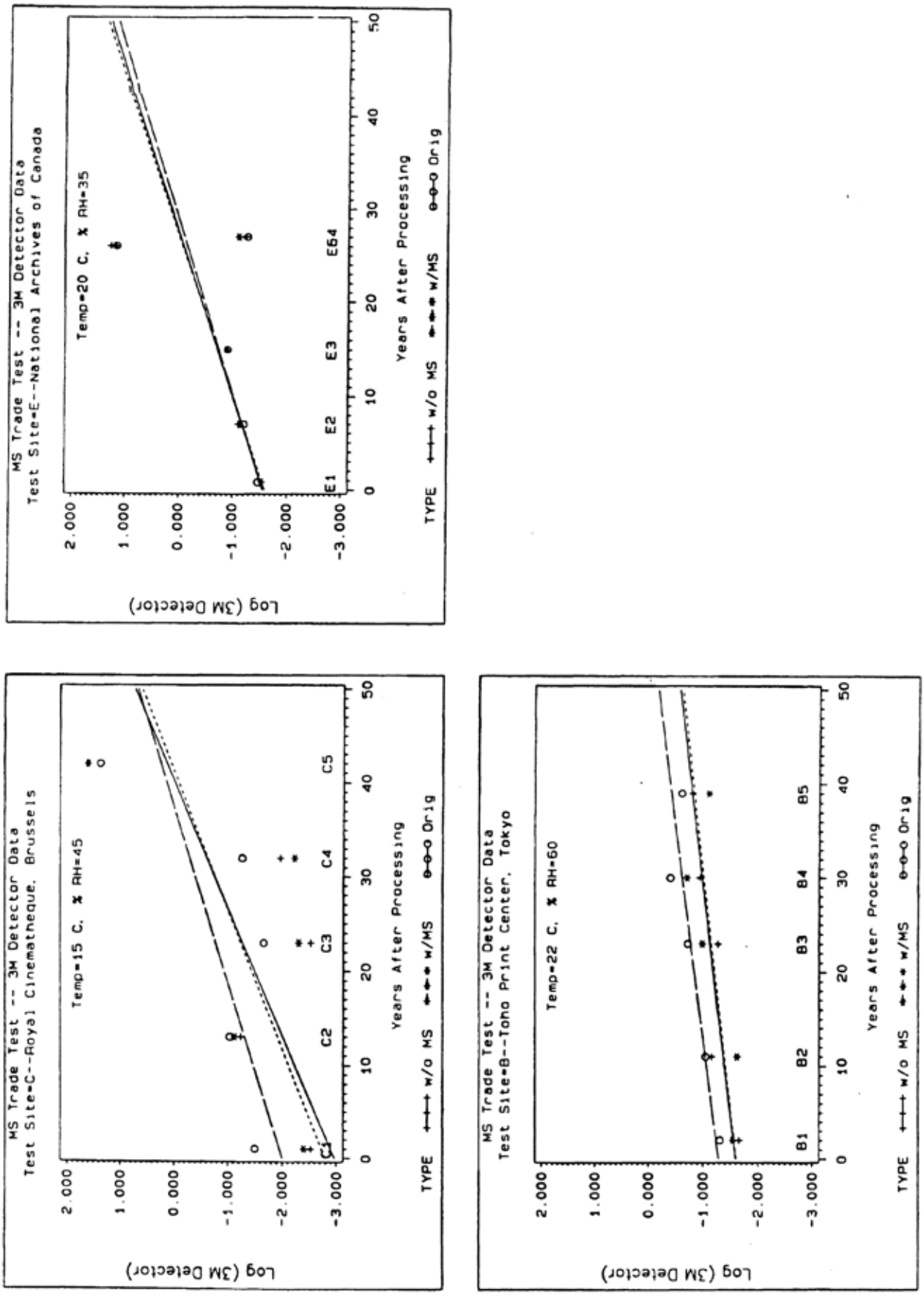



**Figure 1: 3M Detector Data at the Test Sites**

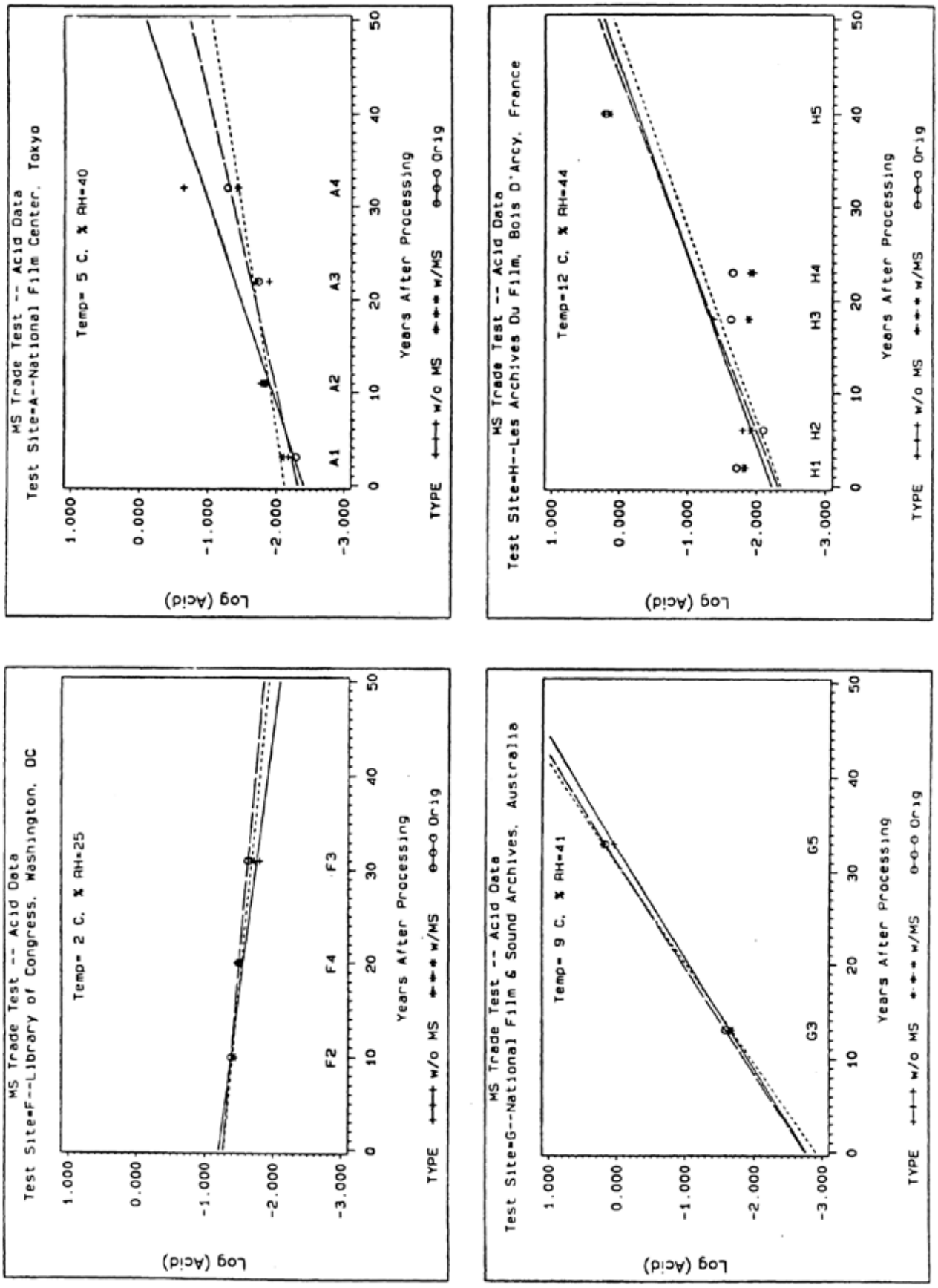



**Figure 2: Film Acidity Data at the Test Sites**

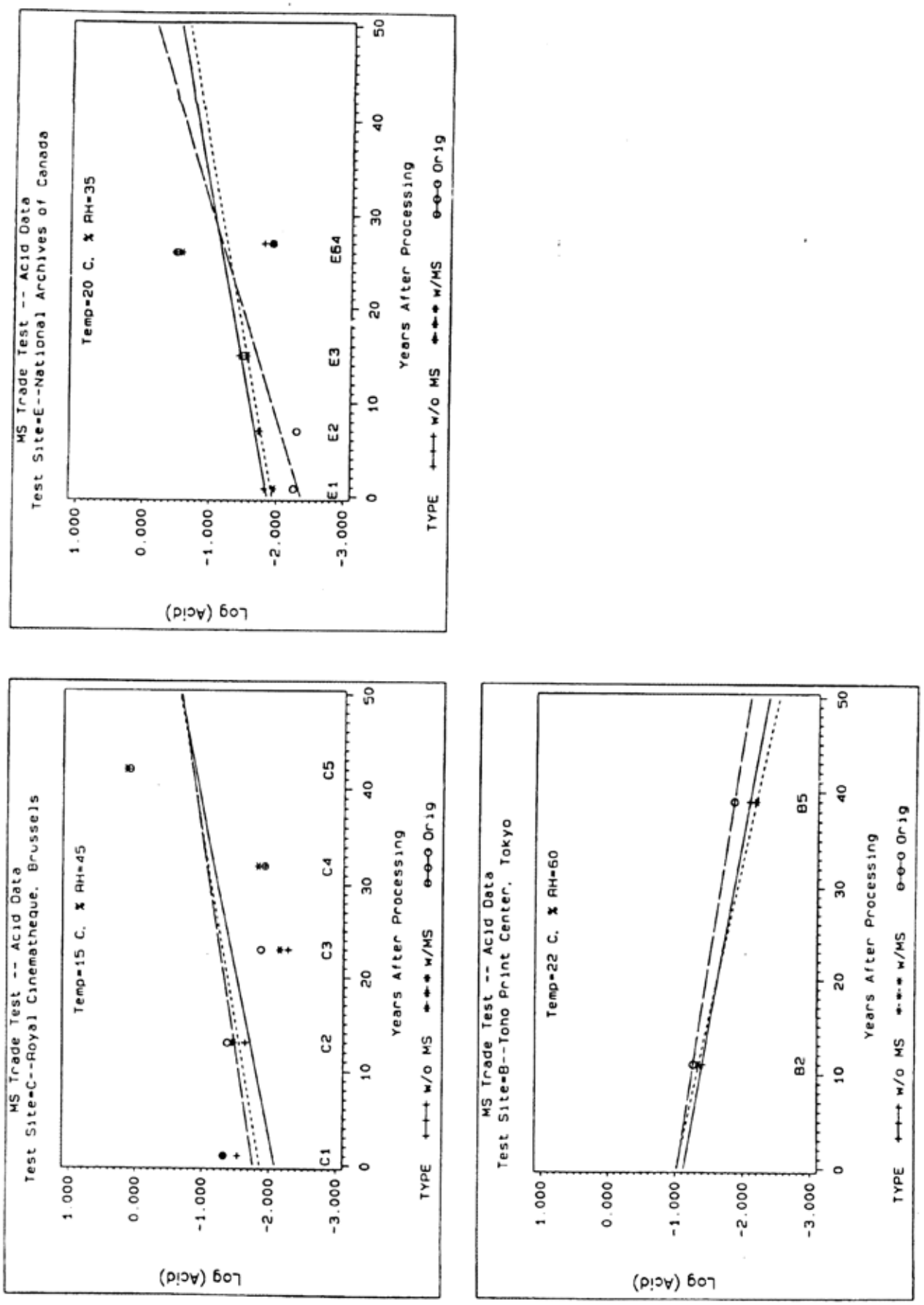



**Figure 2: Film Acidity Data at the Test Sites**

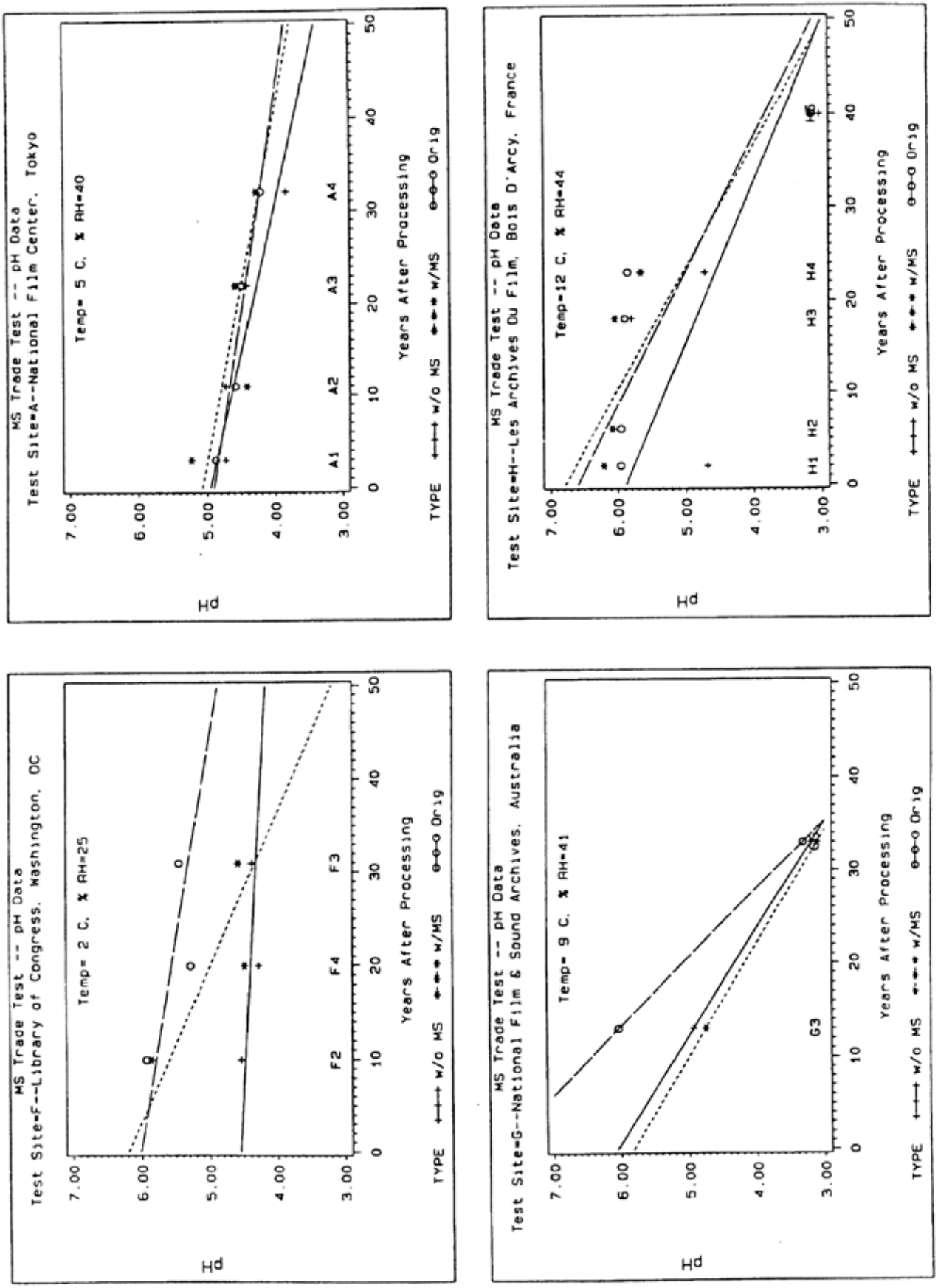



**Figure 3: Film pH Data at the Test Sites**

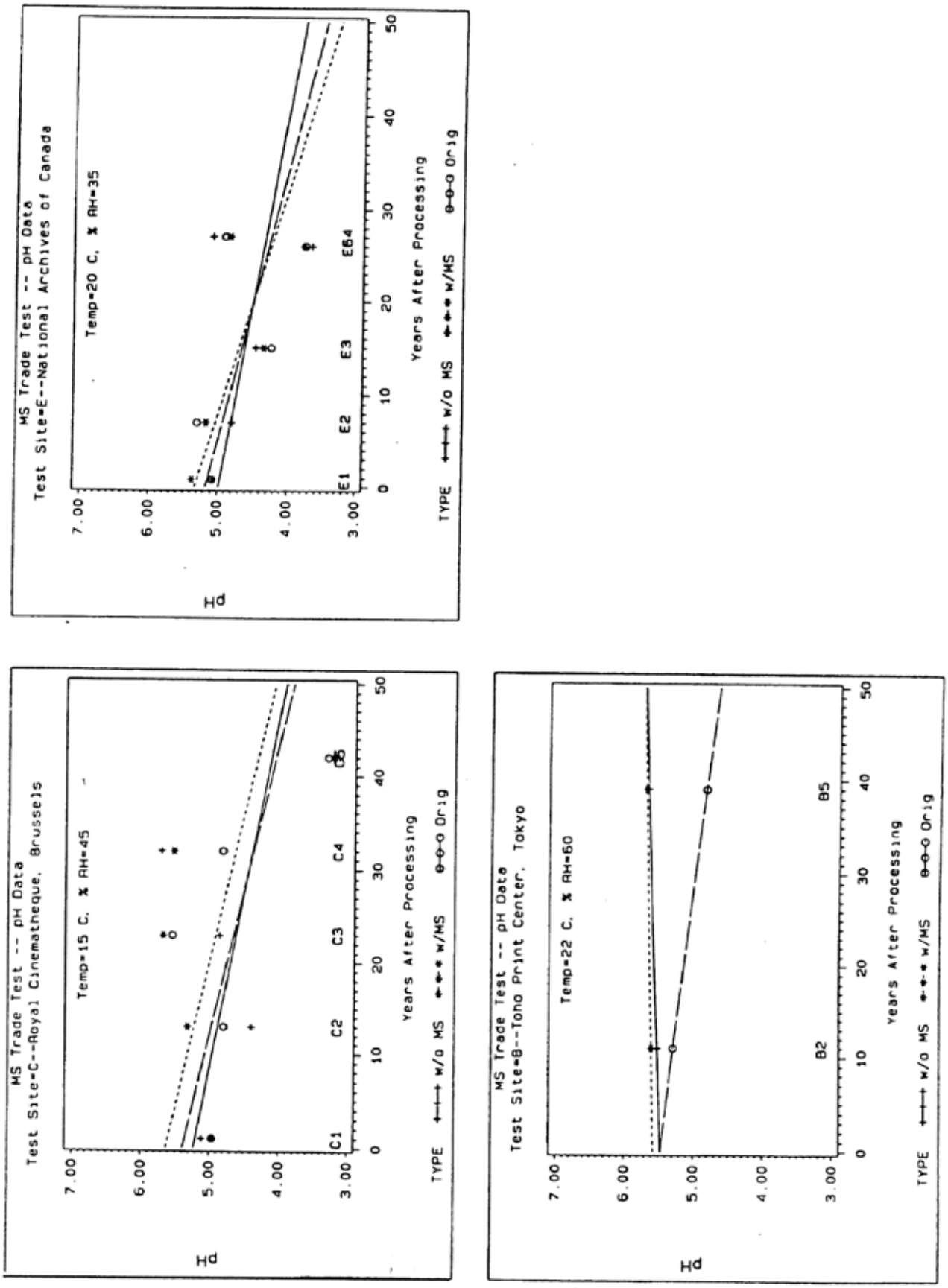



**Figure 3: Film pH Data at the Test Sites**

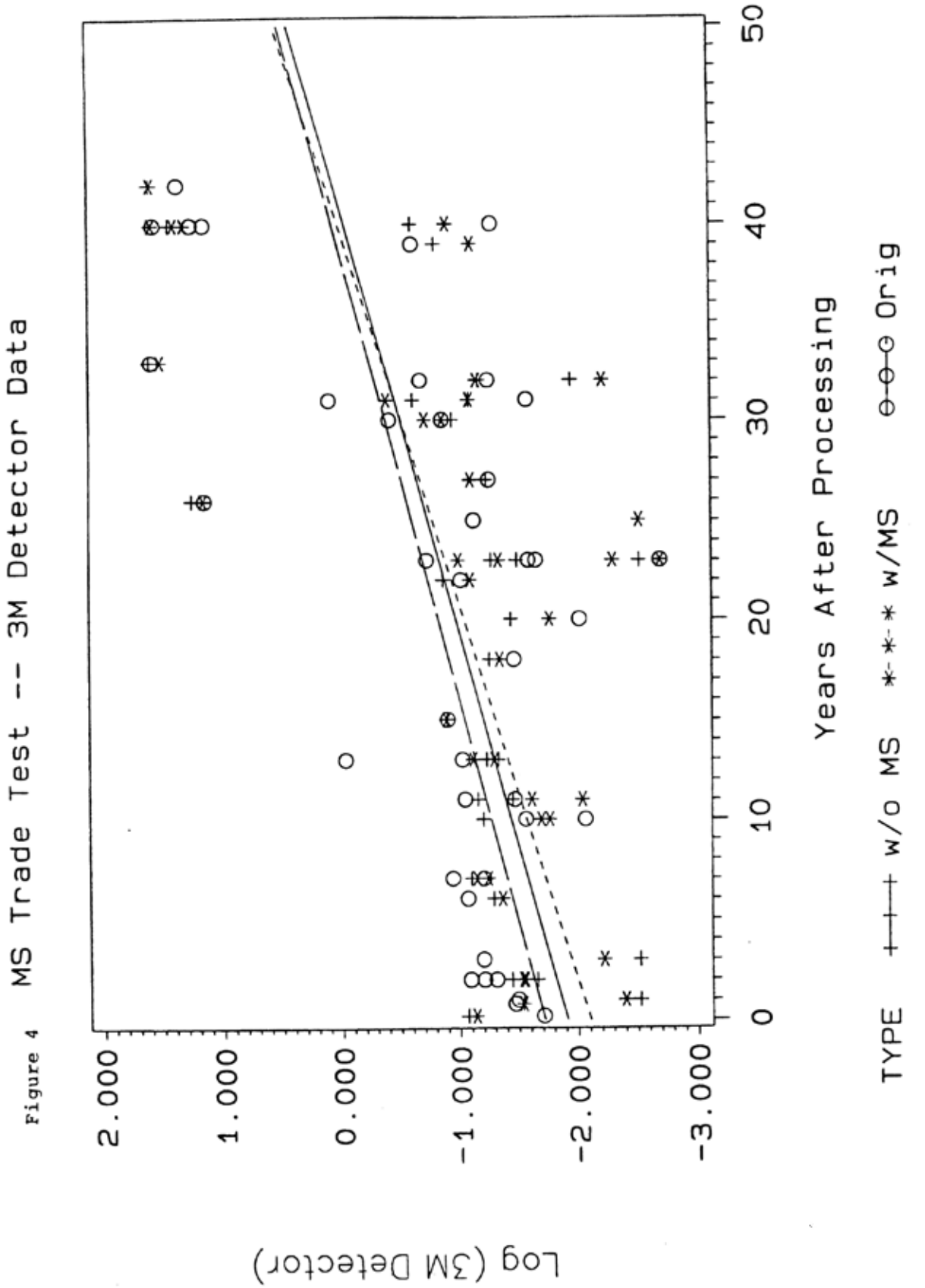



**Figure 4: 3M Detector Data**

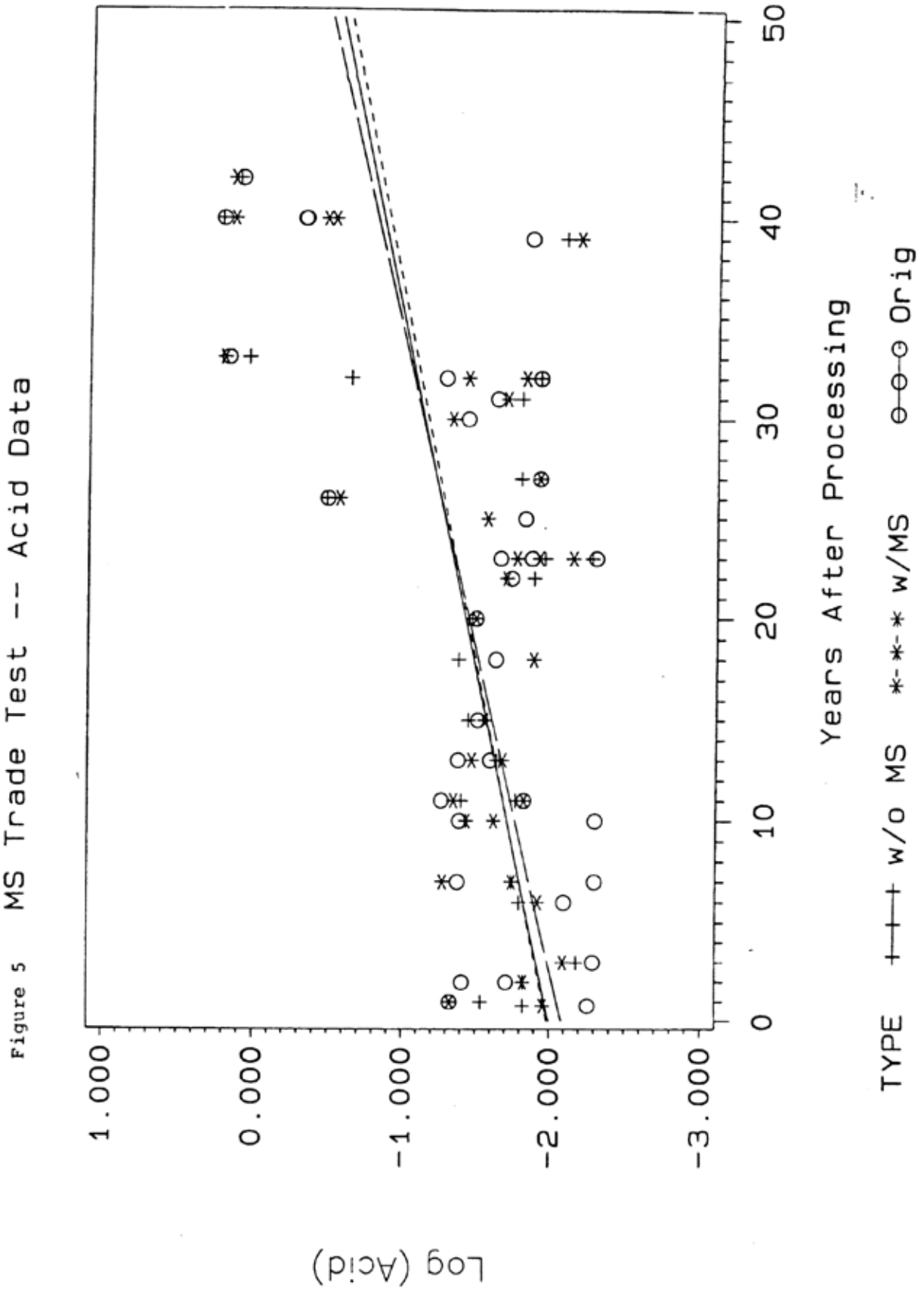



**Figure 5: Acid Data**

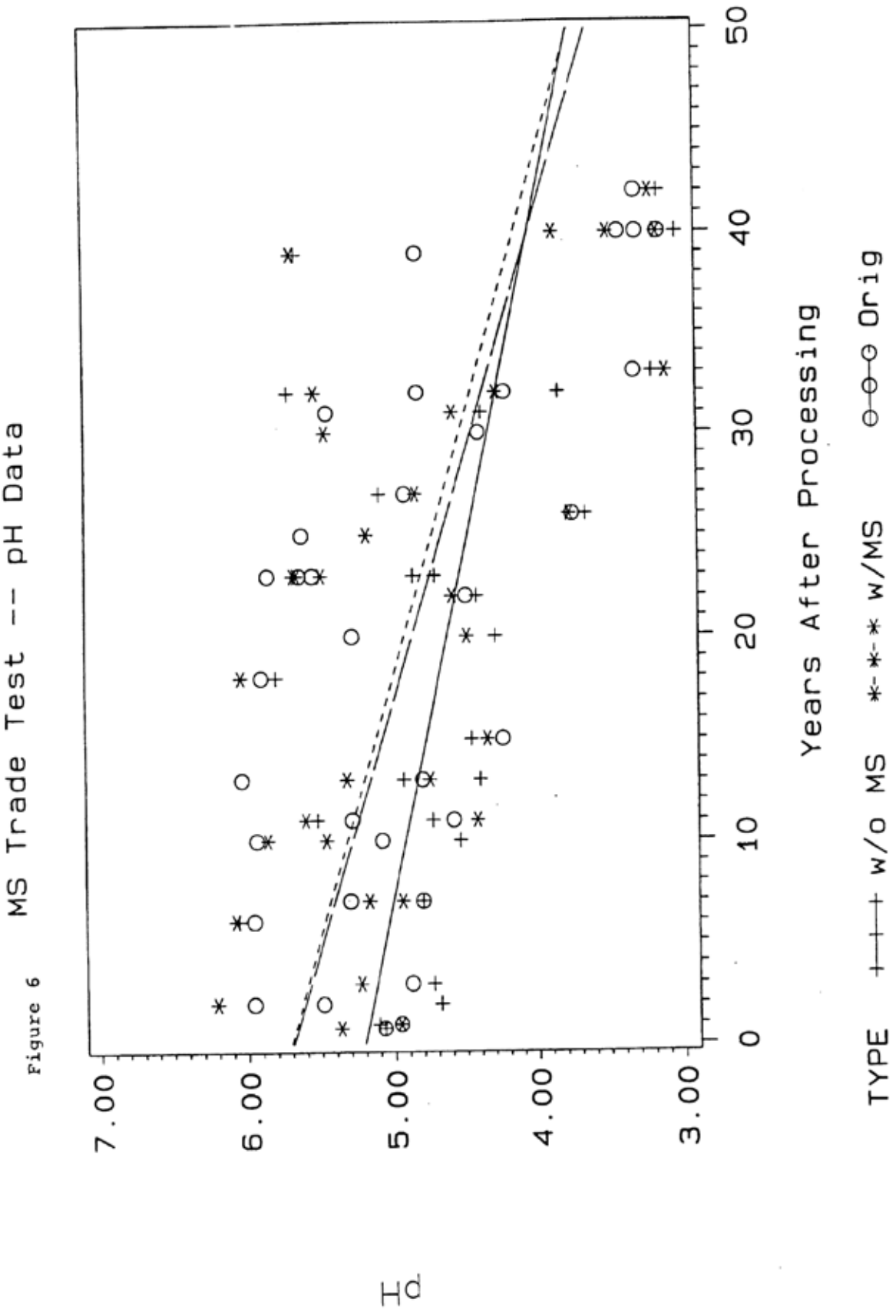



**Figure 6: pH Data**

# Appendices "A" through "H"

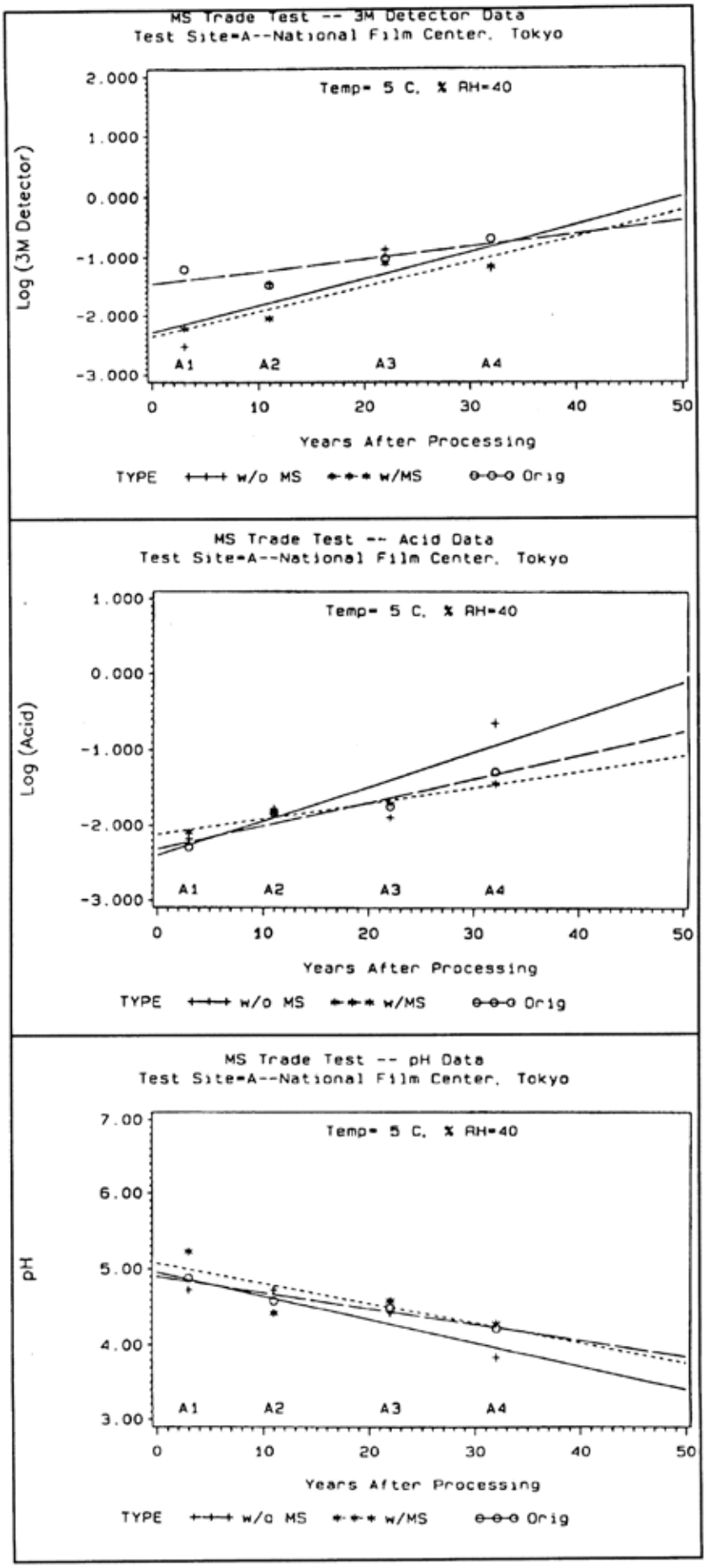
**Appendix A:** National Film Center, Tokyo, Japan
**Appendix B:** Toho Print Center, Tokyo, Japan
**Appendix C:** Royal Cinemathèque, Brussels, Belgium
**Appendix D:** The George Eastman House, Rochester, NY, USA
**Appendix E:** National Archives of Canada, Ottawa, Canada
**Appendix F:** The Library of Congress, Washington, DC, USA
**Appendix G:** The National Film and Sound Archives, Canberra, Australia
**Appendix H:** Les Archives du Film, Bois D'Arcy, France

**NOTE:** In appendices A-H, the Replicate 1 reel of the title film was placed with 2% by weight of molecular sieves, and the Replicate 2 reel of the same title film was evaluated for a duration of 4 months, but without molecular sieves, under identical storage conditions. Only in site D, from the George Eastman House, where the tests were performed initially, we did NOT follow the paired-reel comparisons using the same title film.

TEST SITE A - NATIONAL FILM CENTER, TOKYO, JAPAN
INFO FROM Dr. HARRY IWANO, Fuji, LOW TEMP/LOW RH
VAULTS BUILT IN 1985

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| A 1-1<br>A 1-2 | Hachi-No-Su No Kodomotachi<br>(Children in the Bee Nest) | 1990 | 3 |
| A 2-1<br>A 2-2 | Atatakaki Furusato<br>(A Warm Village) | 1982 | 8 |
| A 3-1<br>A 3-2 | Kan-Tubaki<br>(The Winter Camellia) | 1971 | 8 |
| A 4-1<br>A 4-2 | Eikan Namida Ari<br>(The Victory in Tears) | 1961 | 8 |
| A 5-1<br>A 5-2 | Nichiren Hounan Daisyurai<br>(The Great Trials of Nichiren) | 1953 | 40* |

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| A1 | 0 | 5 | 40 | 3.0 | 3.0 | 0.037 | 0.089 | 5.00 | 4.76 | 0.005 | 0.005 |
| | 4 | 5 | 40 | 3.0 | 3.0 | 0.006 | 0.003 | 5.23 | 4.73 | 0.008 | 0.007 |
| A2 | 0 | 5 | 40 | 11.0 | 8.0 | 0.035 | 0.032 | 4.59 | 4.58 | 0.013 | 0.017 |
| | 4 | 5 | 40 | 11.0 | 8.0 | 0.009 | 0.035 | 4.42 | 4.73 | 0.015 | 0.017 |
| A3 | 0 | 5 | 40 | 22.0 | 8.0 | 0.082 | 0.110 | 4.48 | 4.51 | 0.018 | 0.019 |
| | 4 | 5 | 40 | 22.0 | 8.0 | 0.080 | 0.136 | 4.59 | 4.42 | 0.020 | 0.013 |
| A4 | 0 | 5 | 40 | 32.0 | 8.0 | 0.150 | 0.267 | 4.30 | 4.13 | 0.030 | 0.075 |
| | 4 | 5 | 40 | 32.0 | 8.0 | 0.070 | 0.067 | 4.28 | 3.84 | 0.037 | 0.230 |
| A5 | 0 | 26 | 65 | 40.0 | 40.0 | 31.861 | 23.601 | 3.26 | 3.47 | 1.100 | 0.600 |
| | 4 | 26 | 65 | 40.0 | 40.0 | 23.900 | 35.050 | 3.24 | 3.49 | 1.100 | 0.720 |


MS Trade Test -- 3M Detector Data
Test Site=A--National Film Center, Tokyo
Temp= 5 C, % RH=40
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
A1
A2
A3
A4
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig
MS Trade Test -- Acid Data
Test Site=A--National Film Center, Tokyo
Temp= 5 C, % RH=40
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
A1
A2
A3
A4
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig
MS Trade Test -- pH Data
Test Site=A--National Film Center, Tokyo
Temp= 5 C, % RH=40
pH
7.00
6.00
5.00
4.00
3.00
A1
A2
A3
A4
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig

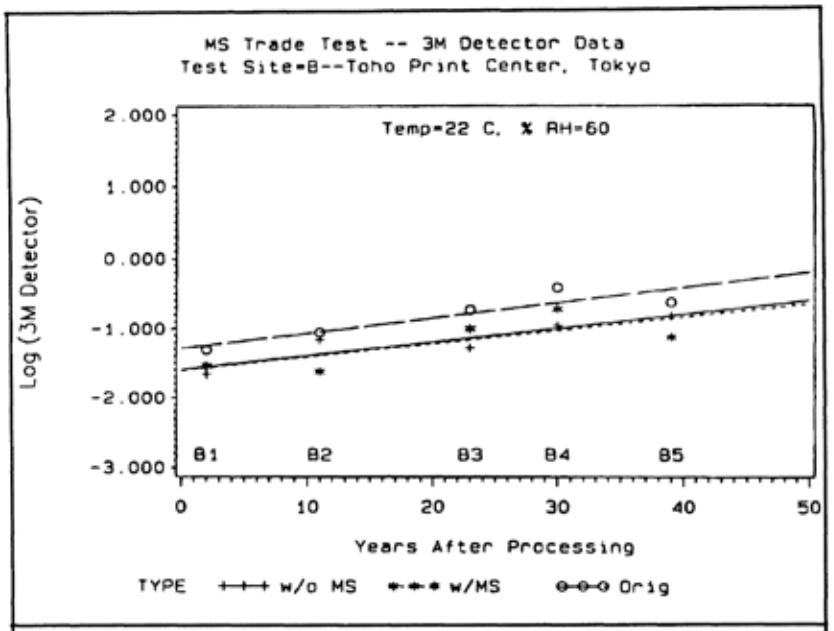
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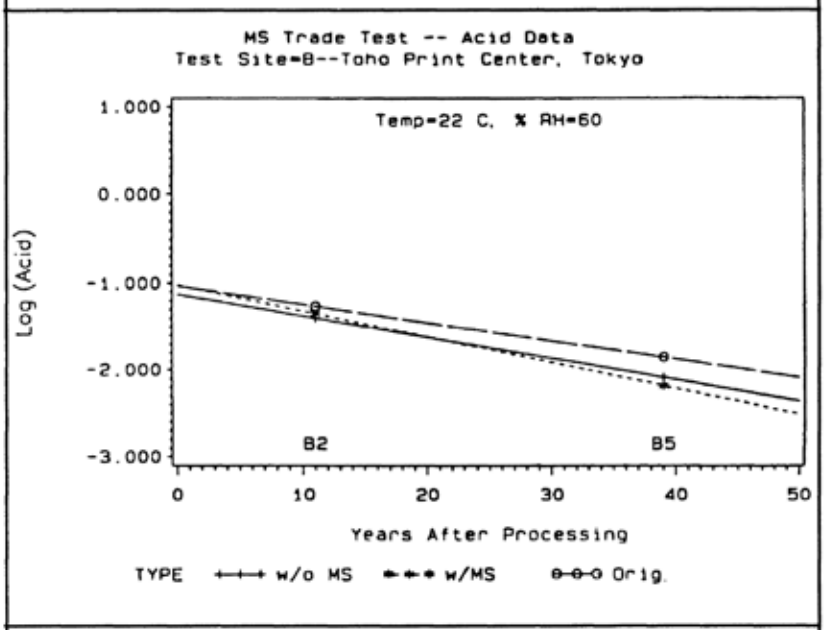
TEST SITE B - TOHO PRINT CENTER, TOKYO, JAPAN -- FILMS ARE CONSTANTLY USED ALTHOUGH MAINTAINED AT 22 C/60% RH
Contacts: Mr. Junichi Kohno, Konica and
Mr. Kazunori Nishida, Imagica, Japan

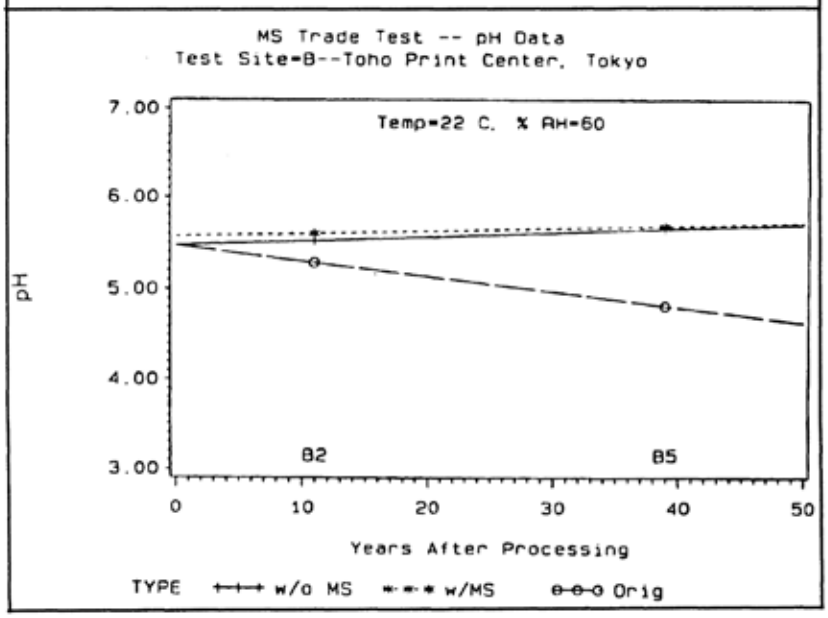
| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| B 1-1<br>B 1-2 | Dorami-Chan | March, 1991 | 2* |
| B 2-1<br>B 2-2 | Miyuki | September, 1983 | 11* |
| B 3-1<br>B 3-2 | Chi Wo Suu Ningyo | July, 1970 | 23* |
| B 4-1<br>B 4-2 | Warera Sarariiman | November, 1963 | 30* |
| B 5-1<br>B 5-2 | Watashi No Subete Wo | May, 1954 | 39* |

* Film reels are constantly used and kept at 22 C and 60% RH storage conditions.

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| B1 | 0 | 22 | 60 | 2.0 | 2.0 | 0.043 | 0.055 | . | . | . | . |
| | 4 | 22 | 60 | 2.0 | 2.0 | 0.029 | 0.022 | . | . | . | . |
| B2 | 0 | 22 | 60 | 11.0 | 11.0 | 0.099 | 0.079 | 4.66 | 5.91 | 0.061 | 0.048 |
| | 4 | 22 | 60 | 11.0 | 11.0 | 0.024 | 0.069 | 5.60 | 5.52 | 0.045 | 0.040 |
| B3 | 0 | 22 | 60 | 23.0 | 23.0 | 0.109 | 0.265 | . | 5.00 | . | 0.039 |
| | 4 | 22 | 60 | 23.0 | 23.0 | 0.101 | 0.053 | . | 5.36 | . | 0.044 |
| B4 | 0 | 22 | 60 | 30.0 | 30.0 | 0.293 | 0.480 | . | 4.20 | . | 0.036 |
| | 4 | 22 | 60 | 30.0 | 30.0 | 0.193 | 0.113 | . | 5.01 | . | 0.030 |
| B5 | 0 | 22 | 60 | 39.0 | 39.0 | 0.184 | 0.301 | 4.73 | 4.91 | 0.010 | 0.018 |
| | 4 | 22 | 60 | 39.0 | 39.0 | 0.077 | 0.156 | 5.68 | 5.65 | 0.007 | 0.008 |


MS Trade Test -- 3M Detector Data
Test Site=B--Toho Print Center, Tokyo
Temp=22 C, % RH=60
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
B1
B2
B3
B4
B5
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig


MS Trade Test -- Acid Data
Test Site=B--Toho Print Center, Tokyo
Temp=22 C, % RH=60
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
B2
B5
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig

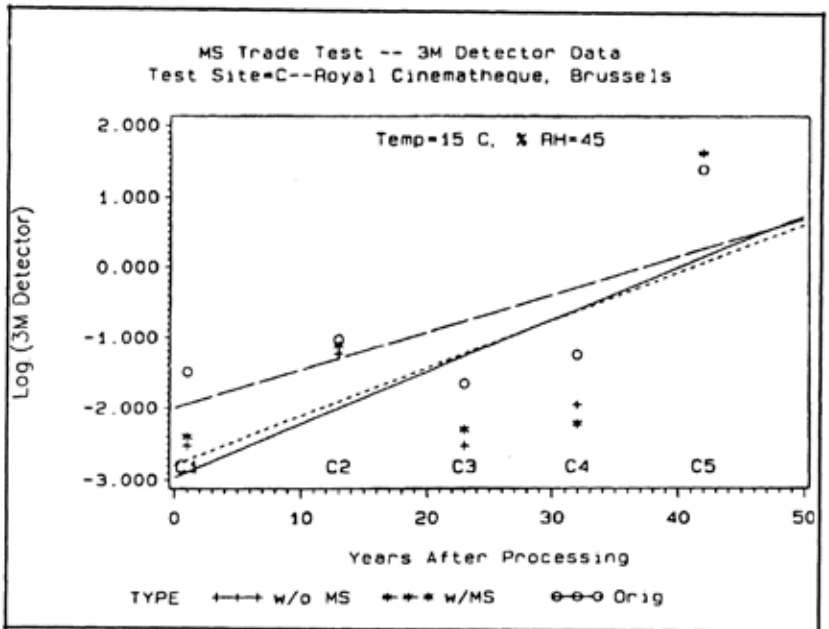

MS Trade Test -- pH Data
Test Site=B--Toho Print Center, Tokyo
Temp=22 C, % RH=60
pH
7.00
6.00
5.00
4.00
3.00
B2
B5
0
10
20
30
40
50
Years After Processing
TYPE +-+-+ w/o MS *-*-* w/MS o-o-o Orig

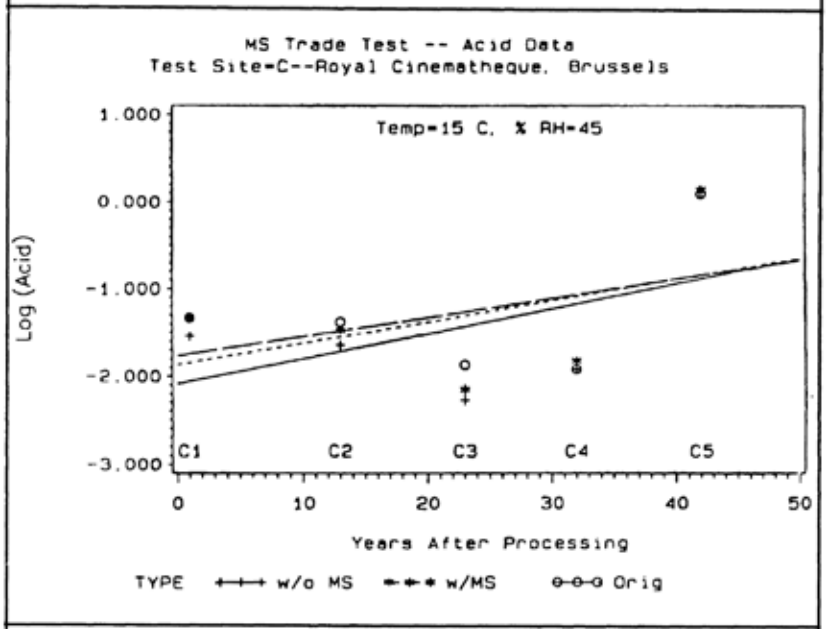
# Appendix C:

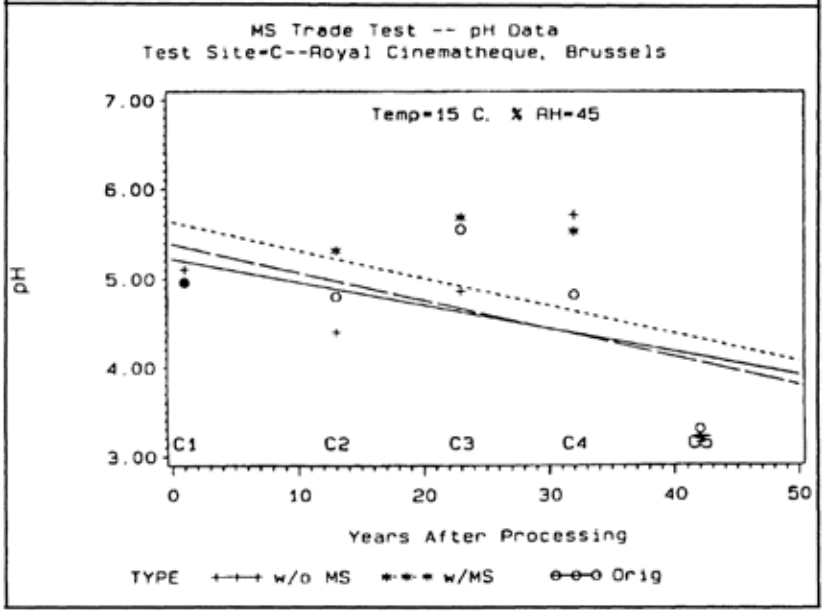
TEST SITE C - ROYAL CINEMATHEQUE, BRUSSELS, BELGIUM-- ACTUAL TIME IN VAULTS AT 15 C/45% RH IS NOT CERTAIN
Contact: Dr. Karel Brems, Agfa, Mortsel, Belgium

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| C 1-1<br>C 1-2 | Addams Family | November, 1992 | 1 |
| C 2-1<br>C 2-2 | Alligator | 1980 | 13 |
| C 3-1<br>C 3-2 | Crime School | January, 1970 | 23 |
| C 4-1<br>C 4-2 | Intolerance | 1961 | 32 |
| C 5-1<br>C 5-2 | Fanfan La Tulipe | 1951 | 42 |

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| C1 | 0 | 15 | 45 | 1.0 | 1.0 | 0.046 | 0.018 | 4.91 | 5.01 | 0.047 | 0.047 |
| | 4 | 15 | 45 | 1.0 | 1.0 | 0.004 | 0.003 | 4.96 | 5.11 | 0.047 | 0.029 |
| C2 | 0 | 15 | 45 | 13.0 | 13.0 | 0.095 | 0.092 | 4.89 | 4.71 | 0.049 | 0.035 |
| | 4 | 15 | 45 | 13.0 | 13.0 | 0.076 | 0.058 | 5.32 | 4.40 | 0.034 | 0.023 |
| C3 | 0 | 15 | 45 | 23.0 | 23.0 | 0.024 | 0.020 | 5.93 | 5.17 | 0.014 | 0.013 |
| | 4 | 15 | 45 | 23.0 | 23.0 | 0.005 | 0.003 | 5.68 | 4.86 | 0.007 | 0.005 |
| C4 | 0 | 15 | 45 | 32.0 | 32.0 | 0.061 | 0.050 | 5.13 | 4.51 | 0.014 | 0.010 |
| | 4 | 15 | 45 | 32.0 | 32.0 | 0.006 | 0.011 | 5.53 | 5.71 | 0.015 | 0.012 |
| C5 | 0 | 15 | 45 | 42.0 | 42.0 | 26.874 | 20.255 | 3.31 | 3.30 | 1.200 | 1.300 |
| | 4 | 15 | 45 | 42.0 | 42.0 | 39.970 | 40.420 | 3.21 | 3.15 | 1.400 | 1.300 |


MS Trade Test -- 3M Detector Data
Test Site=C--Royal Cinematheque, Brussels
Temp=15 C, % RH=45
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
C1
C2
C3
C4
C5
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig


MS Trade Test -- Acid Data
Test Site=C--Royal Cinematheque, Brussels
Temp=15 C, % RH=45
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
C1
C2
C3
C4
C5
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig


MS Trade Test -- pH Data
Test Site=C--Royal Cinematheque, Brussels
Temp=15 C, % RH=45
pH
7.00
6.00
5.00
4.00
3.00
C1
C2
C3
C4
C5
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig

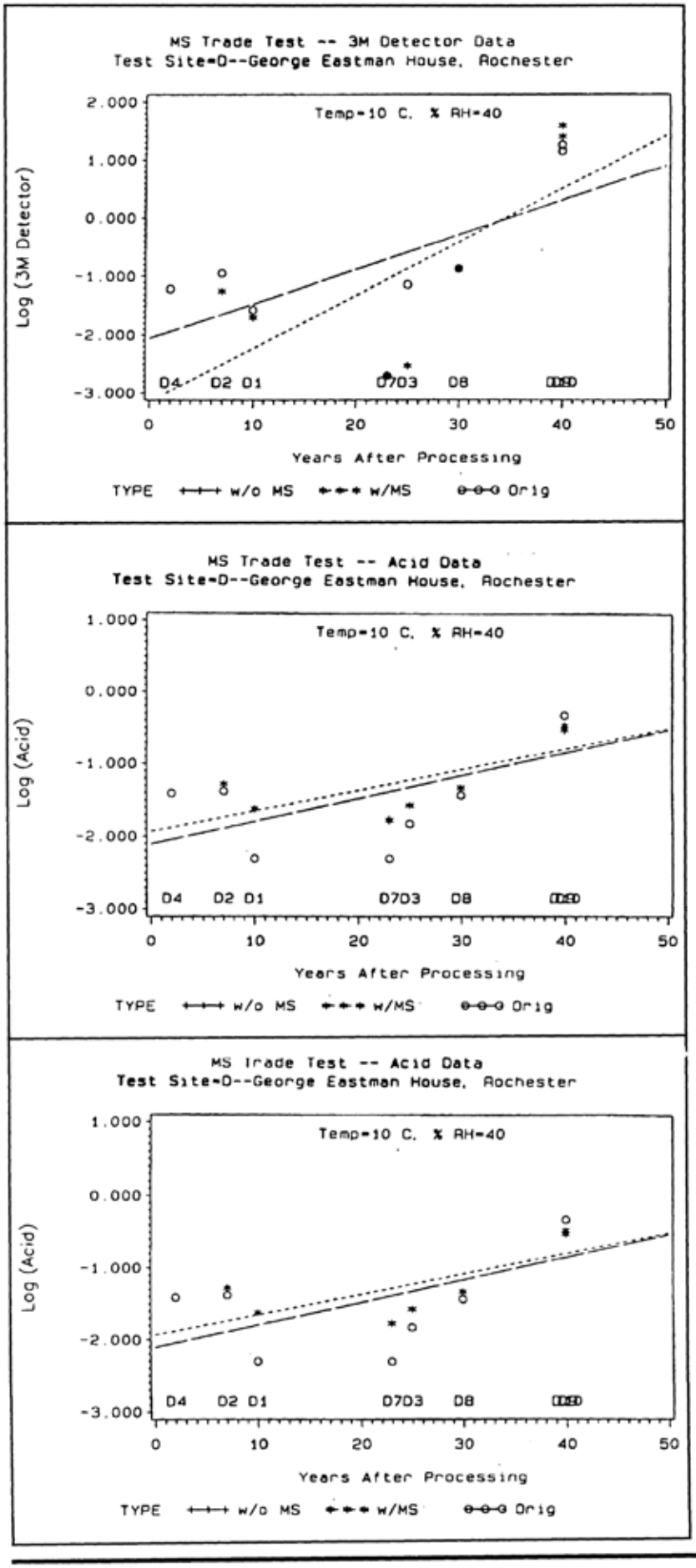
# Appendix D:

TEST SITE D - GEORGE EASTMAN HOUSE, ROCHESTER, NY, USA
INFO FROM Dr. CHRIS HORAK, NITRATE VAULT BUILT IN 1952 AND TEMP/RH CONTROLLED VAULTS IN 1970

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| D 1 | Pandora's Box (stored @ 10 C/40% RH) | 1983 | 10 |
| D 2 | Three Day Gold (stored @ 10 C/40% RH) | 1986 | 7 |
| D 3 | Philadelphia Story (stored @ 15 C/50% RH) | 1974 | 19 |
| D 4 | Alpine Fire (stored @ 15 C/50% RH) | 1991 | 2 |
| D 5@ | Broadway Melody (stored @ 10 C/50% RH) | 1936 | 57 |
| D 6@ | The Virginian (stored @ 10 C/50% RH) | <1950 | >43 |
| D 7* | Act of Love (A/C storage, no RH control) | 1980 | 13 |
| D 8* | Cyrano Be Bergerac (A/C storage, no RH control) | 1975 | 18 |
| D 9* | Snow White & The Seven Dwarfs (Discarded films, ambient basement strorage) | 1983 | 10 |
| D 10* | The Miracle (Discarded films, ambient basement storage) | 1974 | 19 |

@ - CELLULOSE NITRATE FILMS, * - REPEATS FOR WITH AND WITHOUT MOLECULAR SIEVES FOR LONG-TERM KEEP (ORIGINAL VALUES ONLY)

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| D1 | 0 | 10 | 40 | 10.0 | 10.0 | 0.027 | . | 5.08 | . | 0.005 | . |
| | 4 | 10 | 40 | 10.0 | 10.0 | 0.020 | . | 5.46 | . | 0.024 | . |
| D2 | 0 | 10 | 40 | 7.0 | 7.0 | 0.114 | . | 4.80 | . | 0.042 | . |
| | 4 | 10 | 40 | 7.0 | 7.0 | 0.057 | . | 4.94 | . | 0.053 | . |
| D3 | 0 | 15 | 50 | 25.0 | 19.0 | 0.074 | . | 5.62 | . | 0.015 | . |
| | 4 | 15 | 50 | 25.0 | 19.0 | 0.003 | . | 5.18 | . | 0.027 | . |
| D4 | 0 | 15 | 50 | 2.0 | 2.0 | 0.062 | . | 5.49 | . | 0.039 | . |
| D5 | 0 | 10 | 50 | 57.0 | 41.0 | . | . | 5.09 | . | 0.019 | . |
| | 4 | 10 | 50 | 57.0 | 41.0 | . | . | 4.75 | . | 0.025 | . |
| D6 | 0 | 10 | 50 | 45.0 | 41.0 | . | . | 4.53 | . | 0.042 | . |
| | 4 | 10 | 50 | 45.0 | 41.0 | . | . | 5.12 | . | 0.053 | . |
| D7 | 0 | 22 | 50 | 23.0 | 13.0 | 0.002 | . | 5.64 | . | 0.005 | . |
| | 4 | 22 | 50 | 23.0 | 13.0 | 0.002 | . | 5.49 | . | 0.017 | . |
| D8 | 0 | 22 | 50 | 30.0 | 18.0 | 0.137 | . | 4.40 | . | 0.037 | . |
| | 4 | 22 | 50 | 30.0 | 18.0 | 0.137 | . | 5.46 | . | 0.047 | . |
| D9 | 0 | 25 | 60 | 40.0 | 10.0 | 18.360 | . | 3.30 | . | 0.480 | . |
| | 4 | 25 | 60 | 40.0 | 10.0 | 25.500 | . | 3.50 | . | 0.340 | . |
| D10 | 0 | 25 | 60 | 40.0 | 19.0 | 14.260 | . | 3.42 | . | 0.470 | . |
| | 4 | 25 | 60 | 40.0 | 19.0 | 38.972 | . | 3.87 | . | 0.300 | . |

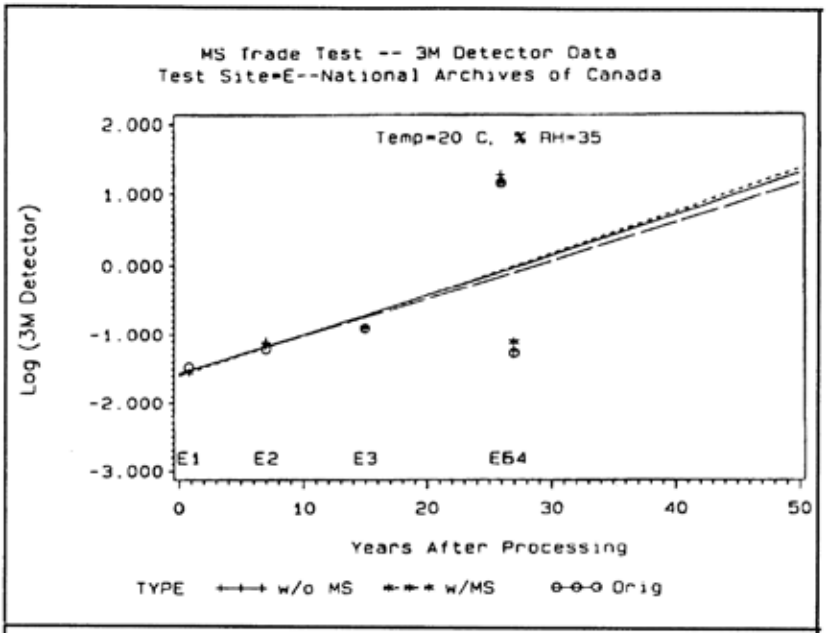

MS Trade Test -- 3M Detector Data
Test Site=D--George Eastman House, Rochester
Temp=10 C, % RH=40
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
D4
D2 D1
D7D3
D8
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- Acid Data
Test Site=D--George Eastman House, Rochester
Temp=10 C, % RH=40
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
D4
D2 D1
D7D3
D8
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- Acid Data
Test Site=D--George Eastman House, Rochester
Temp=10 C, % RH=40
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
D4
D2 D1
D7D3
D8
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig

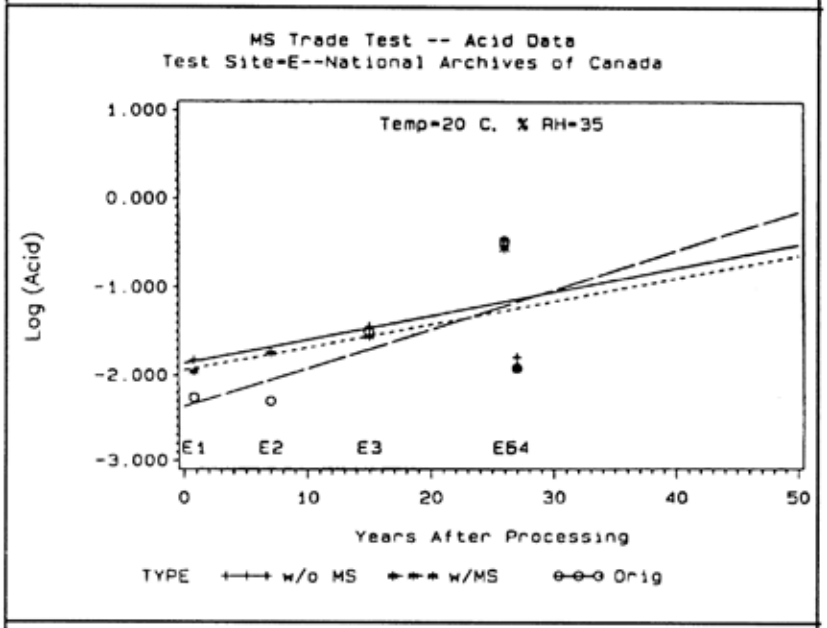
## Appendix E:

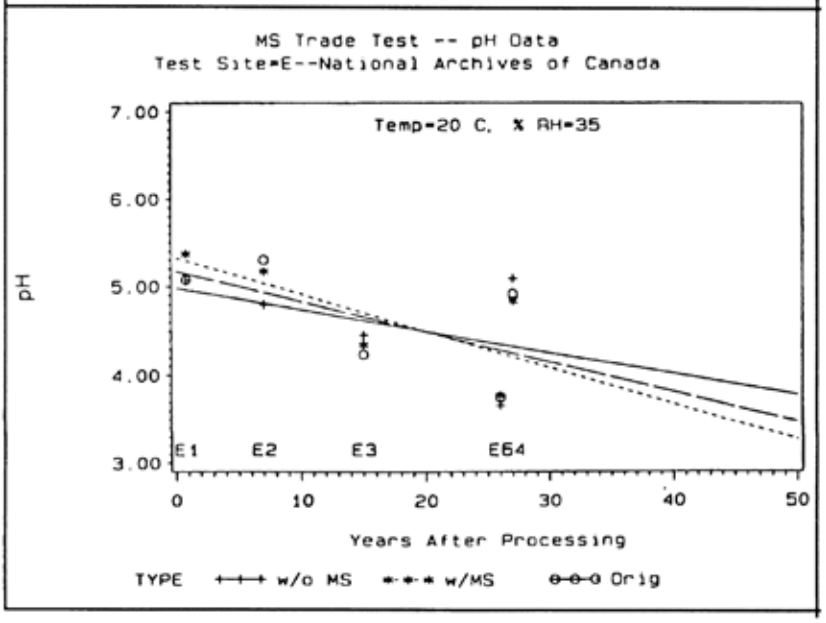
TEST SITE E - NATIONAL ARCHIVES OF CANADA FROM BILL O'FARRELL
WITH FILMS KEPT AT 68 F (20 C) AND 35% RH.
Contact: Dr. Klaus Hendriks, Ottawa, Canada

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| E 1-1<br>E 1-2 | Wildfire | 1993 | 0.8 |
| E 2-1<br>E 2-2 | Dancing in the Dark | 1986 | 6 |
| E 3-1<br>E 3-2 | The Brood | 1978 | 8 |
| E 4-1<br>E 4-2 | Take Her By Surprise | 1966 | 20 |
| E 5-1<br>E 5-2 | We Are Young | 1967 | 20 |

| | | Temp (C) | % RH | Years After Processing | Years in Vault | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | | | | | 1 | 2 | 1 | 2 | 1 | 2 |
| E1 | 0 | 20 | 35 | 0.8 | 0.8 | 0.033 | 0.035 | 5.18 | 4.97 | 0.005 | 0.006 |
| | 4 | 20 | 35 | 0.8 | 0.8 | 0.029 | 0.029 | 5.37 | 5.07 | 0.011 | 0.015 |
| E2 | 0 | 20 | 35 | 7.0 | 6.0 | 0.061 | 0.063 | 5.03 | 5.57 | 0.005 | 0.005 |
| | 4 | 20 | 35 | 7.0 | 6.0 | 0.071 | 0.079 | 5.17 | 4.80 | 0.018 | 0.018 |
| E3 | 0 | 20 | 35 | 15.0 | 8.0 | 0.127 | 0.122 | 4.30 | 4.18 | 0.027 | 0.035 |
| | 4 | 20 | 35 | 15.0 | 8.0 | 0.127 | 0.126 | 4.35 | 4.46 | 0.028 | 0.036 |
| E4 | 0 | 20 | 35 | 27.0 | 20.0 | 0.063 | 0.047 | 4.88 | 4.95 | 0.013 | 0.011 |
| | 4 | 20 | 35 | 27.0 | 20.0 | 0.079 | 0.058 | 4.84 | 5.09 | 0.012 | 0.016 |
| E5 | 0 | 20 | 35 | 26.0 | 20.0 | 15.200 | 13.400 | 3.75 | 3.75 | 0.340 | 0.310 |
| | 4 | 20 | 35 | 26.0 | 20.0 | 14.700 | 18.300 | 3.77 | 3.66 | 0.270 | 0.330 |


MS Trade Test -- 3M Detector Data
Test Site=E--National Archives of Canada
Temp=20 C, % RH=35
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
E1
E2
E3
E64
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig


MS Trade Test -- Acid Data
Test Site=E--National Archives of Canada
Temp=20 C, % RH=35
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
E1
E2
E3
E64
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig

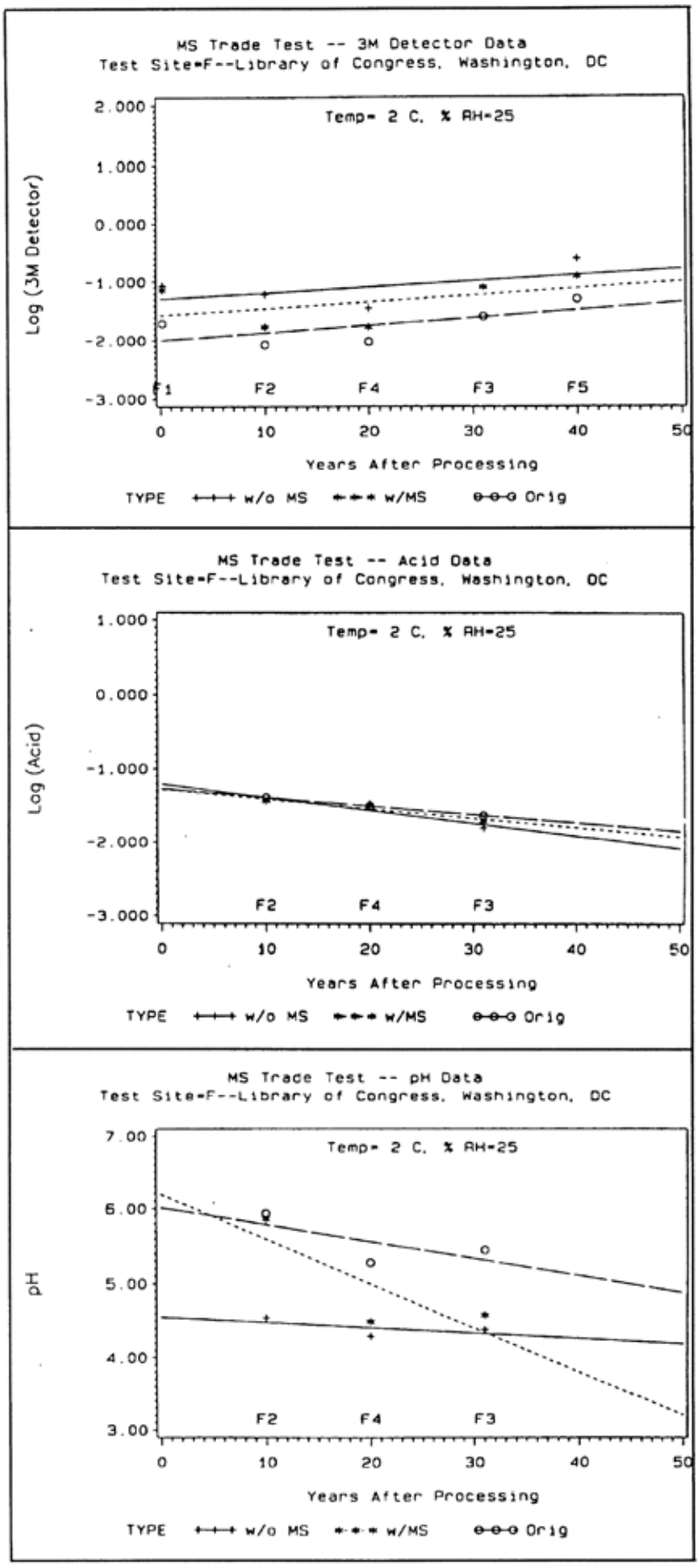

MS Trade Test -- pH Data
Test Site=E--National Archives of Canada
Temp=20 C, % RH=35
pH
7.00
6.00
5.00
4.00
3.00
E1
E2
E3
E64
0
10
20
30
40
50
Years After Processing
TYPE +++ w/o MS *** w/MS ooo Orig

# Appendix F:

TEST SITE F - LIBRARY OF CONGRESS, WASHINGTON, DC FROM DAVID FRANCIS/GERRY GIBSON -- ALL FILMS KEPT AT 55 F (2 C) AND 25% RH SINCE 1977 -- THE LONGEST COLD AND DRY STORAGE CONDITIONS.
Three additional samples F 6-1 thru F 8-2 were submitted for analysis on March 15, 1994. Only initial data is recorded currently.

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| ? 1-1<br>? 1-2 | Gena La De Blas | September, 1993 | 0.2 |
| ? 2-1<br>? 2-2 | Haloween III | 1983 | 10 |
| ? 3-1<br>? 3-2 | Notorious Landlady | 1962 | 16 ? |
| ? 4-1<br>? 4-2 | Nightmare | 1973 | 16 ? |
| ? 5-1<br>? 5-2 | Another Man's Poison | 1953 | 16 ? |
| ? 6-1*<br>? 6-2* | Christopher Columbus | 1992 | 1 |
| ? 7-1*<br>? 7-2* | Children of Lesser God | 1986 | 6 |
| ? 8-1*<br>? 8-2* | Being There | 1979 | 14 |

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| F1 | 0 | 2 | 25 | 0.2 | 0.2 | 0.022 | 0.017 | . | 5.57 | . | 0.022 |
| | 4 | 2 | 25 | 0.2 | 0.2 | 0.073 | 0.086 | 4.86 | . | 0.020 | . |
| F2 | 0 | 2 | 25 | 10.0 | 10.0 | 0.008 | 0.009 | 6.01 | 5.86 | 0.046 | 0.036 |
| | 4 | 2 | 25 | 10.0 | 10.0 | 0.017 | 0.062 | 5.86 | 4.54 | 0.037 | 0.037 |
| F3 | 0 | 2 | 25 | 31.0 | 16.0 | 0.012 | 0.040 | 5.68 | 5.21 | 0.024 | 0.023 |
| | 4 | 2 | 25 | 31.0 | 16.0 | 0.081 | 0.081 | 4.58 | 4.38 | 0.020 | 0.016 |
| F4 | 0 | 2 | 25 | 20.0 | 16.0 | 0.008 | 0.011 | 5.28 | . | 0.032 | . |
| | 4 | 2 | 25 | 20.0 | 16.0 | 0.017 | 0.036 | 4.49 | 4.29 | 0.032 | 0.034 |
| F5 | 0 | 2 | 25 | 40.0 | 16.0 | 0.044 | 0.058 | . | 5.59 | . | 0.020 |
| | 4 | 2 | 25 | 40.0 | 16.0 | 0.124 | 0.248 | . | 4.52 | . | 0.038 |
| F6 | 0 | 2 | 25 | 2.0 | 1.0 | 0.015 | 0.020 | 5.82 | 5.60 | 0.044 | 0.041 |
| F7 | 0 | 2 | 25 | 8.0 | 6.0 | 0.002 | 0.003 | 5.88 | 5.66 | 0.031 | 0.011 |
| F8 | 0 | 2 | 25 | 15.0 | 14.0 | 0.037 | 0.018 | 5.48 | 5.33 | 0.038 | 0.037 |

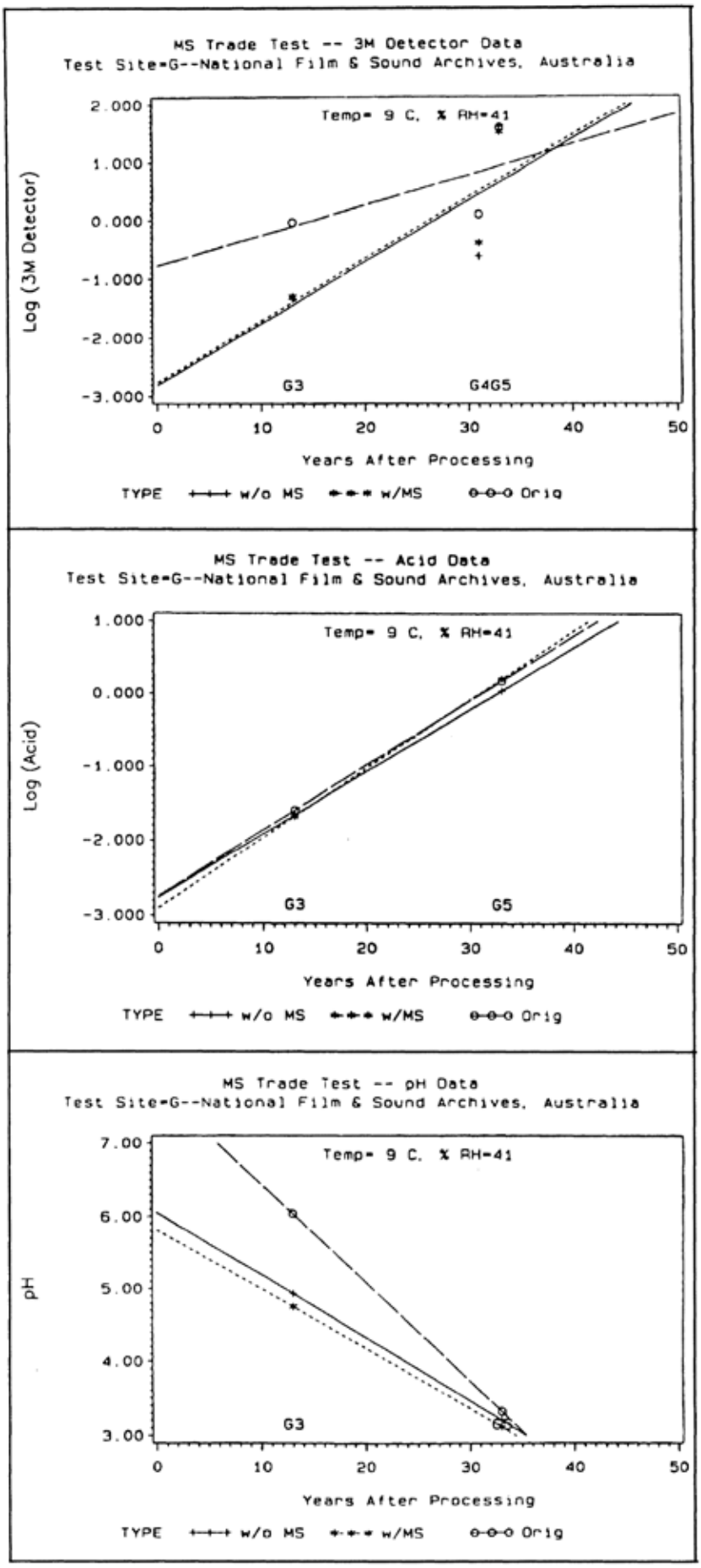

MS Trade Test -- 3M Detector Data
Test Site=F--Library of Congress, Washington, DC
Temp= 2 C, % RH=25
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
F1
F2
F4
F3
F5
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- Acid Data
Test Site=F--Library of Congress, Washington, DC
Temp= 2 C, % RH=25
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
F2
F4
F3
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- pH Data
Test Site=F--Library of Congress, Washington, DC
Temp= 2 C, % RH=25
pH
7.00
6.00
5.00
4.00
3.00
F2
F4
F3
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig

# Appendix G:

TEST SITE G - NATIONAL FILM & SOUND ARCHIVES, CANBERRA, AUSTRALIA
MARK NIZETTE -- FILMS KEPT UNDER A VARIETY OF STORAGE CONDITIONS -- DATA TO BE REVIEWED WITH MARK ON THE ACTUAL KEEPING TIMES IN FILM VAULTS.

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| G 1-1<br>G 1-2 | Strictly Ballroom (stored @ 21 C/40% RH) | 1991 | 2 |
| G 2-1<br>G 2-2 | Undercover (stored @ 21 C/40% RH) | 1987 | 7 |
| G 3-1<br>G 3-2 | Touch And Go (stored @ 9 C/41% RH) | 1980 | 13 ? |
| G 4-1<br>G 4-2 | Festival in Adelaide (stored @ 7 C and 47% RH) | 1962 | 31 ? |
| G 5-1<br>G 5-2 | Namgang Maul Yosongoul (stored @ 7 C and 47% RH) | 1960 | 33 ? |

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| G1 | 0 | 21 | 40 | 2.0 | 2.0 | 0.070 | 0.150 | 5.11 | 4.98 | 0.020 | 0.039 |
| | 4 | 21 | 40 | 2.0 | 2.0 | 0.084 | 0.090 | 4.90 | 4.66 | 0.031 | 0.031 |
| G2 | 0 | 21 | 40 | 7.0 | 7.0 | 2.900 | 3.200 | 5.60 | 5.51 | 0.063 | 0.060 |
| | 4 | 21 | 40 | 7.0 | 7.0 | 0.968 | 1.163 | . | . | . | . |
| G3 | 0 | 9 | 41 | 13.0 | 13.0 | 0.060 | 1.800 | 5.97 | 6.10 | 0.024 | 0.027 |
| | 4 | 9 | 41 | 13.0 | 13.0 | 0.050 | 0.046 | 4.75 | 4.93 | 0.021 | 0.022 |
| G4 | 0 | 7 | 47 | 31.0 | 31.0 | 2.200 | 0.330 | . | . | . | . |
| | 4 | 7 | 47 | 31.0 | 31.0 | 0.410 | 0.243 | . | . | . | . |
| G5 | 0 | 7 | 47 | 33.0 | 33.0 | 37.100 | 42.300 | 3.20 | 3.44 | 1.800 | 1.200 |
| | 4 | 7 | 47 | 33.0 | 33.0 | 33.400 | 41.100 | 3.11 | 3.20 | 1.600 | 1.100 |

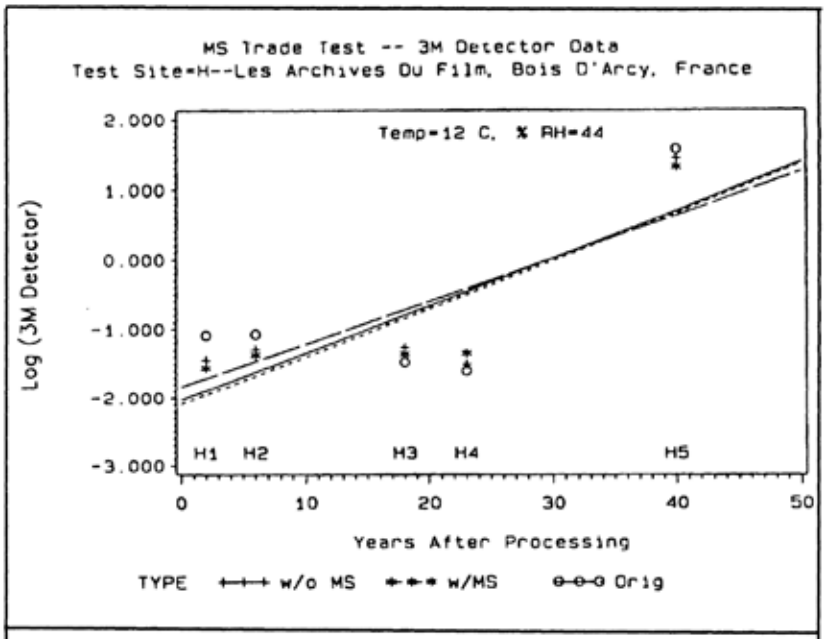

MS Trade Test -- 3M Detector Data
Test Site=G--National Film & Sound Archives, Australia
Temp= 9 C, % RH=41
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
G3
G4G5
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- Acid Data
Test Site=G--National Film & Sound Archives, Australia
Temp= 9 C, % RH=41
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
G3
G5
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig
MS Trade Test -- pH Data
Test Site=G--National Film & Sound Archives, Australia
Temp= 9 C, % RH=41
pH
7.00
6.00
5.00
4.00
3.00
G3
0
10
20
30
40
50
Years After Processing
TYPE w/o MS w/MS Orig

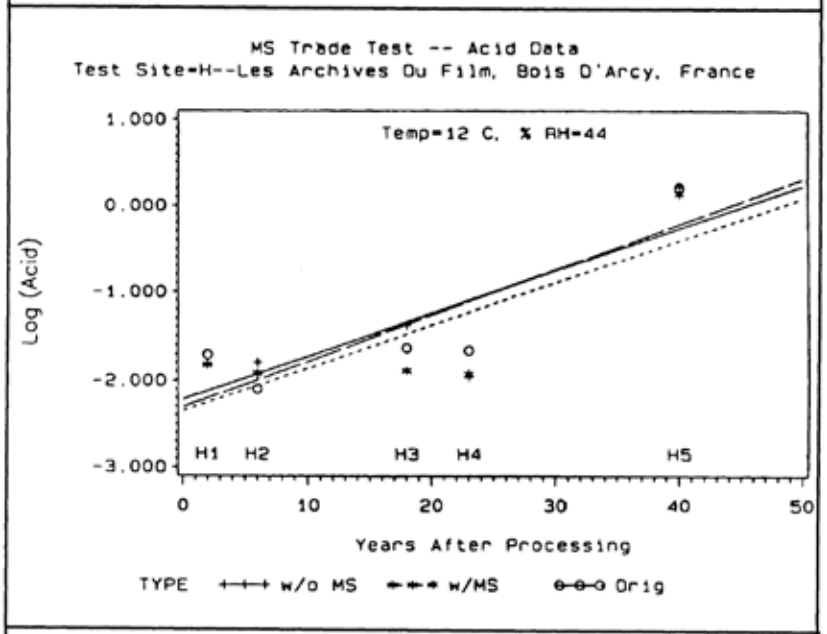
# Appendix H:

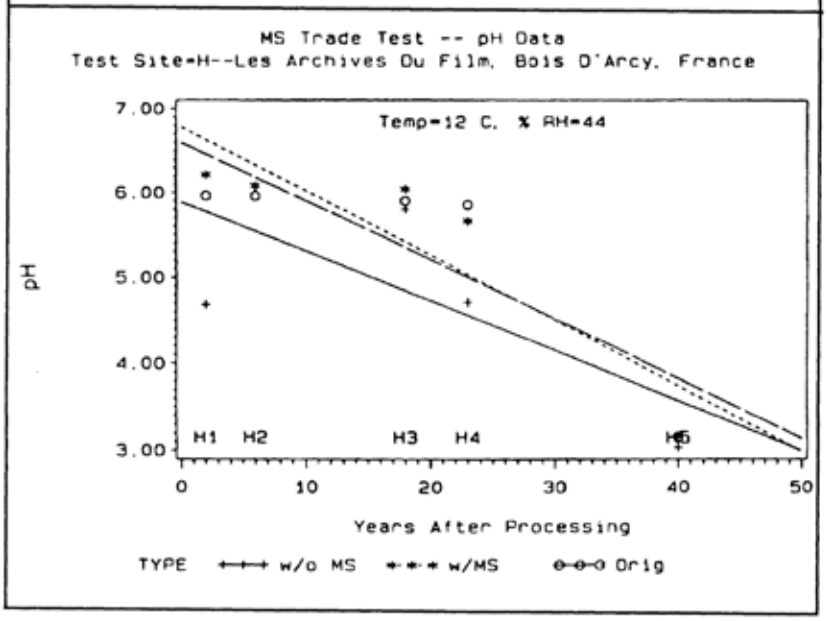
TEST SITE H - LES ARCHIVES DU FILM, CENTRE NATIONAL DE LA CINEMATOGRAPHIE, BOIS D'ARCY, FRANCE, Initial test samples received only June 10, 1994.
Contact: Daniel Toussaint

| Film Codes | Film Title | Year Processed/ Acquired | # Years in Controlled Vault/Storage |
|---|---|---|---|
| H 1-1<br>H 1-2 | Etudes Sur Paris | 1992 | 2 |
| H 2-1<br>H 2-2 | Nous Sonnes Tous Des Assassins | 1988 | 6 |
| H 3-1<br>H 3-2 | La Plus Belle Fille Du Ronde | 1976 | 18 |
| H 4-1<br>H 4-2 | La Vie De Bohne | 1971 | 23 |
| H 5-1<br>H 5-2 | Groenland | 1953 | 40 |

| | | | | | | 3M Detector mg/sample | | pH | | Acid meq/gm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Replicate | | Replicate | | Replicate | |
| Sample | Months | Temp (C) | % RH | Years After Processing | Years in Vault | 1 | 2 | 1 | 2 | 1 | 2 |
| H1 | 0 | 12 | 44 | 2.0 | 2.0 | 0.095 | 0.068 | 6.03 | 5.89 | 0.026 | 0.013 |
| | 4 | 12 | 44 | 2.0 | 2.0 | 0.028 | 0.036 | 6.21 | 4.68 | 0.015 | 0.015 |
| H2 | 0 | 12 | 44 | 6.0 | 6.0 | 0.054 | 0.116 | 5.93 | 5.98 | 0.008 | 0.008 |
| | 4 | 12 | 44 | 6.0 | 6.0 | 0.043 | 0.051 | 6.08 | 6.06 | 0.012 | 0.016 |
| H3 | 0 | 12 | 44 | 18.0 | 18.0 | 0.059 | 0.009 | 5.89 | 5.91 | 0.016 | 0.031 |
| | 4 | 12 | 44 | 18.0 | 18.0 | 0.045 | 0.055 | 6.04 | 5.80 | 0.013 | 0.042 |
| H4 | 0 | 12 | 44 | 23.0 | 23.0 | 0.042 | 0.009 | 5.78 | 5.93 | 0.020 | 0.024 |
| | 4 | 12 | 44 | 23.0 | 23.0 | 0.046 | 0.032 | 5.66 | 4.71 | 0.012 | 0.011 |
| H5 | 0 | 12 | 44 | 40.0 | 21.0 | 38.007 | 36.839 | 3.11 | 3.19 | 1.540 | 1.780 |
| | 4 | 12 | 44 | 40.0 | 21.0 | 21.000 | 28.000 | 3.16 | 3.03 | 1.400 | 1.690 |


MS Trade Test -- 3M Detector Data
Test Site=H--Les Archives Du Film, Bois D'Arcy, France
Temp=12 C, % RH=44
Log (3M Detector)
2.000
1.000
0.000
-1.000
-2.000
-3.000
H1 H2 H3 H4 H5
0 10 20 30 40 50
Years After Processing
TYPE w/o MS w/MS Orig


MS Trade Test -- Acid Data
Test Site=H--Les Archives Du Film, Bois D'Arcy, France
Temp=12 C, % RH=44
Log (Acid)
1.000
0.000
-1.000
-2.000
-3.000
H1 H2 H3 H4 H5
0 10 20 30 40 50
Years After Processing
TYPE w/o MS w/MS Orig


MS Trade Test -- pH Data
Test Site=H--Les Archives Du Film, Bois D'Arcy, France
Temp=12 C, % RH=44
pH
7.00
6.00
5.00
4.00
3.00
H1 H2 H3 H4 H5
0 10 20 30 40 50
Years After Processing
TYPE w/o MS w/MS Orig

***Henning Schou:***
*Thank you very much Tulsi for that status report and I invite questions.*

***James O 'Reilly:***
*The implications of the statements from the distribution centre in Tokyo are quite frightening to collections managers. The idea that we would have to regularly rewind our collections in order to reduce acidity levels is mind-boggling.*

*Would Kodak be interested in pursuing research with some of the institutions represented in the audience which have known active collections? Every collection has examples of films collected from a variety of sources in the recent past. One example received from an active film distributor with low acidity is of interest. If you have several examples of low acid films that would help confirm the problem.*

***Tulsi Ram:***
*Jim O'Reilly at the Image Permanence Institute has reported in his Acetate Base Degradation report that films kept out of their cans in a 50% RH atmosphere have shown decreasing levels of acidity. Acetic acid is extremely volatile and the acid quickly escapes to the atmosphere and the acidity level in the film is reduced.*

*The point raised by the Tojo Film Centre is exceptional. What it tells us is that the confined storage of a film in a can creates the conditions that assist the auto-catalytic process of decay. Re-winding will help release this build-up of acetic acid and slow the decay. Scavaging the acid will also help preserve the film.*

***George Brock-Nannestad:***
*It seems to me that a lot of these problems are intimately concerned with the cans. There are many factors that I have not seen covered yet.*

*For example, the influence of the area available for evaporation of acetic acid, the mass of film generating the acid and the diffusion of the acid vapour through the mass. Perhaps your correlations would be improved if you could bring these factors into account. In a square film can, there is a greater volume of air and the breathing due to barometric changes in air pressure is a definite factor in countries with wide variations in air pressure. These factors are also at play in the research performed by Dr Edge and her colleagues. We do not know what influence these have on the experimental results.*

*I suppose that, like other zeolites, molecular sieves can be re-generated by heating them. Would it be possible to place a very accurately determined quantity of zeolite into film cans and to weigh and analyse them at regular intervals to see how much acid they pick up. That would provide a lot of information about the activity of the molecular sieves.*
*One final point, would the molecular sieves prevent "sniffer" dogs from detecting explosives etc?*

***Tulsi Ram:***
*The quantity of molecular sieve placed in film cans varies as a function of the weight of the film. The recommended amount is 2% of the weight of the roll of film. The sieves should also be replaced periodically depending upon the storage conditions. If you store at 2°C and 20% RH then the sieves should last about 20 years. If, however, you are storing at ambient conditions, then the sieves will need to be changed every three years.*

*We do not recommend re-generation of the zeolites. As the acid is picked up, hydrolysis of the zeolite takes place. The zeolite has a pH of about 11.5 to 12.0 when fresh. As it collects acid and hydrolysis takes place, its pH drops and its ability to act as a scavenger is decreased because the pores become blocked. In some tests, the pH of the zeolite dropped to 5.0.*

*Your idea about testing the acidity of the zeolite at regular intervals is a good one and we are working on some form of monitoring.*

*One of the best detectors of acid is the nose. The nose can detect as little as 1 part in $10^6$ of acetic acid. We do not, however, recommend this as a detection method. For health reasons, people should not be allowed to sniff cans. The same applies to the used zeolite because the solvents escaping from the plastic are collected by the zeolite as well. We are considering pressing for used zeolite to be declared a "Hazardous Material" and it*

*should be thrown away after use.*

*To answer your point about detection of vapours. Zeolites are already added to certain plastics such as soft drink bottles, to prevent the flavours escaping. They are also used in bottles of aspirin and other drugs by the pharmaceutical industry to keep drugs dry.*

***Amy Kronish:***
*We are talking about using the molecular sieve to collect the acid given off by the "Vinegar Syndrome" process. Is there any possibility of the sieve, over a period of time, reversing the process?*

***Tulsi Ram:***
*No, the molecular sieves cannot reverse the action of the "Vinegar Syndrome" process. As we discussed earlier, the molecular sieves have pore sizes designed specifically to pick up and contain acids. In preserving the film, the sieves get destroyed because the process of hydrolysis uses the acid and changes the pH of the zeolite.*

***Henning Schou:***
*In archives with very large collections, there may be 250,000 cans of film in each vault. Can you give some practical advice about the use of the molecular sieve in these conditions?*

***Tulsi Ram:***
*What we have demonstrated is based on a limited trade test in about eight sites. The preservation community is recommended to periodically inspect its holdings to verify the levels of acidity.*

*If you are going to use an indicator, you are going to have to open the cans to check the indicators. What we thought was that, at the time of inspection, you place the molecular sieves in the cans. At subsequent inspections, sieves can be replaced. Even if they are not replaced, that amount of acetic acid has been removed from the film.*

*For larger archives, the concern, obviously, is the amount of labour required. This will possibly be the major element in the cost of using the sieves. Some of Martin Scorsese's collection at the Eastman House contains molecular sieves. We have also used molecular sieves in micrographic products - around 100,000 micro-film containers in Japan. We are using a smaller size because it tends to attract the water associated with oxidation and moisture induced problems such as mould growth, blocking and ferrotyping. Even after attracting the water, the sieve catalytically decomposes the peroxides.*

*We are just gathering the information and trying to find out what the problems are. So far, other than the labour involved in the initial stages, we have not found much.*

***Gerry Gibson:***
*How long does it take to place the sieve in the film can?*

***Tulsi Ram:***
*Once the can is opened, only a few seconds. Most of the effort required is in opening the cans.*

***Henning Schou:***
*One piece of practical information. You may have gone into your storage vaults and smelt acid in the air and wished to ventilate the vault to remove the acid. I have learnt recently that the company, Munter, which is well-known for its water-pumps that use silica gel to remove water from the air, have started to market a similar device that uses the molecular sieve material to pump air-borne acid out of a vault as well.*

# Anomalies in the Treatment of Hydrolysed Tapes: Including Non-Chemical Methods of Determining the Decay of Signals

**Kevin Bradley**

National Library of Australia, Canberra, Australia

## Summary of Paper

Research into the restoration of degraded polyester urethane binders has, with some exceptions, concentrated on the experimental use of data tapes. Digitally encoded tapes facilitate the measurement of the success of the restoration of the restoration process by virtue of the assessment of the level of data recovery. The treatment of analogue tape recordings has been extrapolated from these results on the grounds of chemical similarity.

The measurement of signal quality in the restoration of analogue tape recordings has been much more subjective, relying on the listeners appraisal of the signal quality and pseudo measurements like "squeal index".

Using analogue measurement techniques, a process for measuring the efficiency of binder restoration with regard to analogue recordings is proposed. The process is used to evaluate the effectiveness of the most common treatments, cleaning, exposure to high temperature and low humidity for short periods, and lower temperature and low humidity for longer periods.

The differences between naturally and artificially aged tapes are examined in terms of the effect on signal quality rather than chemical changes.

The paper will consider the effect of the various restoration processes on the signal quality and will note various anomalies between the common understanding of the degradation of tape binder and the result of treatment.

# Anomalies in the Treatment of Hydrolysed Tapes: Including Non-Chemical Methods of *Determining the Decay of Signals*

## Kevin Bradley

As archives all over the world begin to transfer their collections to new digital storage media, an increasing number of analogue recordings are being found to demonstrate the artefacts of binder degradation. It is most likely, given the current state of technology and the high labour cost of the work, that the transfer made now to the digital domain will be the last from the analogue original. Any distortion artefacts included in the signal will be transferred, in the digital domain, to all future copies. In the process of restoring the degraded tape carriers, the signal, which is the artefact proper, may be affected. It behoves the archivist to observe the oft quoted tenet of traditional conservation that no treatment that changes an object (signal) should be carried out if it cannot be documented or reversed.

In the restoration of tapes containing digitally encoded information, it is relatively easy to assess the accomplishment of any improvement by the measurement of the successfully retrieved data. Consequently data tapes have been used extensively in research projects designed to estimate the treatment of degraded tapes [Cuddihy 1980, Brown, Lowrie and Smith 1982, 1983, 1984, 1986 etc.]. The apparent fact that research into the treatment of degraded tapes has been largely driven by the computer based industries rather than audio archives have contributed to this dependence on data tapes for testing. The process of assessment of the restoration of data tapes does not necessarily measure distortion artefacts that may be significant in the case of analogue audio.

The recommended restoration processes have been few, mostly focusing on the application of heat, or exposure to low humidity. These treatments have been effective in removing the squeal indicative of the degradation of the binder. However, while the incomplete restoration may make the tape playable, it does not necessarily reverse all the degradation artefacts. The purpose of this paper is to assess the effectiveness of the processes with regard to analogue audio recordings and to evaluate the impact on the signal of the treatment itself. It is also intended to measure the level of restoration where the tape has been made playable insofar as the squeal is no longer apparent, but the tape may not have been completely restored. The knowledge of the consequence and the efficacy of the treatment will allow the conservator of recorded material to judge the most appropriate process, or at least to be aware of the artefacts of the action.

# The Test Set Up

## Tapes

The tapes tested were as follows.

**Tape Type 1: Ampex 406**, purchased approximately 11 years ago on 10½" NAB reels. These tapes were the working duplicates of original items held in the National Library of Australia's Oral History and Folklore collections. The tapes have, since purchase, been stored under carefully controlled conditions, i.e. 18°C, and at 50% RH from purchase until 1988, and 30% RH since that period. The variations in conditions have been slight, particularly since 1988 when the level and tolerances associated with the specification of the humidity in the tape store were significantly tightened, typically ±2% RH and ±1°C. Nonetheless, when played, these tapes now leave a light coloured deposit on the heads and exhibit the characteristic squeal associated with one form of binder degradation.

**Tape Type 2: Scotch 226**, purchased approximately 12 years ago on 10½" NAB reels but never used. These tapes were stored under standard office conditions since purchase, i.e. approximately 50% RH and 21°C, 24 hours/day. Like all large building systems the office air-conditioning exhibited variations of around ±15% RH and ±3°C according to seasonal variations and staff demands. When played, these tapes leave large dark deposits on the heads and, if left with the tape and head engaged, stick and become difficult, if not impossible, to play.

**Tape Type 3: Ampex 406,** purchased approximately 8 years ago on NAB hubs, stored under standard office standard conditions since purchase, i.e. approximately 50% RH and 21°C, 24 hours/day. In spite of the unsuitable storage conditions these tapes do not exhibit the artefacts of binder degradation. They were used as a control and in attempts to artificially age tapes.

**Tape Type 4: BASF 911.** New. Exhibited no signs of binder degradation. Used as a control in the testing procedure.

All four tapes have a type of polyester urethane binder, backcoat, and are a standard play tape, i.e. 50µm thick.

Other tapes have been, and continue to be, tested, but not in sufficient quantities to be included in this paper. The selected tapes were used because they are present in significant numbers in the National Library of Australia's collection, both as original recordings, as well as working duplicates, and as a consequence, provided a ready supply of expendable tapes suffering from binder degradation.

## Test Equipment

The test equipment used to measure the results of the tests is an Audio Precision SYS-22A, PC controlled audio test and alignment system. The replay machine was a Studer A820, chosen because it uses rollers rather than fixed guides and exhibited low levels of speed variations, resulting in measurements that would reflect the condition of the tape rather than the characteristics of the machine. The only fixed components across which the tape passes are within the head block.

# The Tests

Four sets of tests were carried out on the tapes.

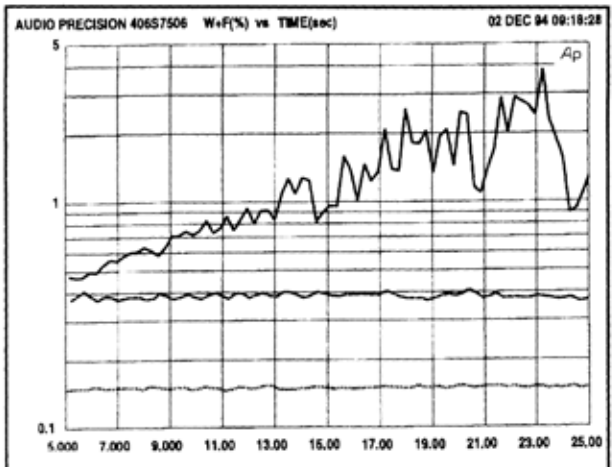
**Frequency response**: Swept from high to low with 11 discrete tones between 20kHz and 10kHz and 27 discrete tones between 10kHz and 20Hz, at IEC centres. The high frequencies were tightly grouped as initial tests indicated that this was the area most likely to show any effect of the restoration process.

**Wow and Flutter:** Wow and Flutter (W&F) was measured using a 3.15kHz tone recorded onto the tape under test. IEC/DIN standard measurement was performed which reveals Frequency Modulation (FM) in the 0.5 to 200Hz range. In the graphical representation, the solid line represents the wow and flutter measurement and the broken or dotted line, the percentage speed variation.

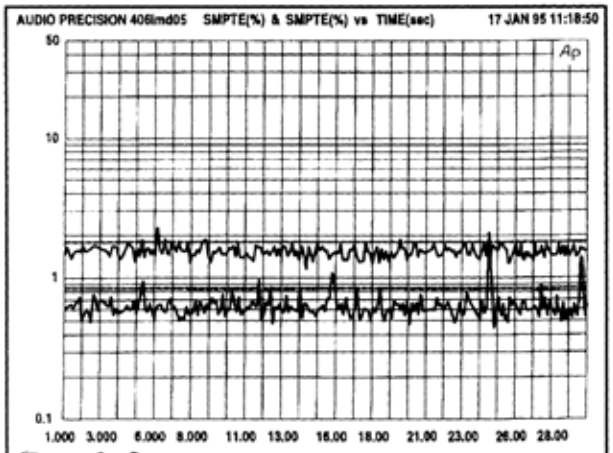
**Scrape Flutter**: Due to the frictional effects of a tape passing over the heads, higher frequency FM products than can be measured using standard wow and flutter tests may be revealed by other analytical practices. The frictional effect of the tape on the heads may produce FM components as much as 5Khz away from the signal [Cabot 1988:16.53-16.56]. Using a 12.5kHz tone allows for a measurement bandwidth of 5kHz without aliasing errors caused by that bandwidth.

The higher frequency FM products are not perceived by listeners in the same way as lower frequency W&F products, rather these high frequency components are described as grit, added noise or harshness. At extreme levels, scrape flutter can be heard as squeal.

Where single figures are quoted for either the wow and flutter or scrape flutter measurements, they are displayed as 2-SIGMA values, i.e. the value which was exceeded over 5% of the time during the 25 second sweep. This value is calculated by the test equipment.




**Graph 1: Three Levels of Measured Scrape Flutter in a Tape Suffering Binder Degradation to Show the Limits of the Test**




**Graph 2: Limits of the Acceptable Range of Dropout Based on SMPTE Intermodulation Dropout Measurement**

Graph 1 shows three typical scrape flutter sweeps. The lower sweep shows the level of scrape flutter apparent in a reel of Ampex 406 exhibiting no signs of binder degradation. The middle sweep shows the replay characteristics of a reel of Ampex 406 suffering binder degradation. It exhibits a stable but unacceptably high scrape flutter level which does not escalate into squeal.

The upper sweep in Graph 1 shows a scrape flutter measurement on a reel of degraded Ampex 406 that exhibits the characteristic squeal associated with that type of binder degradation. At the initial state, around 0.4%, there is no squeal and the effect of the higher than usual scrape flutter measurement is somewhat audible. As the scrape flutter value rises the audible effect increases and the squeal associated with binder degradation becomes apparent. Once beyond the squeal threshold the measurement of the scrape flutter becomes unstable though still exhibiting a higher than normal level.

**Drop Out:** Using a SMPTE Inter modulation (IM) high frequency tone of 7kHz and disabling the 60Hz modulation tone, a comparative value can be produced to indicate the level of drop out. The SMPTE detector reveals the level of amplitude modulation due to the effect of particle loss. The comparative levels have not, to my knowledge, been quantified. Graph 2 shows the expected acceptable window based on typical measurements from two commercially available reels of tape.

## Differences in Degraded Tapes.

The Ampex 406 and the Scotch 226 both exhibit different characteristics as a result of degradation. As has been previously noted, the degraded Ampex 406 tape sheds a lighter coloured deposit on the heads and produces the characteristic audible squeal. When replayed a degraded Ampex tape shows excessive levels of scrape flutter, and the wow and flutter figures remain near normal.

The Scotch 226 sheds a darker coloured deposit which appears more sticky and causes the tape to slow. Measuring reveals an extremely high level of wow and flutter and replay speed deviation. There is little or no high frequency components in the modulation of the signal and the scrape flutter figure remains low. Though the tapes exhibit different characteristics the most common explanation for the degradation process is hydrolysis [1] and the most common treatment is elevated temperatures and low humidities for a short period.

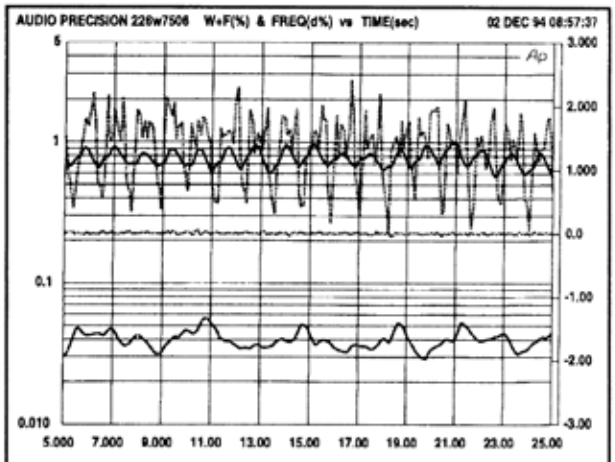
## Evaluation of Traditional Restoration Treatments.

The traditional treatment for the amelioration of any faults associated with binder degradation is to place the offending tape in an oven at a temperature somewhere below the flow temperature of the plastics for sequential periods of 8 hours until the problem "sounds" better and the tape can be played from end to end.

Using the previously mentioned evaluative processes, reels of Ampex 406 and Scotch 226 were placed in a laboratory oven at fixed and stable temperatures of between 75°C and 30°C. The oven maintained 0% RH, even at lower temperatures, by pumping preheated dry air into the chamber. The conditions were generally kept within 0.2°C and 0.5% RH and secondary checks on the internal monitoring system were made using a "Datalogger" that allowed for graphic representation over time.

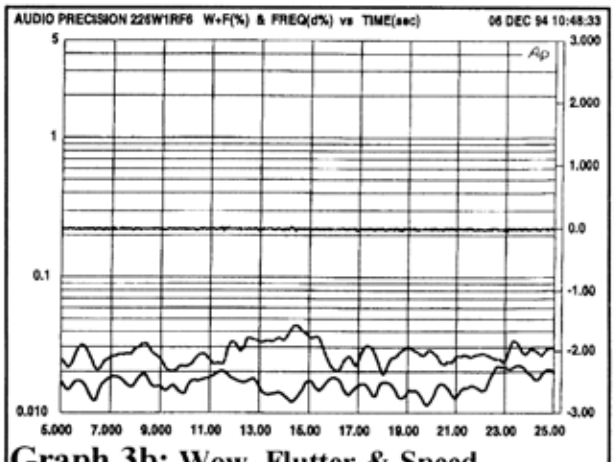
At temperatures of between 50°C and 75°C for periods of between 8 and 12 hours, scrape flutter and wow and flutter were reduced to levels at least equal to the unhydrolysed control tapes.

Graph 3a and 3b documents the difference between the two tapes and the restoration level achieved at 65°C and 0% RH. The upper sweeps in graph 3a show an unacceptably high level of wow and flutter on a reel of Scotch 226, and a replay speed variation of 2%. The lower sweep in the same graph shows a reel of Ampex 406 which has an acceptable level of wow and flutter, and no change in replay speed. Both tapes were showing the artefacts of binder degradation, and the Ampex tape, is exhibiting the "squeal" associated with that form of binder breakdown.



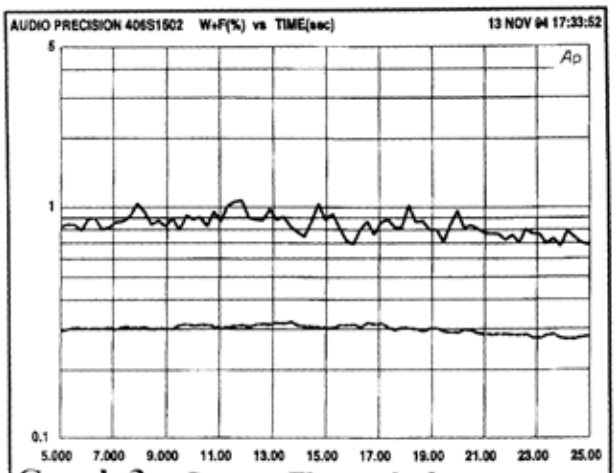

**Graph 3a: Wow, Flutter & Speed Deviation before Treatment of Degraded Tapes**

Graph 3b shows the level of wow and flutter after restoration. The upper sweep is the Ampex 406, which exhibited very little change in measured wow and flutter, and the bottom sweep is the 226, in which the wow and flutter was reduced to optimum levels. Graphs 3c and 3d show the reverse situation when scrape flutter is measured. The upper sweep in graph 3c is Ampex 406 and the lower sweep is Scotch 226. Graph 3d shows both tapes after restoration. This convincingly demonstrates the earlier point regarding different tapes exhibiting different faults.

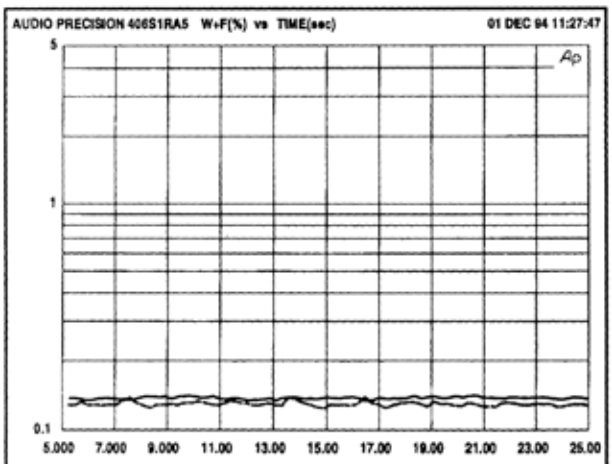



**Graph 3b: Wow, Flutter & Speed Deviation after Treatment of Degraded Tapes**

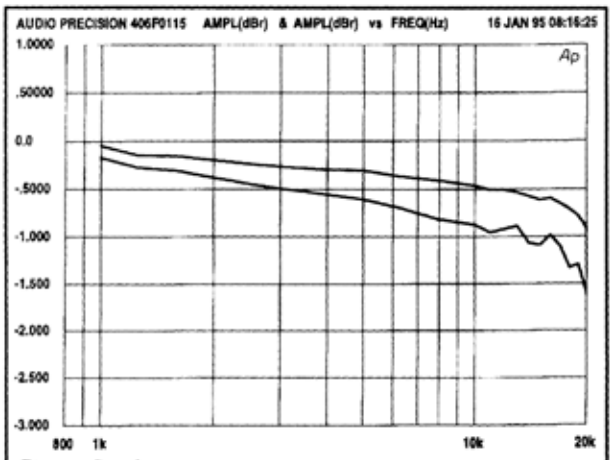
It was noted that higher temperature treatment resulted in a low level loss to higher frequency signals, generally above 2kHz. Scotch, Ampex and BASF tapes were prepared with swept tones




**Graph 3c: Scrape Flutter before Treatment of Degraded Tapes**




**Graph 3d: Scrape Flutter after Treatment of Degraded Tapes**




**Graph 4: Loss of High Frequency Response after Treatment at 60°C**

to quantify this observation. To negate any possible effect from adjacent layer print through which may have altered the signal level, the tapes were interleaved with either paper leader, or layers of similar tape, and the tapes exposed to higher temperatures. Theoretically the print through in a standard play tape should be at its maximum at around 1kHz, depending on speed, well below the problem area. However, at the frequencies identified, the movement in the length of the tape due to temperature increase would approximate the wavelength of the signal, producing an uncertain phase relation between the print through and adjacent signal. Hence interleaving was considered prudent.

Graph 4 shows of loss at higher frequencies of ½dB after treatment at 60°C, which while not large, was measurable and repeatable. The loss occurred only once in a treatment cycle, subsequent high temperature cycling did not increase the reduction in high frequencies.

At temperatures below 40°C there is no measurable loss in high frequency. The restoration, however, of the other artefacts of binder degradation is incomplete.

Graph 5 shows a succession of measurements of scrape flutter performed over a six week period on Ampex 406. The tapes were placed in a chamber at 32°C and 0% RH and checked on a regular basis. After reaching the minimum shown on the graph, no further improvements were noted. This minimum level of 0.23% is above the full restoration level attainable of around 0.12%. Nonetheless the tape was playable from end to end without any squeal.

At 40°c and 0% RH the loss in high frequency was low, typically close to ¼dB, though still consistently repeatable.

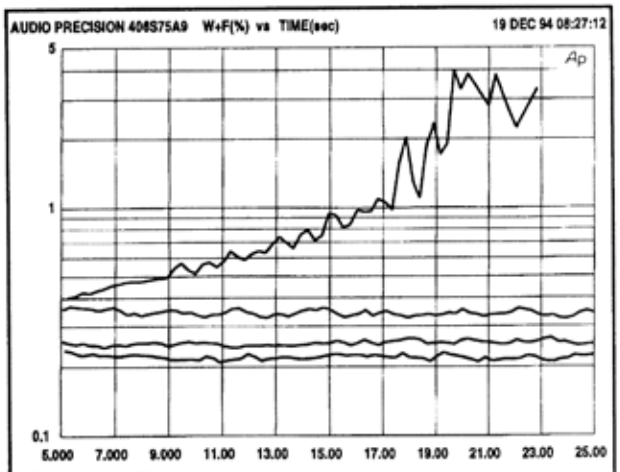
Graph 6a shows the scrape flutter measured on a typical reel of degraded Ampex 406 across a five day period. The tape was treated at 40°C, 0% RH. Graph 6b shows the time taken to reach a point beyond which there was no further improvement.

As discussed above, the analyses of the low frequency wow and flutter components are a better guide to the effective treatment of the

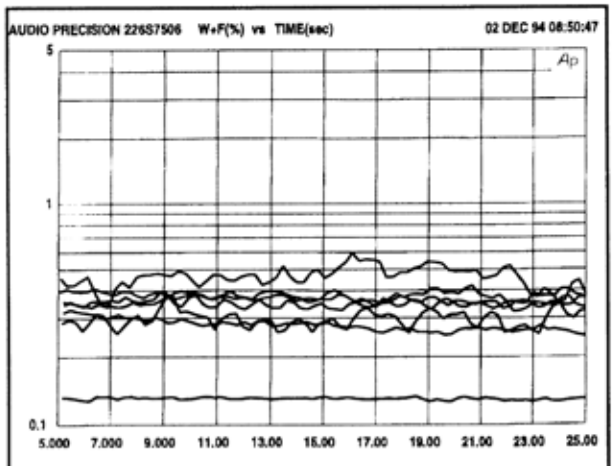
degraded Scotch tape than the higher frequency components of the scrape flutter test.

Graph 7 shows the first, third and final measurement of wow and flutter over a five day period in which the tapes were exposed to conditions of 40°C and 0% RH. The examination of the wow and flutter showed no measurable change in high levels of wow and flutter, though the tape was patently playable.

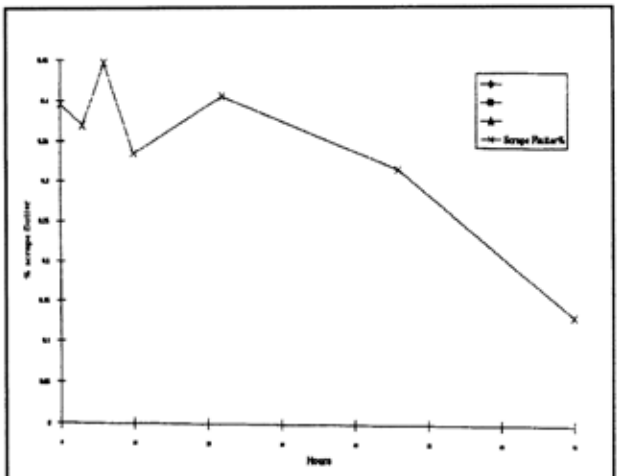
If the explanation of hydrolysis is to be accepted, then it seems feasible that sealing the degraded tapes in bags with moisture absorbing material and keeping them in standard tape storage conditions would reverse the reaction.




**Graph 5: Successive Measurement of Scrape Flutter over a Six week Period during Treatment at 32°C and 0% RH**




**Graph 6a: Successive Measurements of Scrape Flutter over a Five Day Period during Treatment at 32°C and 0% RH**

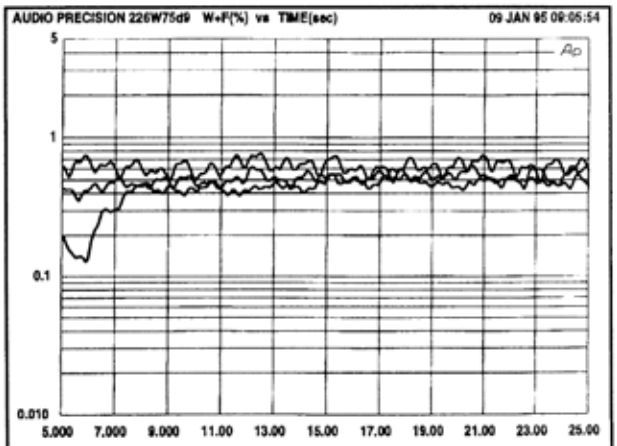


**Graph 6b: Time Taken to Reach a Stable Level of Restoration**

Tests to ascertain this are underway, but in the light of results of the lower temperature conditions in the laboratory oven, the time scale for testing has been revised and tapes have yet to be examined. It is possible to extrapolate that such treatments will, like the 0% RH, 32°C process tested, produce an incomplete restoration, that may nonetheless be playable.

## Evaluation of Some Other Methods

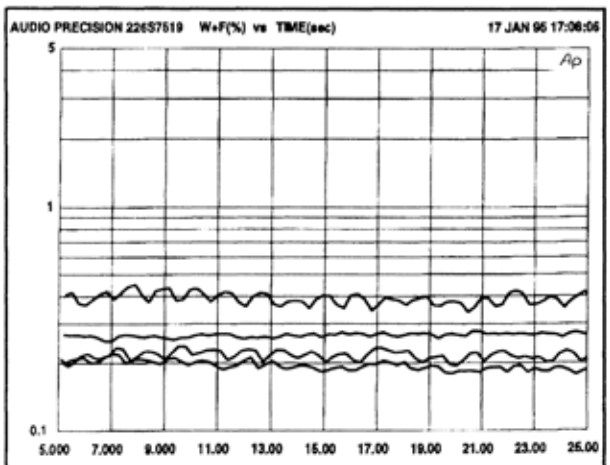
Other suggested methods of playing a degraded tape include the cleaning of the tape to remove the sticky artefacts of binder degradation. Using the previously discussed tests to measure the effectiveness of this, a slowly rotating cylinder of 40mm diameter covered with a lint free cloth



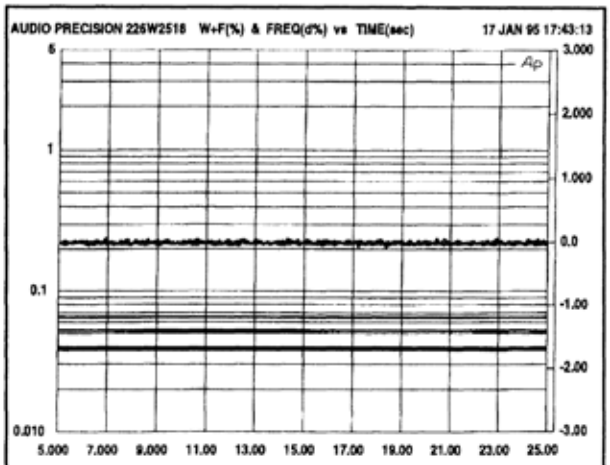

**Graph 7: Successive Measurements of Wow & Flutter over a Five Day Period during Treatment at 40°C & 0% RH**

was applied to the tape between passes and the resultant difference measured. The cleaning had no effect on tapes that had high levels of signal degradation, but was thought to be potentially effective for tapes that exhibited low levels of signal degradation or when used in combination with low temperature treatment.

Graph 8a shows the improvement in scrape flutter achieved on a reel of Scotch 226 on successive cleaning and measurement passes. The level of restoration achieved was of a similar level to that of long term low temperature baking. The cleaning process was unable to restore the tape to original condition, typically reaching a scrape flutter figure of about 0.21%. Subsequent cleaning had no further effect. The cleaning had a greater effect with respect to the Wow and Flutter readings on the Scotch 226. Sequential measurement wow and flutter after cleaning passes achieved a minimum of 0.03%, which while not the optimum that can be achieved, was within acceptable bounds.




**Graph 8a: Successive Measurements of Scrape Flutter to Evaluate Cleaning**



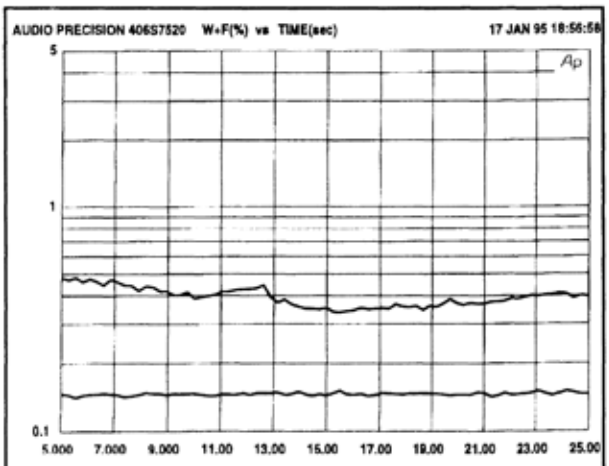

**Graph 8b: Successive Measurements of Wow & Flutter to Evaluate Cleaning**
(The Straight Lines are Calculated 2-sigma Values)

Graph 8b shows the successive measurements. The straight lines in the graph are a result of the 2-sigma calculation already mentioned and thus represent a single value for the 25 sec period. This was implemented to enable easy distinction between the small successive changes. As expected, the cleaning process had the most effect on tapes that already produced low levels of degradation artefacts in the signal.

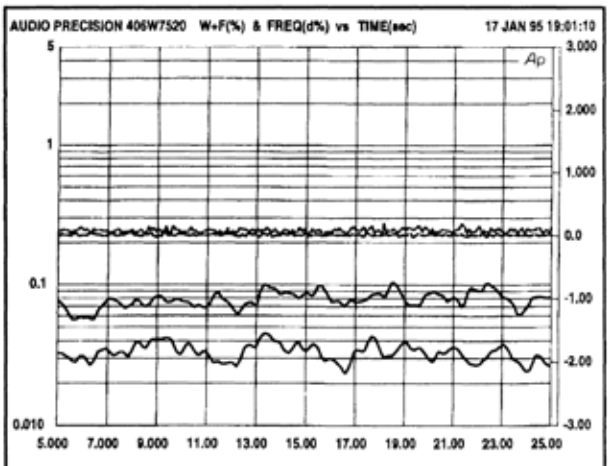
Discussions regarding the use of microwave ovens for the treatment of tapes are prevalent, if not published, throughout the archiving industry, and with the high levels of moisture and other organic materials present, the tapes achieve a surface temperature much higher than that attained in conventional ovens in a very short period of time. Eight hundred foot lengths of tape, on plastic reels, were baked singly for periods of between 1'30 and 2'00 at the lowest setting (typically 10% on). Similarly to tapes baked in conventional ovens, a loss approaching ½dB was noted in tapes treated in the microwave oven.

After the short microwave treatment, scrape flutter and wow and flutter were measured at the optimum level. Graph 9a indicates the order of improvement in scrape flutter achieved on a reel of degraded Ampex 406, and 9b, the level of improvement in wow and flutter in the same reel. In the case of a small number of tapes, notably Ampex 406, some deformation in the pack was noted, though it did not seem to affect the previous two measurements.

An extra measurement of THD+N to assess if the exposure to microwave fields, and any associated magnetic fields, produced an effect on the signal, was carried out. This was implemented by sweeping slowly across the frequency band at 1/3 octave centres and measuring THD+N associated with that particular frequency. After treatment it was possible to measure a slight increase from 0.5% to about 0.6% at 50-100Hz, but no repeatable or significant change at the frequencies above that.




**Graph 9a: Scrape Flutter before and after Treatment for 90 seconds in a Microwave Oven**



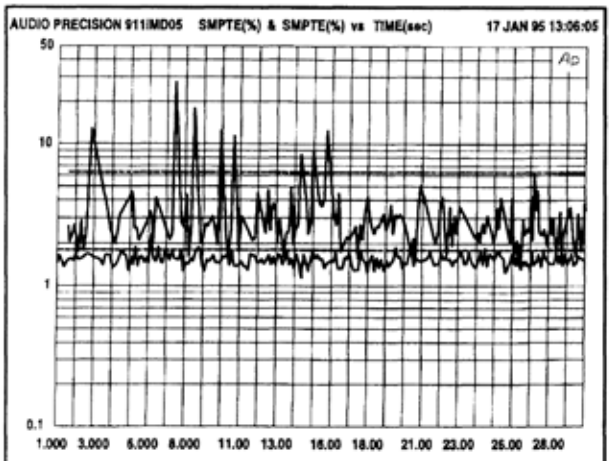

**Graph 9b: Wow & Flutter before and after Treatment for 90 Seconds in a Microwave Oven**

Drop out produced the only real measurable difference between treatment in a conventional and microwave ovens. When drop out was compared between the degraded and restored Ampex and Scotch tapes, no appreciable difference was noted in the already high readings.

However the control tape, BASF 911, showed a large increase in drop out between the pre and post treatment. Graph 10 is a measurement of dropout, as described earlier. The lower sweep is a measurement taken before treatment, and the upper sweep is a measurement after 1'30", at 10% setting, in the microwave oven. It appears that the microwave treatment, far from improving, could have a deleterious effect on drop out levels. The high levels apparent in the pre-treatment degraded tape masked the effect in the case of the Ampex 406 and Scotch 226.

With the generation of such high temperatures, for such a short period, and in the presence of microwave fields,

thorough testing should be carried out to assess the effect of the treatment. The amount of testing on microwave ovens for this paper has been very small and should not be seen as an indication of the worth or otherwise of this sort of treatment. It is included to indicate the manner in which this testing procedure can be used.




**Graph 10: Increase in Dropout in Artificially Aged Tape after 90 Seconds in a Microwave Oven**

## Artificial Ageing

The original intention of this project was to evaluate a testing program by recording known signals onto a known tape, subjecting the tape to increased levels of humidity and temperature and measuring the level of degradation. It would then be possible to measure the effectiveness of various proposed treatments by evaluating the level of restoration achieved. To this end various reels of tape have been placed in conditions approaching 100% humidity and temperatures ranging from 35°C to 65°C for periods of between six weeks and six months.

Though in a previous paper I have questioned the validity of solvent extraction as an indication of actual signal condition when used on segments of "naturally" aged tapes [Bradley 1992:87-93], I have used it in this case as evidence of any chemical changes. A new tape should exhibit a solvent extraction figure of less than 2%, an old tape, such as the 8 year old Ampex 406 used in testing and which does not exhibit any evidence of binder degradation, will produce a figure of around 3%. Artificially aged tapes tested in this project all revealed a solvent extraction figure of between 4.9% and 5.5%. Though "naturally" aged tapes exhibiting the artefacts of binder degradation produced solvent extraction figures which covered the full gamut of these figures, i.e. 2% to 5.5%, none exceeded 5.5%, and certainly within the literature 5% is generally considered an indication of hydrolytic breakdown (see Cuddihy, Brown Lowry and Smith etc.).

The artificially aged tapes, all of which produced an extraction level of near 5%, were assessed using the non-chemical criteria described. The artificially aged tapes, after prolonged exposure to the extreme environmental conditions, showed a tendency to shed and a high drop out level was measured.

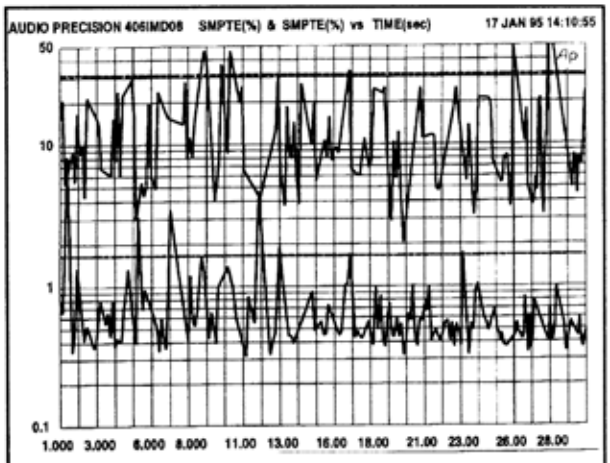
Graph 11 shows the level of drop out, the upper sweep represents the level found in an artificially aged reel of Ampex 406, and the lower sweep a naturally aged reel of Ampex 406. The level in the artificially aged tape is significantly higher, and characteristically different, from that found in any of the naturally aged tapes.

The level of scrape flutter, and wow and flutter remained low, never exhibiting the non chemically measured artefacts that

distinguish a naturally aged tape, even after the tapes had spent 6 months at 40°C and near 100% RH. In other words, the measurement of the level of hydrolytic breakdown by chemical means approximates our understanding of the breakdown of tapes, but the physical manifestation of those faults does not match with a naturally aged tape.

To check the concerns with artificial ageing, naturally aged tapes were placed in a 100% humidity oven at a temperature of 50°C. After 12 hours the scrape flutter, wow and flutter and frequency response were measured.

As documented on graph 12, the tape's scrape flutter, had been restored to its optimum level, the upper sweep representing the measurement before exposure to 50°C, and 100% RH. There was also a loss of level in the high frequencies identical to that found in treatment using dry ovens.




**Graph 11: Dropout in Artificially Aged Tape (Upper Trace) and Naturally Aged Tape (Lower Trace)**

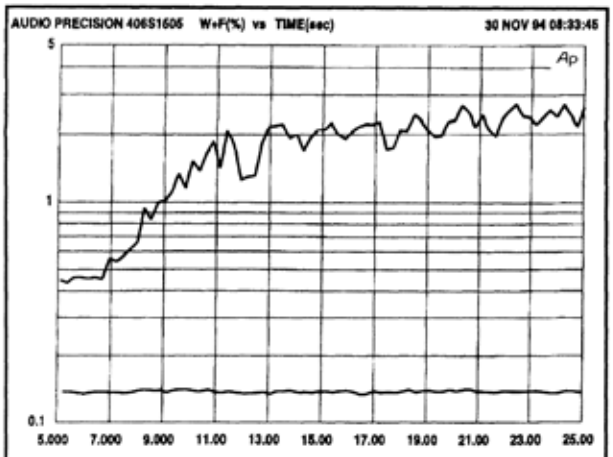
The initial inference that can be drawn from this is that in recovering tapes, high temperature operates to restore the playability of the tape independently of humidity. It also casts some doubt on identifying hydrolysis as the only mode of breakdown, or at least that in the more complex process described by Edge, it seems unlikely that a hydrolytic reaction is being reversed. Lemaire [personal communication] is able to demonstrate that even under high humidity conditions, the higher temperature is sufficient to encourage a certain amount of cross-linking between the shortened polymer chains. If this is the case, then it casts some doubt on the use of high temperatures and humidity as means of accelerating the ageing process. Either way it opens a conundrum that is not resolved by the current chemical explanations.

## References:

Bradley, K. 1992 *Restoration of Tapes with a Polyester Urethane Binder* in IASA Phonographic Bulletin no 61 87-93.

Brown, D.W., Lowry, R.E. and Smith, L.E. 1984 *Predictions of the Long Term Stability of Polyester-Based Recording Media* NBSIR 84-2988, US Department of Commerce.

Brown, D.W., Lowry, R.E. and Smith, L.E. 1983 *Predictions of the Long Term Stability of Polyester-Based Recording Media* NBSIR 83-2750, US Department of Commerce.




**Graph 12: Scrape Flutter before (Upper Trace) and after (Lower Trace) Exposure to 50°C & 0% RH**

## Summary

In summary the testing procedure has revealed a number of significant pieces of information relevant to the treatment of degraded polyester-urethane tapes.

All tapes suffering from some form of binder degradation do not behave in the same manner. It can be inferred from this that the manner of breakdown is chemically different in different tapes and situations

Artificial ageing does not approximate the artefacts of the known degradation processes.

All the tested restoration processes have areas of compromise. Either the signal is not fully restored or it is affected in some way, measured here as incomplete restoration, loss of frequency response or increases drop out.

## Conclusion

This paper describes a methodology for quantifying what many recording engineers and sound archivists have been doing empirically, i.e. finding the most appropriate method for dealing with the multiplicity of problems presented by the degradation of large collections of recorded materials. Most importantly it attempts to set the parameters for determining the condition of a recording not with the chemical composition of the carrier, but with the signal itself. It therefore follows, in determining the most appropriate treatment for the restoration of a tape, that the recorded content be an important consideration in the choice.

Brown, D.W., Lowry, R.E. and Smith, L.E. 1982 *Predictions of the Long Term Stability of Polyester-Based Recording Media* NBSIR 82-2530, US Department of Commerce.

Cuddihy, E.F. 1980 *Ageing of Magnetic Recording Tape* IEEE Transaction on Magnetics, 12(2), 126-135.

Smith, L.E., Brown, D.W., and Lowry, R.E. 1986 *Predictions of the Long Term Stability of Polyester-Based Recording Media* NBSIR 86-3474, US Department of Commerce.

***Henning Schou:***
*Thank you Kevin for a most interesting paper. Are there any questions?*

***Mike Turpin:***
*Why were the tests restricted to polyester tapes?*

***Kevin Bradley:***
*I was trying to assess the effect of the restoration processes that have been suggested for polyester tapes that are suffering poly-urethane binder breakdown. This is a major problem in our collection.*

*Before subjecting the 10% of the collection that is suffering from this problem to the treatment, I wanted to check the actual effects of the restoration process. The research was, therefore, totally focussed on that area.*

*It would be good to do further research on the effects of the process on acetate and PVC based tapes and on different binder formulations.*

***Ian Gilmour:***
*With the heat treatment of tapes at the NFSA in Canberra, we found that there is often a secondary mechanical effect. This is because, at temperatures over 50°C, there is a certain amount of flow in the binder layer.*

*We confirmed this last year when we did some tests using laser con-focal micrography. Basically,this technique measures the surface fluctuations of materials. With tapes that have been exposed to temperatures in excess of 50°C, we found that the surface was often smoother. This will, in turn, often give better head-to-tape contact and improved high frequency performance.*

*What we were also alerted to, however, was that the treatment causes permanent changes in the tape. If I can add to the "Health Warning" issued by George Boston this morning - exercise caution when treating tapes. Most tapes can be treated for longer periods at very low humidity and without such excessive temperatures.*

*And finally Kevin, a question. How do you manage to introduce a 3150Hz tone to a tape that is already badly degraded?*

***Kevin Bradley:***
*Because we are unable to artificially age tapes, I used 25 to 30 second lengths of blank tape taken from the end of old spools and recorded on them. I relied on the tape machine to pull them through for the recording and then played them again. Every subsequent test was carried out on an adjacent, unplayed section of tape.*

*On the question of frequency response, subjecting a tape to elevated temperatures and replaying it does, in fact, smooth the surface and give a better frequency response. Subjecting a tape to high temperature and then playing a previously unplayed section gives a completely different set of readings. So the playing of a tape after treatment also affects the tape.*

***George Brock-Nannestad:***
*Microwave ovens have a very focussed energy distribution pattern within them. The antenna or distributor does not really give the required even spread of energy through the tape pack. It is not possible, therefore, to be sure of the temperature at any point in the tape pack.*

*Using a low setting of the microwave does not alter the energy output of the microwave generator, it merely adjusts the timing of the on-off cycle of the oven. When the oven is at "on" section of the cycle, the energy output is always at full strength.*

***Kevin Bradley:***
*I absolutely agree. I was not recommending the use of microwave ovens to heat tape: I was merely testing their use and reporting my findings.*

*In fact, because of the makeup of a tape - the base layer, the binder and the carbon particles in the back coating - heat is transferred through the tape very rapidly and in quantity but to small sections only. This means that small sections of the tape become very hot in a very short time.*

*My tests have done nothing more than evaluate the effects of this on the signal and, as I said earlier, one of the effects is a very high dropout rate. I do not treat any of the tapes in the collection in a microwave although some institutions do.*

***Jacques Lemaire:***
*When heat treating tapes you are dealing with three dynamic processes:*

1. *The thermal oxidation of the polymers.*
2. *The hydrolysis of the oxidised polymers.*
3. *The cross links occurring during the high temperature of oxidation.*

*We are, therefore, dealing with three dynamic processes that vary according to the experimental conditions. You might find some detrimental effect at low temperatures and some recovery at high temperatures without any surprises. But it is a very difficult situation to control.*

# Wet and Mouldy: The Deterioration and Treatment of Water Damaged Films

## Mark Nizette

***Henning Schou:***
*It gives me great pleasure to welcome the second delegate from Australia - an ex-colleague of mine Mark Nizette. Those of you who remember the third JTS held in Ottawa in 1990 will recall that Mark and I presented a paper entitled* The Effect of Temperature and Humidity on Motion Picture Film. *We said that it was a preliminary report on research being undertaken at the NFSA in Canberra and that the final report and conclusions were still to come. Well, they have arrived.*

*Mark has been working in the field of photography and film preservation for more than 15 years. His original training was in the preservation of archaeological artefacts and he completed a MSc at the University of Canberra in 1982. He joined the NFSA in 1990 and is currently Head of the Preservation Branch with responsibility for the sound and video components as well as the motion picture film collection.*

The NFSA was faced with a major problem a few years ago when we discovered that a large collection of our colour film was subject to high humidity conditions. When we examined the film we discovered that a large number of the films exhibited deterioration of various types. This included mould and a number of other biological conditions. In addition, when the gelatine emulsion gets wet it tends to become sticky and expand. Films that were not loosely wound then compress the layers against each other. This leads to problems such as blocking - where the roll of film become so stiff and hard that it becomes like a piece of wood - and the layers sticking together because the gelatine is adhering to adjacent turns.

Today I will present some of the results of our work into mould and other problems caused by high humidity. Many people are aware that mould will grow when the humidity is above about 60% RH. What people are less aware of is that the humidity in the air may not be the same as the humidity in the emulsion. Mould also grows under a range of different conditions including low temperature. Mould does not like acidic conditions so, if you suffer from the Vinegar Syndrome, your collection is less likely to suffer from mould.

I will show a short video of some of the problems that we have suffered and then give a brief summary of the treatments that we used to solve the problems.

***Editor's Note: The rest of this presentation consisted of a video with spoken comments from Mr Nizette. The comments have been transcribed and edited for publication.***

The characteristics of the film deterioration that you will see are divided into two groups:

> Biological -The moulds and the fern-like growths (another form of mould).
> Physical - Ferrotyping, anti-ferrotyping and emulsion lifting of the super-coating and of the layers.

## Biological

Moulds affect the film in differing ways. In the first example, the mould growing across the film is affecting the dye layer but not the emulsion layer. Under a reflected light, it is apparent that the mould is burrowing up and down on the film. However, the enzyme that is produced to digest nutrients from the film is affecting the colour dye but not the emulsion itself.

In another example - of fern like growth seen under high magnification using a scanning electron micrograph - you can see that the gelatin is being eroded away. The enzymes produced by both the spores and the growths are digesting the gelatin and causing a physical deformation of the gelatin layer. In this case, any treatment must not only remove the mould but also treat the physical furrow in the gelatin that has been left behind.

Here the mould is not causing any physical deformation of the gelatin at all. The mould is burrowing through the gelatin but leaving the surface intact.

In this example of reversal film, the mould is damaging only the upper layer, the protective layer, of the film. At a higher magnification you can see that the surface has been eroded. Under transmitted light it is apparent that the colour of the film has not been changed, only the density.

In this case we can see that the mould has grown and eroded the gelatin when conditions were favourable. Later, when the film dried out again, the mould died and decomposed. However, the damage generated by the mould caused the emulsion to crack up as it dried making it impossible to treat the film in any realistic manner.

Here is an example of mould growing on the surface of the film. Both spores and growths are clearly visible. Because of the tight wind of the film, the growths found it difficult to penetrate the film and remained on the surface. It may look badly infected but it is only surface damage. If quickly dried, the mould will die off and decompose leaving an undamaged film.

This example shows how mould has protected a film from frosting when it became wet. The upper protective layer of the film reacted with the water and became frosted.

Here the mould has grown across the surface of the film and has channelled into the letters. Where there is a high level of dye such as black areas, the density increases and the topography of the film surface changes. The mould has grown along the blue area around the deformity.

Some shots of apparently badly affected frames before and after treatment. The mould was spread across the surface only and could be treated quite easily without any damage to the film.

This is an example of a Kodachrome film from the early 1940s. The mould growth in the centre and the density of enzymatic damage in reflected light. In transmitted light the changes in colour density are obvious but there are no changes in hue. The mould has not entered the dye layers and consumed the dye. After treatment, the site of the mould still shows some form of deformation under reflected light but, under transmitted light, the problem is not visible.

In this film, the dye layer has been affected by water and mould has grown on the film. When the film was dried, it became clear that the dye had partly dissolved and spread over the surface of the film depositing a yellow film. By careful cleaning with cotton swabs, much of the yellow film has been removed together with the mould.

We also found some larger examples of biological infestation. Many of these bugs and imnsects were caught in the projection mechanism and I show them to illustrate the full range of problems that may be encouraged by wet conditions.

## Physical Problems

Apart from mould, other problems can occur when film becomes wet.

Ferrotyping - where the surface becomes very shiny
Anti-ferrotyping - where the surface of the film becomes distorted and uneven
Emulsion lifting of the protective super coating
Emulsion lifting of the dye layers.

Here is a cross section of a typical damaged film. Here, as in many other cases, the protective layer on the top of the emulsion does an excellent job. The disruption of the film - the physical deformation - is reduced or limited only to that over protective layer. If the damage extends to one or more of the dye layers, the damage becomes irreversible. If, however, only the protective layer is damaged, then it is possible to treat the film.

In this example, about 30% of the film is affected by anti-ferrotyping. After treatment, the defect is invisible in transmitted light.

This 16mm reversal film shows more than just disruption of the protective surface. An area in the centre shows a colour change and, in this particular case, part of the yellow layer has been removed. Wetgate printing will minimise the effects of the loss

of dye layer.

Two more examples of anti-ferrotyping. The first shows a film where the protective layer has bubbled up like a blister and then sank down again. Despite our concerns about the deformation, the layer returned to its original position. The second example is a film where the protective layer has been partially removed after blistering. The film has a halo effect at the site of the damage.

With ferrotyping the surface of the gelatin is pressed hard against the base of the adjacent layer of film resulting in a very smooth surface. The refractive index of the film is changed at the places where ferrotyping has taken place with the result that the light is transmitted at a different rate to the transmission rate at unaffected parts of the film. The damaged film is treated with various concentrations of alcohol and water with some salts to roughen the smooth areas of emulsion to match the undamaged sections.

## Treatment of Damaged Films

These observations have given us a much better idea of the problems and what action will be required to remedy the situation. Heavy infestation by mould does not necessarily mean that the film is damaged. The film must be examined carefully to see whether the infestation is a surface problem only or if the mould has penetrated the gelatin and/or dye layers.

The film should be examined under both reflected and transmitted light to see what damage has been caused. Under transmitted light any erosion or burrowing into the emulsion layers can be easily seen. In a multi dye layer film, if the upper dye layer is affected, there will be a colour change.

When we were trying to categorise the different types of deterioration and the extent of damage we were faced with several possible methods. For example, we could try to identify the type of mould, or we could determine the form and extent of the damage. We finally agreed that the most efficient method for categorisation of damage was to look at the colour changes with transmitted light.

All 26 million feet (nearly 8 million metres) of film in the collection were examined and notes made of any blemishes. This helped us to plan the treatment processes. We treated many samples of film by hand but the large scale treatments were done by using two specially purchased film cleaning machines which we adapted with various solutions.

# Microspectrophotometric Analyses of Changes in the Organic Materials Used in Optical Discs

**Jacques Lemaire***, **Nicolas Pichon*** and **Jean-Marc Fontaine****

*Université Blaise Pascal (Clermont-Ferrand 11), France.
**Bibliothèque Nationale de France, Université Paris 6, Villepreux, France

*Professor Lemaire was born in 1936 and qualified as "Ingénieur" at the Ecole Nationale Supérieure des Industries Chimiques. After Graduating from the Université de Nancy in 1960, he obtained his State Doctorate Diploma in 1964. He was elected Professeur at the Université de Clermont-Ferrand in 1968 and founded the Laboratoire de Photochimie whose main activities are in the fields of polymer photo-oxidation, aqueous photochemistry and co- ordination photochemistry.*

*Since 1972, Prof. Lemaire has developed many long-term collaborations with industry and with other Institutions. In 1985, he founded the Centre National d'Evaluation de Photoprotection which is devoted to the study of the problems connected with the control of the long-term preservation of polymers and the impact of chemicals on the environment.*

*Prof. Lernaire is still devoting special attention to the prediction of the life of polymeric materials based on the recognition of the mechanisms of photochemical changes.*

## Summary of Paper Presented by Prof. Lemaire

In conservation conditions, when the life of an audio-visual Carrier is controlled by the chemical changes of a polymeric component, the prediction of the durability of the carrier can be based on accelerated aging tests carried out in laboratory conditions. The acceleration factor of the ongoing chemical modifications is used to convert the time-scale of the laboratory experiment into the time scale of the actual conservation conditions.

The prediction of the long-term behaviour of commercial CD-audio is presented as an example. The labelling protection coating was shown to be the most sensitive part to dehydration and thermo- oxidation, as opposed to the polycarbonate substrate which was not significantly modified by laser reading and aging.

The evolution of the nitrocellulose protection coatings was largely dependent on the composition and the polyacrylate coatings present a greatly improved durability. Correlations between the profile of the error readings and chemical modifications were observed, ascertaining the chemical origin of the physical detriment.

# Microspectrophotometric Analyses of Changes in the Organic Materials Used in Optical Discs

***(Analyse Microspectrophotométrique de l'Evolution des Matériaux Organiques Utilisés dans les Disques Optiques)***

**Jacques Lemaire, Nicolas Pichon and Jean-Marc Fontaine**

In conservation conditions, when the Lifetime of an audio-visual system is controlled by a chemical evolution of a polymeric component, the prediction of the durability of this system could be based on accelerated ageing experiment carried out in laboratory conditions. The acceleration factor of the ongoing chemical modifications is used to convert the time scale of the laboratory experiment into the time scale of the actual conservation conditions. The prediction of the long-term behaviour of commercial CD- audio is presented here as an example. The labelling protection coating was shown to be the most sensitive part to dehydration and thermo-oxidation as against the polycarbonate substrate which was not significantly modified by laser reading and ageing. The evolution of the nitrocellulose protection coatings was largely dependent on the composition and the polyacrylate coating presents a durability largely improved. Correlations between the reading defect profiles and chemical modifications were observed, indicating the chemical origin of the physical detriment.

The long term ageing of polymeric materials used as components of signal carriers could limit the lifetime in conservation conditions in some circumstances. In such cases, any detrimental effect related to recording and reading does not significantly affect the properties of the system and the lifetime is only controlled by chemical ageing in the presence of oxygen and water occurring at room temperature. Chemical ageing in conservation conditions indeed involves thermo-oxidation and hydrolysis in oxidizing conditions and these reaction mechanisms are generally complex in the solid state.

That complexity does not allow any extrapolation from short to long conservation periods and prediction of lifetime could only be based on the accelerated ageing experiment carried out. An accelerated ageing experiment cannot be designed only on the basis of the variations of the macroscopic system. The system should rather be considered as a chemical reactor and the following points should be emphasized:

***Henning Schou:***

*Our next paper is by Jacque Lemaire, Nicolas Pinchon and Jean-Marc Fontaine and will be presented by Jacque Lemaire. M. Lemaire was elected Professeur at the Université de Clermont-Ferrand in 1968 and subsequently founded the* Laboratoire de Photo Chimie. *The main activities of the laboratoire are in the fields of polymer photo-oxidation, aqueous photo-chemistry and co-ordination photo-chemistry.*

*In 1985, Prof. Lemaire founded the* Centre National d'Evaluation de Photoprotection *which is devoted to the study of the problems connected with the control of the long-term preservation of polymers and the impact of chemicals on the environment.*

*The paper is entitled* Microspectrophotometric Analyses of Changes in the Organic Materials Used in Optical Discs.

1. In conservation conditions, the physical strain is limited to heat (at room temperature) and the chemical reagents are generally oxygen and water (gas or liquid). When in the solid system, the conditions of oxygen and water saturation[1] are observed, the chemical evolution rate generally obeys an Arrhénius law:

$$\frac{R_T}{R_{T_0}} = \exp\left[-\frac{E_{act}}{R}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]$$

where $R_T$ is the chemical evolution rate at absolute temperature T and $E_{act}$ is the activation energy (R = 2 cal/mol).

An accelerated ageing experiment of a polymeric system should be controlled as relevant to non accelerated ageing, i.e. obeying the same mechanism at the molecular level, through chemical analysis of the products and determination of activation energy. In the whole temperature range investigated, stoichiometry should be unchanged and the activation energy should be constant. When both the conditions are respected, the chemical evolution rate at room temperature can be calculated. Generally, 100°C is the highest temperature used in accelerated conditions.

2. The extent of the chemical evolution which corresponds to the complete loss of the useful physical property (i.e. readability of a signal on a CD audio for example) is generally very low with macromolecular substrates (less than 1%). Very sensitive analytical techniques are therefore required to determine the concentration of the transformed groups which provoke the degradation of the physical properties. Such a determination should be carried out in accelerated conditions. Moreover, since the degree of chemical modifications is low, kinetics at initial time are indeed observed, and the build up rate of the products should be constant with time.

3. The chemical transformation of a solid polymeric substrate is advantageously analysed with vibrational spectroscopic techniques: Fourier-Transform IR and Fourier-Transform. Raman represents the best compromise between high sensitivity and precise information on the molecular structures of the transformed groups. Chemiluminescence and electronic spectroscopies are more sensitive, but not as informative. NMR in the solid state is very informative, but is not sensitive (and is rather complex with non amorphous polymer). Moreover, vibration spectroscopies now offer the possibility of spatial resolution. Recently equipped with IR microscope, FTIR and FT Raman

[1] An oxygen (or water) starvation effect would lower the evolution rate in accelerated conditions and would, therefore, be misleading in the prediction of lifetime.

spectrophotometers allow the full analysis of very small microzones (10µm x 10µm). Profiles of products can, therefore, be determined along any direction.

In the field of art conservation, and more especially in Sound Activity, ageing is often examined by submitting the system to the "environmental" stresses in the most severe conditions and following the readability of the AV document. Such a direct approach could not allow to predict the lifetime in conditions which differ from the test even in relative terms (comparing different systems). As emphasized in the previous sections, when chemical ageing appears to be the basic reason for evolution, conversion of lifetimes in different experimental conditions could be based on kinetics law. As an example, we are reporting an analysis carried out on various CD, which considers the CD systems as chemical reactors.

**CD Audio**

It is well accepted that the laser reading has no detrimental effect on CD. To ascertain more quantitatively this fact, a polycarbonate sector of a commercial CD (Dire Straits, PPO) has continuously been exposed to a 632.8 nm laser (0.8 mW) during 60, 330 and 1097 hours. Micro-FTIR analysis has been carried out on various 40 µm elementary layers of the exposed PC, localised at the front surface, in the core and the close vicinity of the metallic layer. No chemical evolution of the PC was detected. The reading time equivalent to the experimental conditions of the test was calculated to be $2.7 \times 10^8$ hours.

In a second preliminary experiment, two commercial CD have been exposed in the dark to heat (at 60, 80, 100 and 140°C) and $0_2$ during 280, 560, 1016, 1688 and 2600 hours. The PC substrate and the protection coating were examined with the FTIR technique. Even after 2600 hours at 140°C, the various elementary layers of the PC substrate were not thermo-oxidized at a significant extent. This is consistent with the thermal stability of PC in oxidizing conditions. As opposite, the protective coating was significantly modified. The chemical modification of this thin layer was followed through the variations of the IR spectra recorded by means of an ATR/MIR (Attenuated Total Reflectance Multiple Internal Reflection) technique.

Due to the perfect surface aspect of the protective coating, the ATR/MIR technique could be handled up to the complete degradation of the surface. At 50°C, the IR spectra could be recorded during 45 hours, at 60°C during 25 hours. This means that the protective coating is readily modified even at 50°C. The lifetime of a CD-audio would be therefore controlled by some chemical modifications, at room temperature, of the protective coating (independently of any labelling).

In a third series, the various materials used in the production of CD and 2 aged CD (5 years old) were received from a CD producer. The protective coating on the aged CD had significantly been oxidized and the PC substrate was unchanged. The PC supplied by BAYER to the CD producer was checked to behave like an unstabilized PC in thermo-oxidation and in photo-oxidation (SEPAP 12.24). A 50 µm isolated film of the protective coating was processed and maintained at 60, 80 and 100°C during respectively 605, 605 and 78 hours. As shown on figures 1 and 2, large variations in the IR spectra were observed, due to the formation of hydroxylated (after an earlier dehydration) and carbonylated oxidation products.

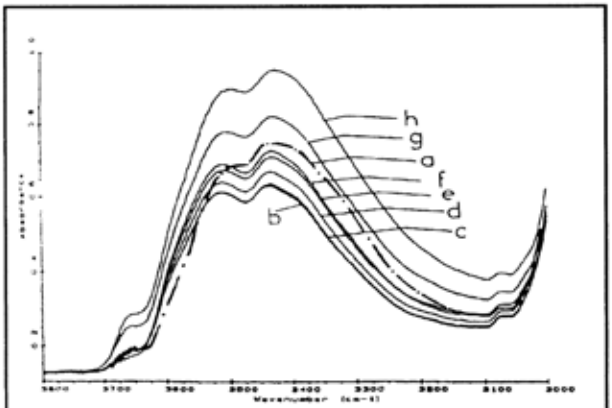



**Figure 1: Chemical evolution at 100°C of an isolated film (50 µm) of a nitrocellulose protective CD-coating. Variations of the IR-absorption of OH groups through dehydration (0 hrs - 3 hrs) and thermo-oxidation (3 hrs -78 hrs).**

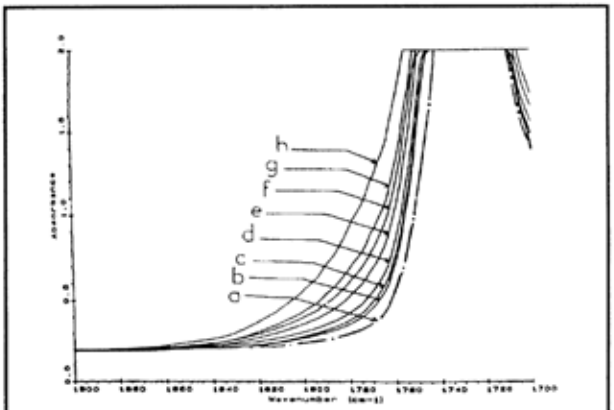



**Figure 2: Chemical evolution at 100°C of an isolated film (50 µm) of a nitrocellulose protective CD-coating. Variations of the IR absorption of carbonyl groups through dehydration and thermo-oxidation.**

Figure 3 represents the build up of carbonylated products absorbing at 1780 cm-1 as a function of thermo-oxidation time at 60, 80 and 100°C.[2] Large variations in the UV-visible spectra were as well observed. Figure 4 represents the formation of products absorbing at 350 nm throughout the thermo-oxidation. The protective coating yellowing was observed early. Conclusively, the protective coating was indeed found to be the most sensitive component to long term room temperature thermo-oxidation. As shown by the ATR-MIR technique, a degradation of the very superficial layers was observed after 100 hours at 60°C, i.e. 2000 hours at 20°C considering the activation energy found.

[2] The ATR/MIR spectrum of the protective coating can be recorded up to an oxidation equivalent to a variation of the 1780 cm-1 absorbency equal to 0.016 for a 50 µm film; it is a very early detector of the oxidation.

The protective coatings examined in the 3 first series were indeed complex mixtures of nitrocellulose containing plasticizers (like alkyl phthalates, alkyl abietates, Ricin oil ..) and synthetic or natural resins (like alkyde resins, acrylic resins ... ). In a fourth series, the protective coatings of 23 commercial CD were analysed through the ATR/MIR technique. 11 different compositions were found and the corresponding CD were submitted to thermo-oxidation at 80°C during 642 hours. On

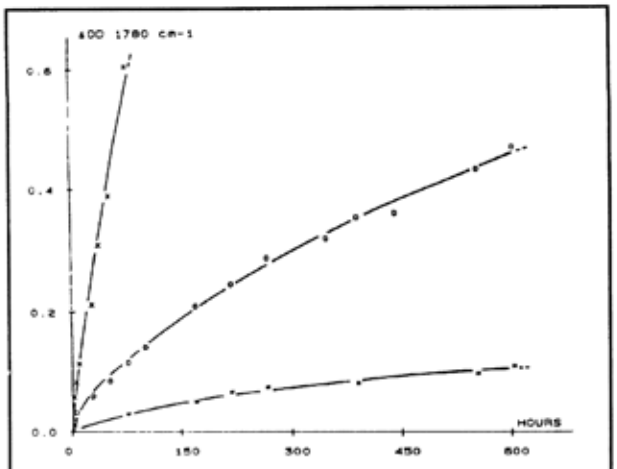



**Figure 3: Variations of absorbency at 1780 cm-1 of a 50 µm protective CD-coating maintained at various temperatures.** (*) 60°C - (o) 80°C - (x) 100°C

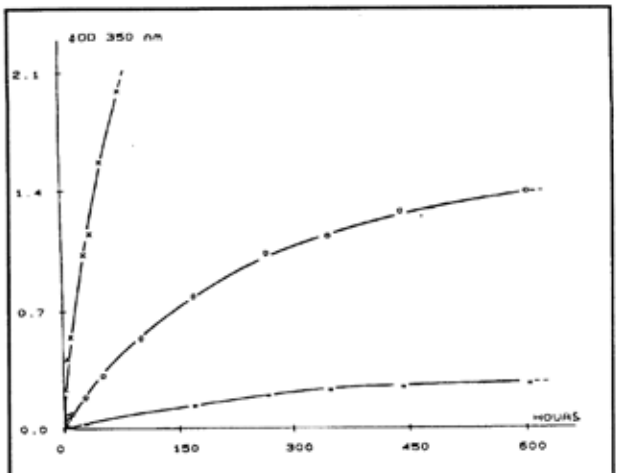



**Figure 4: Variations of absorbency at 350 nm (yellowing) of a 50 µm protective CD-coating maintained at various temperatures.** (*) 60°C - (o) 80°C - (x) 100°C

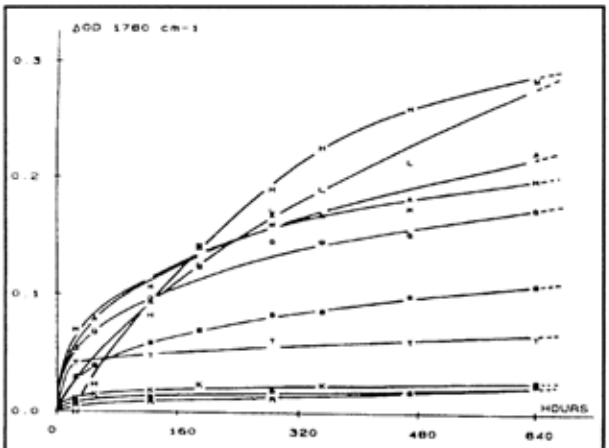



**Figure 5: Variations of the absorbance at 1780 cm-1 measured by AIR-MIR technique on various commercial CD-protective coatings: nitrocellulose H, L, A, M, Q, S, T - polyacrylate K, B, R.**

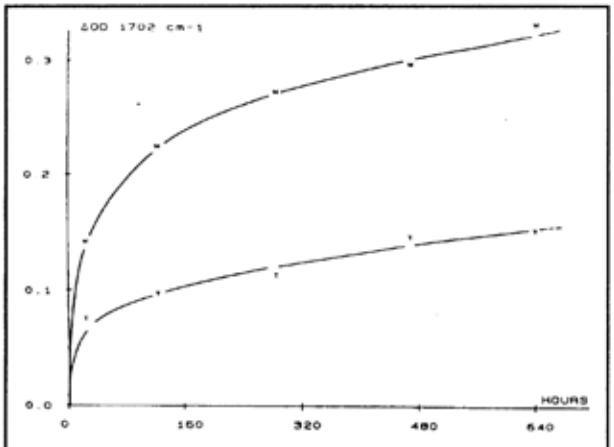



**Figure 6: Variations of the absorbency at 1702 cm-1 measured by ATR-MIR technique on 2 commercial CD nitrocellulose protective coatings (W and T).**

figures 5 and 6, formation of the thermo-oxidation products absorbing at 1780 cm-1 or 1702 cm-1 could be compared for the 11 compositions (obviously, the B, R and K compositions correspond to the more stable acrylic coatings).

From the accelerated ageing tests described in the previous sections, it was anticipated that most nitrocellulose-based protective coatings would be progressively thermo-oxidized in the conditions of long term conservation over periods extending from 10 years to 20 years. We had therefore to examine the consequences of the detriment of this specific component on the development of reading defects of the whole CD system. It was indeed observed that the number of reading defects were increasing with the duration of a thermal treatment at 80°C. More

interestingly, it was observed with 3 different CD that the variations of the reading defects with the distance to the CD centre could present different profiles, those profiles being closely related to the profile of the oxidation extent of the protective coatings:

- With the first CD examined (G. NEVEU-BRAHMS), after 6400 hours at 80°C, the number of defects was decreasing from the centre to the outside (as shown on figure 7). The chemical composition of the nitrocellulose coating, before any thermal treatment, was not homogeneous, as revealed by the variations of absorption bands at 3500- 3400 - 3200 - 1673 - 1634 cm-1.
- After 6400 hours at 80°C, the variations of these absorption bands were more important in the close vicinity of the centre (as shown on figure 8 (3400 cm-1)). In this complex mixture, thermo-oxidation is superposed to dehydration and loss of additives, specially in the central zone.

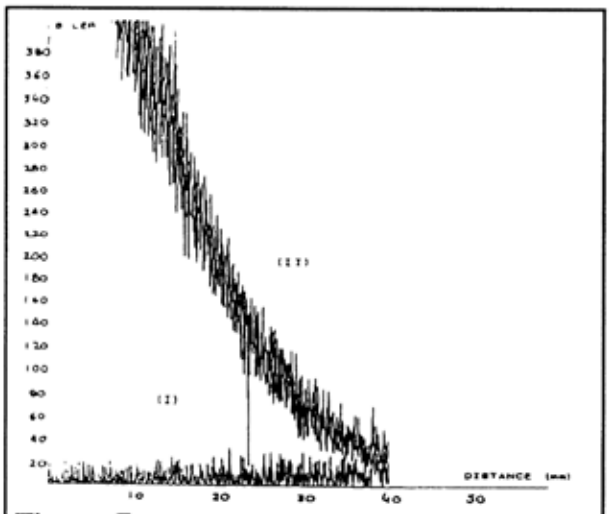



**Figure 7: Variations of BLER with the distance to the centre of a commercial CD (G. Neveu-Brahms) exposed to thermal treatment at 80°C for 6400 hrs** (I) untreated - (II) treated CD.

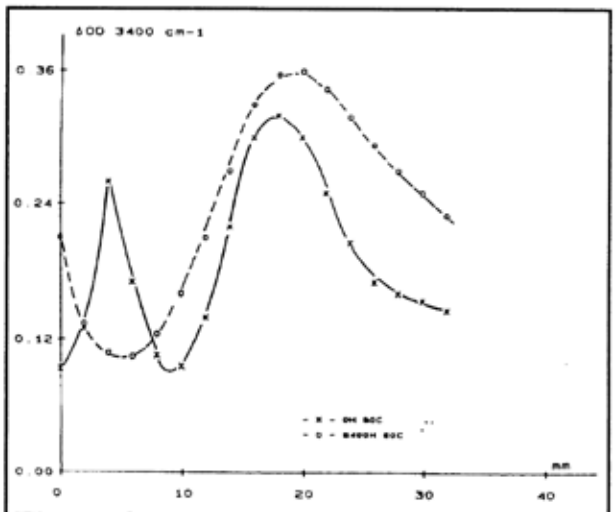



**Figure 8: Variations of absorbency at 3400 cm-1 with the distance to the centre of a commercial CD (G. Neveu-Brahms) exposed to thermal treatment at 80°C for 6400 hrs**

With the second CD examined (P. HOLSAPPLE), after 6400 hours at 80°C, the number of defects was increasing from the centre (see figure 9). The coating was indeed heavily printed for labelling and the spectrophotometric determinations were only carried out at the centre and at the extreme external zone. The chemical modifications through thermo-oxidation of the external zone was more pronounced than on the internal one;

The third CD examined (PRIMAL SCREAM) presents a limited number of reading defects with no profile (see figure 10). The chemical modifications are also very limited with constant profiles.

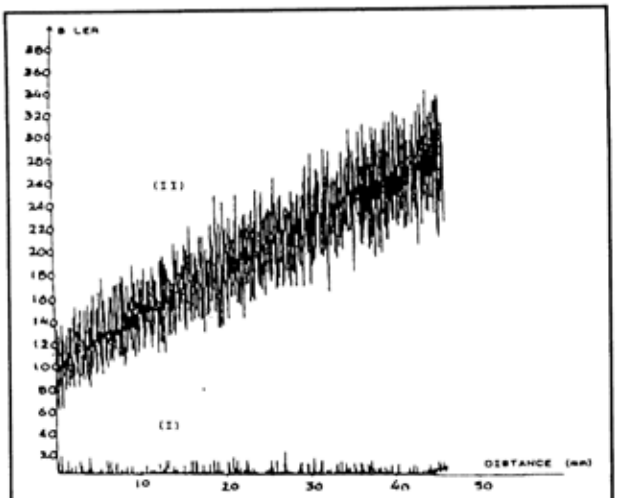


**Figure 9: Variations of BLER with distance to centre of a commercial CD (P. Holsapple) exposed to thermal treatment at 80°C for 6400 hrs.** I untreated & II treated CD

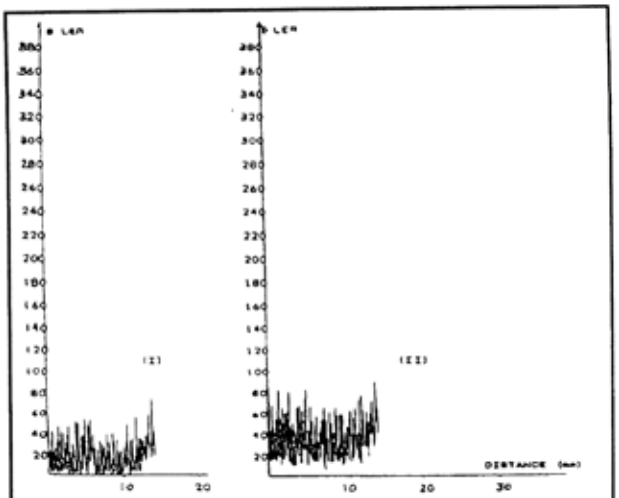


**Figure 10: Variations of BLER with distance to centre of a commercial CD (Primal Scream) exposed to thermal treatment at 80°C for 6400 hrs.** I untreated & II treated CD

## Conclusions

In spite of appearances, the collections of CD-Audio form an heterogeneous set. Because the disparities in fabrications, the chances of records to survive are fairly unequal. The parallel studies of the effects of an accelerated ageing on both the chemical evolution of the CD and the evolution of the signal enable to establish a direct relation between these variations. The very low chemical evolution of the most sensitive component, which correspond yet to a very high loss of information, required the implementation of high performance analytical techniques.FTIR micro- spectrophotometry enables to show the prevalent role of the so-called protecting coating which is, when considering some CD-A of the first generation, the most worrying component in view of the long-term survival.

Counting up the ratio of errors, of BLER in particular, is a precise and easy to carry out method with which an evaluation of the initial state of the collections and the detection of some eventual degradations are possible, although the detriment causes could not be detected and understood. The complementary chemical approach could bring some insight on the undesired evolution of materials.

The modelisation laws of the evolution of the ratio of errors within time will be normalized in a next future (Technical Commission ANSI IT-9/AES). Although estimations of the lifetime of CD (Arrhénius-Eyring model) and of reading failures (Weibull distribution) are not still understood through the physico-chemical degradation of records, a fruitful contribution is brought with research works on both behaviours of signal and material.

*Henning Schou:*
*We will take the questions for Prof. Lemaire with those for the following paper.*

# Relevance of the Parameters Defining the Quality of CDs

## Jean-Marc Fontaine

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Villepreux, France.

## Summary of Paper

Among the many parameters used by certain analysers when reading compact discs, the error rate readout allows us to judge the quality of new CDs before they are placed in a collection. This information will also form a reference file for future consultation when checking for any changes caused by normal or accidental aging processes.

The state of the physical quality of a sub-set of a collection can be evaluated and discussed using measurements taken from CDs made at different periods before carrying out an investigation into the complete collection.

Analyses based on the error rate must, however, be used in conjunction with other measurements to help with the full investigation of the source of failures as soon as they appear. A statistical methodology assists with the characterisation of the complete collection from the sub-set that is investigated. The main results of the work will be presented.

*Jean-Marc Fontaine was born in 1945 in Tours. After studying music, he studied acoustical sciences and Graduated as an Engineer from the Conservatoire NI des Arts et Métiers in Paris. He joined the Ministére de la Culture in 1980 to study the preservation and restoration processes for sound recordings held by the Département de la Phonothèque et de l'Audiovisuel of the Bibliothèque Nationale. He has initiated and developed several projects in these areas on behalf of a consortium formed by the Bibliothèque National de France, the Université Pierre et Marie Curie (Paris 6) and the Centre National de la Recherche Scientifique (CNRS).*

*Jean-Marc Fontaine is a member of the Technical Co-ordination Committee (TCC) and of the Technical Committee of the International Association of Sound and Audiovisual Archives.*

# Relevance of the Parameters Defining the Quality of CDs

## Jean-Marc Fontaine

## 1. Introduction

We know that digital recording is not synonymous with the preservation of information carriers. Current procedures for examining the life of carriers do not answer our questions about the future possibilities of information access, i.e. questions about player and equipment maintenance in the short term and questions about obsolescence of recording format in the long term.

Nevertheless, for very large collections, such as that of CDs-Audio held by the Bibliothèque Nationale de France (whose number exceeds 100,000 items), information preservation is achieved by the material preservation of discs, which benefits moreover from the use of a common format.

To set up a system to check the CDs' physical condition, we can count the number of errors thanks to the readouts given by error detection and correction systems. The recognition of erroneous data during playing is systematically made by every player but but not always with an output for monitoring the condition of the discs. Providing specific equipment is used, it is possible to access this quality control data.

Generally, the studies concerning the quality control and ageing of optical discs are essentially based on only one parameter - Block Error Rate or BLER - for CDs' family behaviour. We can then legitimately question whether BLER describes correctly the state of discs - if it is sufficient to understand the origin of problems. As might be expected, such an investigation is carried out in conjunction with chemical studies as presented by Professeur Lemaire in the preceding paper.

Standardization groups have been working on quality control and life expectancy for several years.

More particularly ANSI, AIIM, AES in USA and AFNOR in France are elaborating international standards proposals (ISO). Currently concerning the control procedures, the discussions involve, on the one hand, partisans of a very simple control level based on error rate counting and on the other, partisans of control based on the survey of several parameters that imply the practice of analytical means. The first method permits the detection of defective discs, the second to locate the origin of failure as well.

***Henning Schou:***

*Jean-Marc Fontaine is an acoustic engineer who has specialised in research into architectural acoustics. He has been with the Ministré de la Culture et Francophonie in paris for ten years and has worked for the sound and audiovisual department of the Bibliothèque Nationale de France.*

*Jean-Marc is charged with the responsibility for solving problems associated with the department's preservation and restoration activities. Problems connected with storage area conditions, dubbing equipment and the detection of degradation of different media, especially magnetic tape and, more recently, optical discs.*

- *Proposed standard for controlling the quality of CD-ROM discs.* Draft DCI Central Intelligence, Oct. 1991.
- *Life Expenctancy of Optical System.* Draft Document Task Group IV - Joint Technical Commission - ANSI IT9-5/AES.
- *Permanence de l'information sur disque optique numérique - Disque Compact entièrement préenregistré.* Norme Expérimentale AFNOR, Z-42-011-2.
- *Electronic imagery. Permanence of information on digital optical disk entirely pre-recorded compact disks/Permanence of information recorded on CD-ROM.* AFNOR/ISO/CD, 12024
- *Media error monitoring and reporting techniques for verification of the information stored on optical digital data disk.* AFNOR ISO/CD 12142. Proposition AFNOR/ANSI/AIIM.

We have to face questions like:

> Should our action be limited to a simple error rate check in order to allow a decision to be made when discs exceed error rate limits? This will allow discs to be classified into two groups - the good and the bad.
>
> Or should we use more elaborate techniques which give detailed information about the quality of discs that can be useful to set up a diagnosis (typically up to 40 parameters)? But such procedures are very complex and expensive when they have to be applied to several thousand discs . .

Thanks to specialist apparatus, access to such information is very easy, and without any risk to discs. Hence, much digital and electrical data is simply collected during disc playing and displayed.

**Table 1**

| | |
|---|---|
| Acrotronic | U.K. |
| Audio Development | Sweden |
| Clover Systems | U.S.A. |
| Digital Intelligence System Corporation | U.S.A. |
| Disc Manufacturing Inc. | U.S.A. |
| Kalteren International | The Netherlands |
| Kenwood | Japan |
| Koch Digital Disc | Austria |
| Optical Tool Corporation | U.S.A. |
| Toolex Alpha | Sweden |
| | etc. |

At present, many analysers are available (see Table 1). The prices vary according to the number of parameters and the quality of the measurement (calibration possibilities).

However, these machines have been designed to carry out control during manufacturing in order to detect shortcomings and find their origin as early as possible. As soon as the alarm system is triggered, the problem has to be examined and solved on the production line.

Our position as a user - a longterm user - an eternal user - of CDs is not independent of the manufacturer (in fact, we can say that we are completely dependent on him!), but our actions are totally different: we can only intervene on finished products. So the relevance of the parameters to be used in our application has to be investigated in terms of efficiency and management.

It is important to estimate the quality of discs just before they go into collections for two reasons:

To quickly detect a failure on a disc in order to replace it, if it is possible; we know that a commercial lifetime is sometimes very short. But we are never certain to find another good one, in the whole batch!

To select a reference disc and, therefore, the data which will be used to detect an eventual change in the disc in the future.

So, this study follows the route recommended by the partisans of control based on a survey of several parameters with an emphasis on methods for checking the quality of optical discs in huge collections. It includes the following themes:

- Determination of the most effective parameters to identify defective discs.
- Determination of the most effective parameters to describe the quality of CDs, i.e. to set up a diagnosis in acceptable exploiting conditions.
- Collecting experimental references before the beginning of specific studies concerning pre-recorded discs (CD-A, CD-ROM) and write-once discs (CD-R).

## 2. Main Parameters (See Table 2)

**2.1. Identification Data** - given by Table Of Contents (TOC), digitally en-coded on the disc, or printed or/and moulded onto discs and repeated on other documents concerning the discs:

- Title of disc
- Production number
- Label, production name, ...
- Manufacturing country (if we don't know UPC/EAN code)
- UPC/EAN Code. Universal Product Code / European Article Number Code
- IRSC Code (International Standard Recording Code)
- SID Code (Source Identification Code) implemented by IFPI (International Federation of the Phonographic Industry) since 1994.
- Year of manufacturing, and other useful information for statistical processes.

**2.2. Recording Areas on the Disc**

**2.3. Recording Density** - Scanning Velocity, TrackPitch

**2.4. Mechanical Characteristics** - Eccentricity, vertical deviation etc.

| Table 2 - Compact Disc Parameters | | |
|---|---|---|
| **Parameter Group** | | **Parameter** |
| Miscellaneous | Content and Disc Identifiers | Disc Number<br>Title<br>Production Number<br>Producer<br>UPC/EAN<br>ISRC<br>Manufacturer<br>Country of Manufacture<br>Year of Production<br>Test Date<br>Tracks<br>etc. |
| Electrical Measurements | Areas of Disc | SLD<br>SPL<br>SPD<br>MID |
| | Density | Scanning Velocity<br>Track Pitch<br>Duration |
| | Mechanical | Eccentricity<br>Vertical Deviation +<br>Angular Deflection + |
| | Modulation | Reflection +<br>Eye Pattern +<br>Jitter + *<br>I3 + *<br>I11 + *<br>I3R + *<br>I11R + * |
| | Stamping | Symmetry +<br>Cross Talk + |
| | Radial R | Push Pull +<br>Radial Noise + |
| Digital Data | Errors | Block Error Rate + **<br>TBR<br>E11 + **<br>E21 + **<br>E31 + **<br>E12 + **<br>E22 + **<br>BERL + **<br>BEGL<br>E32 + **<br>E32 Total |

+ Graphical representation * Min & Max & MOY ** Max & MOY

Table (EXCEL) with 5 individual values: 160 O/disc

Table (EXCEL) with 45 individual values: 550 O/disc

All data with graphics (ASCII): 300 KO/disc

**2.5. Signal Modulation Quality** - Reflection Index, the Eye Pattern display, The Jitter, HF signal produced by the smallest pits (I3), HF signal produced. by the longest pits (I11).

**2.6. Pits Conformation and Matrix Quality** - Symmetry between pit area and land area. [Cross Talk]

**2.7. Radial Gap** - Push Pull (PP), Radial Noise (RN).

**2.8. Error Rate** - Because the record format includes an efficient error correcting system (Reed-Solomon Code), during reading of the disc, decoders C1 and C2 inform us of the error rate detected before any correction (BLER); they describe the error repetition which specifies the nature of defaults (random or burst), and the different stages of correction until the final state (E32 or uncorrected error number).

We considered all these parameters in order to keep the most pertinent ones to describe the disc fitness.

## 3. Some Conclusions from 221 CD-A Analyses

**3.1.** The tested discs were essentially produced between 1988 and 1992 (70% / total). (Figure 1)

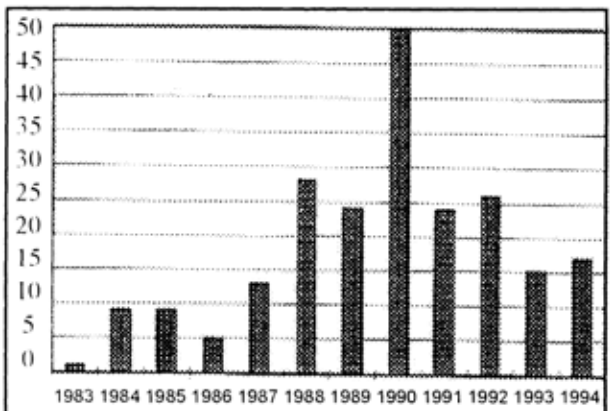



**Figure 1: Number of Discs Produced in Each Year**

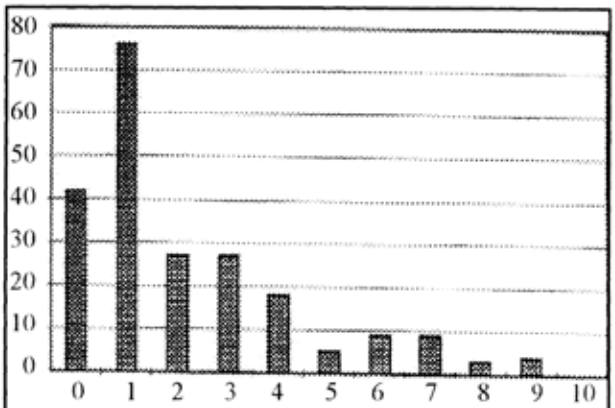



**Figure 2: Age of Discs Tested**

**3.2. Age of Discs** - Tests were carried out between 1990 and 1994 and the majority of discs tested were less than five years old.. (Figure 2)

**3.3. Reflection** - Reflection properties are linked to the quality of the metal used (Gold > Aluminium > Brass); they depend too on matrix operations during moulding process (interpretation of results for discs over lower limit). For instance, a gold layer has a high reflection coefficient: golden discs can be immediately detected.

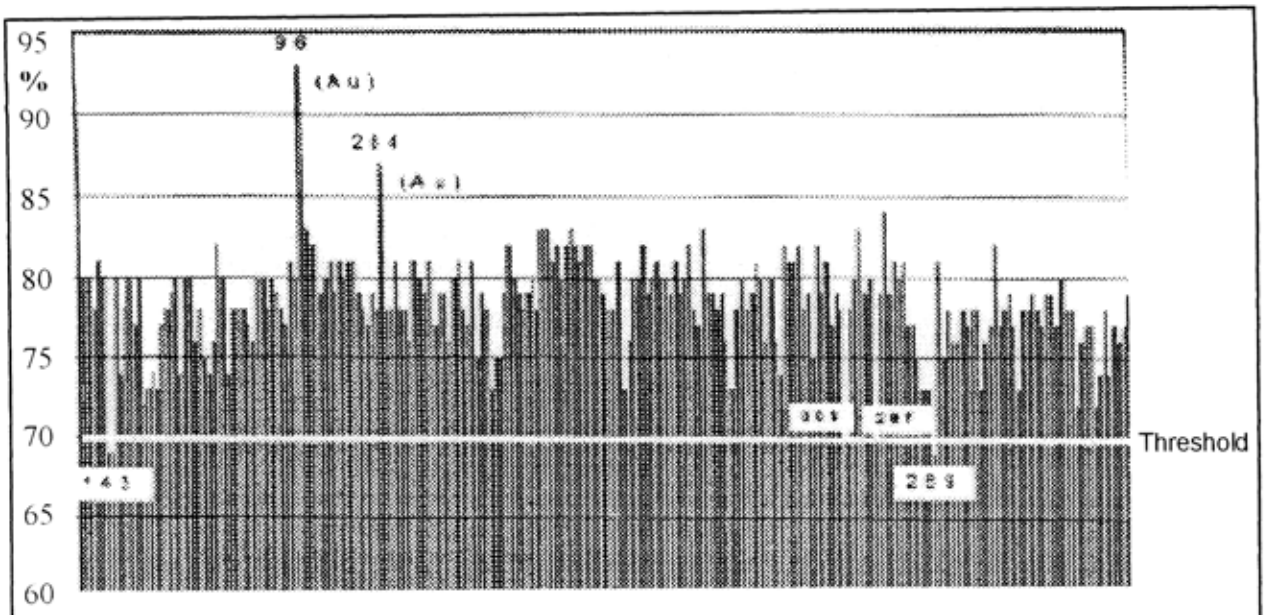



**Figure 3: Minimum Reflectance**

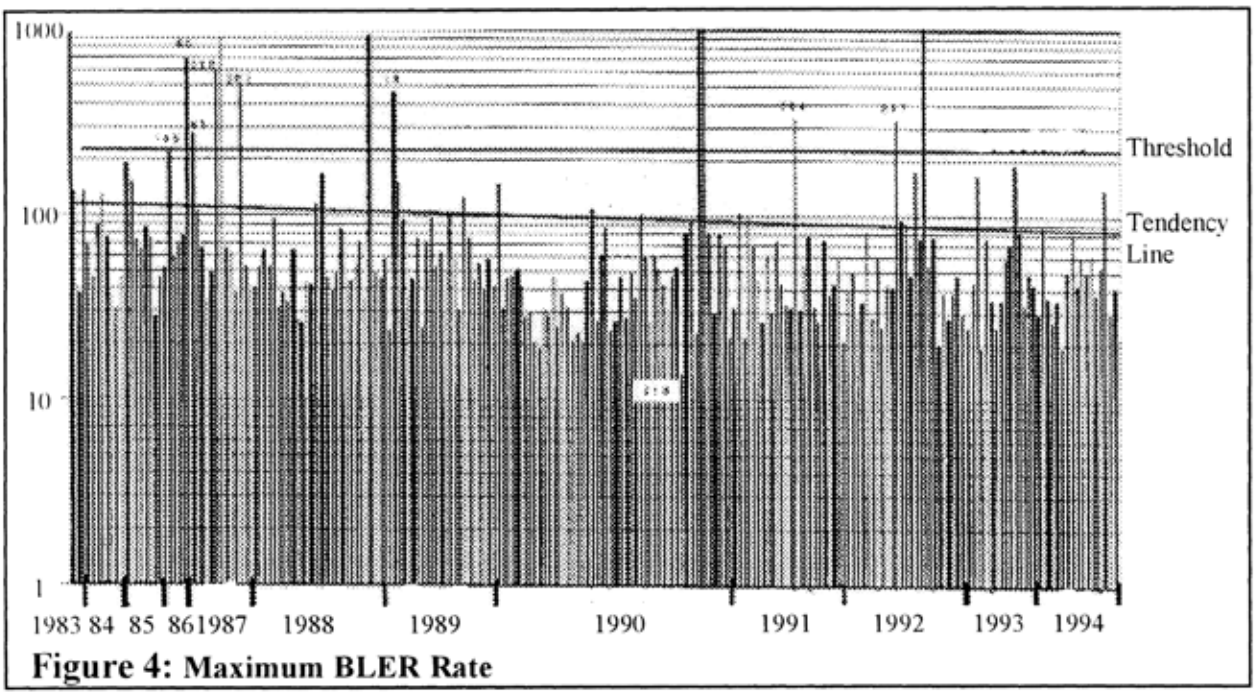



**Figure 4: Maximum BLER Rate**

The numbers on the graph (Figure 3) are relative to the identification of discs presenting particular discs characteristics.

## 3.4. The Error Rate:

**a. Tendency Curve of BLER Rate** - Discs are presented in chronological production order, it is interesting to mention the slight slope corresponding to the inverse function of the disc age (Figure 4). It seems to be an indication of an improvement of disc manufacturing between 1987 and 1994 according to its production time. But we have to be prudent, considering the sampling size and the age distribution of tested discs.

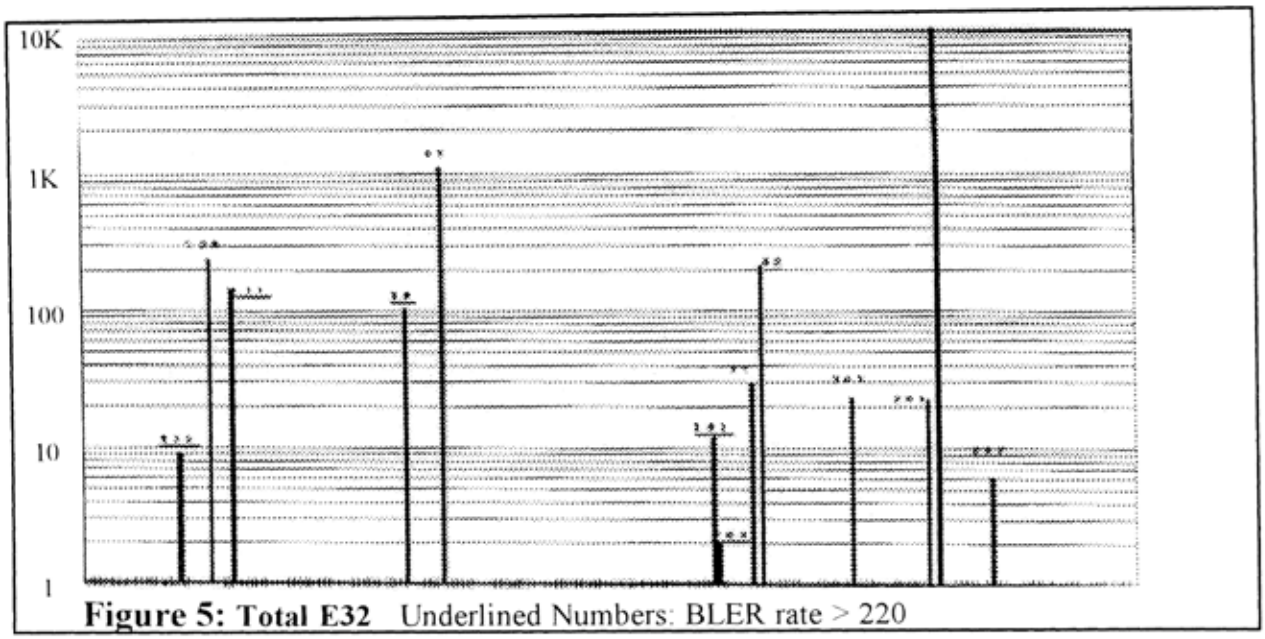



**Figure 5: Total E32** Underlined Numbers: BLER rate > 220

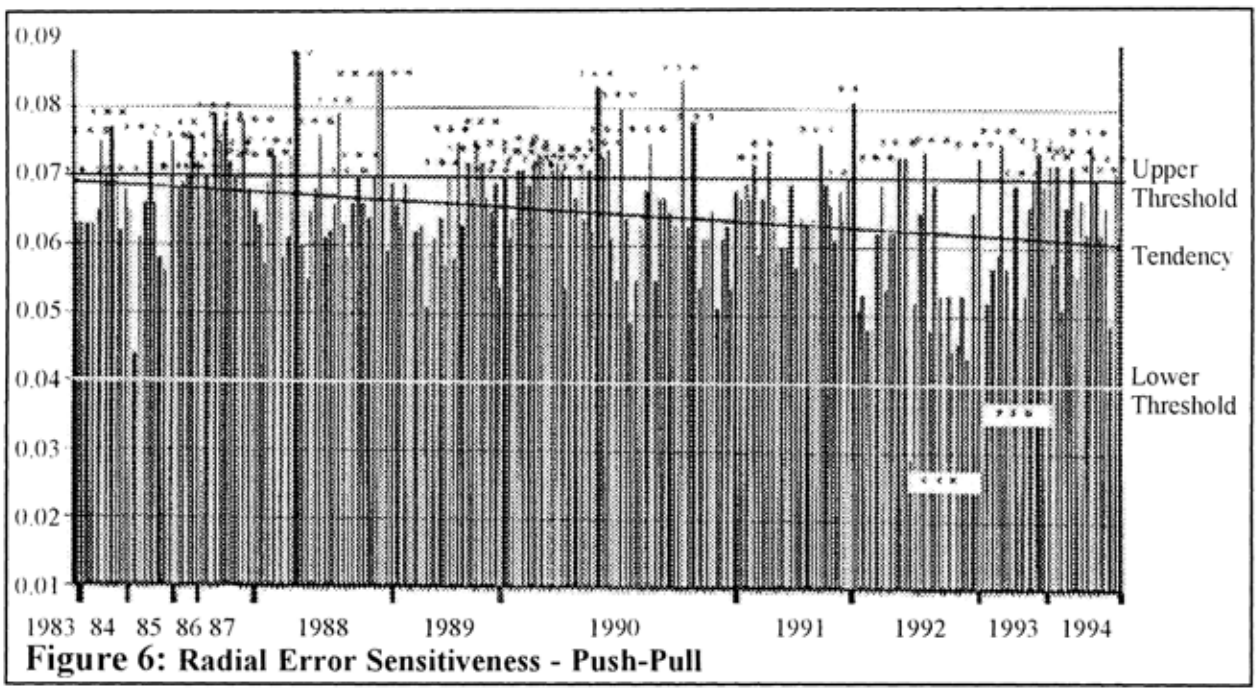



**Figure 6: Radial Error Sensitiveness - Push-Pull**

### b. BLER rate and E32 results

Half values of E32 did not appear on the BLER graph. It means that the detection of bad discs presenting a positive value of E32 have not been tested with the BLER values (Figure 5).

### 3.5. Sensitiveness According to Radial Error - Push-Pull

The tendency curve in relation to the year of production shows a significant decrease (Figure 6). It confirms the BLER curve tendency. This could be interpreted by a progressive increase of moulding conditions.

## 4. STATISTICAL ANALYSIS OF DATA

### 4.1. Principal Component Analysis

We worked with specialists in statistics (*CISIA: Centre International de Statistique et d'Informatique Appliquées*).

In order to analyze a large volume of data in mind (in this case contingency table of 7700 data for only 221 discs), a multidimensional method has been used. Among the statistics descriptive methods, a factorial analysis has been chosen: the Principal Component Analysis. It consists in researching the principal axes of multidimensional distribution from a sampling. This involves calculating the coordinates and the different contributions of each continuous variable. A descriptive graphic is available (Figure 7) to observe the continuous numerical variables.

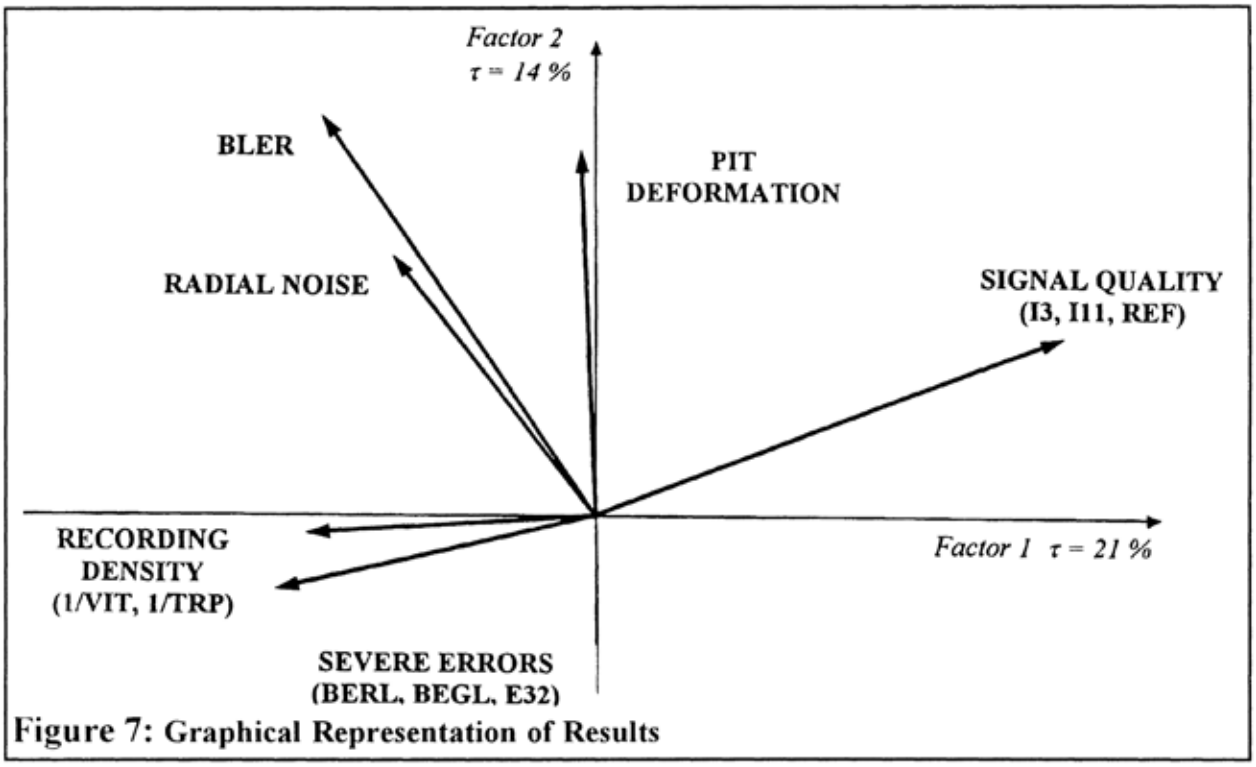



**Figure 7: Graphical Representation of Results**

We can then observe the eventual behaviour similarities between individuals.

The proximities between points represented on the graphic can be directly interpreted by the user.

If, for all individuals, the values of two variables are next to each other, they are represented by two points that are very close. This can mean that these variables describe the same thing or that they are linked by a particular relation.

When two variables are either very close or far from each other, it means that they are correlated by a linear or inverse relation.

The length of the vector is proportional to the representativity (level explicativity) stage of the corresponding parameter.

We observe a high dispersion of the different directions we selected (the others do not appear, for instance those linked to track disposition, which are not explicative).

The correlation between BLER and RN can be understood by the fact that they are both in the first test row (i.e. before any signal processing).

Some remarks about the BLER rate:

- The BLER rate is not closely correlated to other parameters (with the exception of radial noise).
- BLER rate measurement is the right detector to identify discs.
- BLER rate measurement is not sufficient to estimate the real consequences of a high error rate: it is necessary to get to other indicators, at least those which describe severe errors (burst errors and uncorrected errors: E32).

The proximity between directions representing recording density and severe errors is underlined. A high density is used to increase the program time. It is obtained by using one or both of two processes:

Slowing down the scanning speed.
Reducing the track distance.

But such operations make discs fragile: they increase the severe error rate, particularly uncorrectable errors. So the long duration CDs will be more vulnerable to agressive factors than shorter discs. On the other hand, we confirmed this fact with CD-R: during the next months, we plan to experiment the CD-R behaviour in some special circumstances (climate, etc.)

High modulation signal involves better security concerning severe error rate.

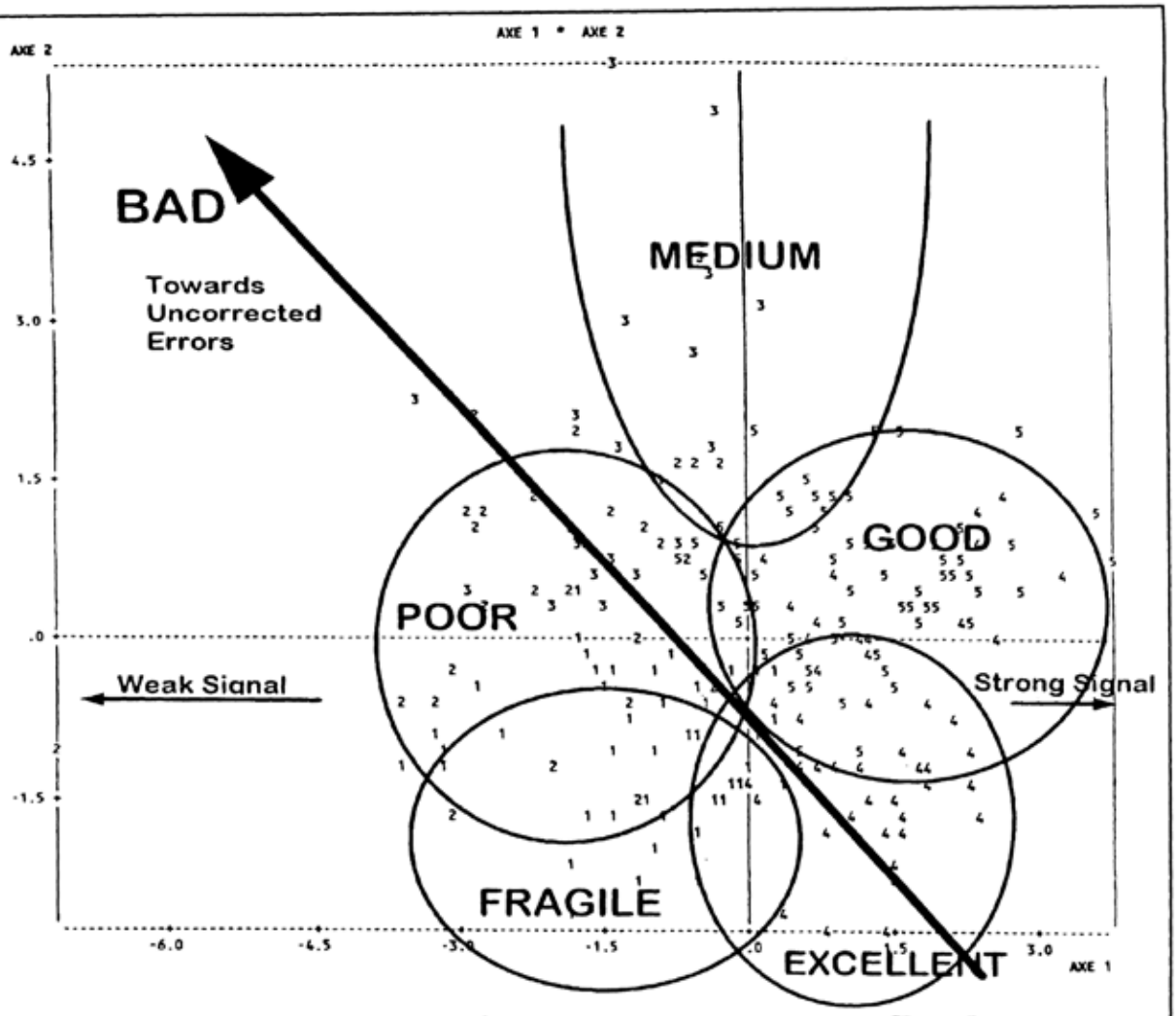
### 4.2. Classification

Statistical calculations produce class families that allow us to group and organize the objects we want to describe. Correlation matrix is calculated then the variable table corresponding to a growing variable order is subsituted to the initial data table.

Classification is based on overvalues of variables compared with the average level. Although reading the cloud representation of variables is rather complex, the distinction between good and bad discs can be clearly observed (Figure 8 and Table 3).

**Table 3:**

| | |
|---|---|
| ***Class 1*** | |
| I 11 min weak and I3 min weak | Fragile discs (weak modulation signal) |
| ***Class 2*** | |
| Radial Noise max high & BR high | High radial noise |
| ***Class 3*** | |
| All parameters near average | Ordinary, atypic discs |
| ***Class 4*** | |
| I11I high, XT weak & PP weak. | High quality, excellent discs |
| ***Class 5*** | |
| I3I strong and XT strong | Good quality |
| ***Class 6*** | |
| BLER X strong, E22 max strong & BLER average strong. | Bad quality |




**Class 1:** Fragile Discs

**Class 2:** Poor Quality Discs

**Class 3:** Typical (Medium Quality) Discs

**Class 4:** High Quality Discs

**Class 5:** Good Quality Discs

**Class 6:** Bad Quality Discs

**Figure 8:**

| | |
|---|---|
| E32 | uncorrected errors |
| BLER | all detected errors |
| I3 | signals produced by the shortest pits |
| I11 | signals produced by the longest pits |
| RN | radial noise |
| XT | cross talk |
| PP | push pull |

With particular attention for long play discs

**Table 4:**

Consequently, taking into account first these results, second the strong correlation between some parameters and finally the "sensitivity" level of some variables, the outcome of this work allows a hierarchical classification of parameters (Table 4).

So, this work prepares future measurements on a large scale, taking into account information about the behaviour of the parameters we obtained. We have now some elements of discussion about the choice of parameters to prepare a methodology of control.

Numerical values corresponding to new and unused CD-Audio form a reference data base, (for instance considering dispersion values) which we will use for our next works about ageing, always connected with chemical analyses : CD-R, CD-A, CD-ROM ...

***Ian Gilmour:***
*Professor Lemaire, in the cases where there were chemical variations across the radius of discs, were these, perhaps, introduced by anomalies in the spin-coating techniques?*

***Jacques Lemaire:***
*The profile of the changes in the chemical composition might be due to the spin-coating technique. The coating is a true chemical emulsion. It is possible that the various chemicals making up the mix - a complex blend of nitrous cellulose plus plasticisers plus fillers plus other things - are dispersed differently across the disc surface.*

***Ian Gilmour:***
*In relation to the disc Life Expectancy prediction extrapolated from the life span of the cellulose nitrate coatings - you suggest an LE of 15 to 20 years - are you likely to predict a longer life for discs with UV cured coatings?*

***Jacques Lemaire:***
*We know that all polyacrylates and polymethacrylates are thermally very, very stable. UV cured polyacrylates and polymethacrylates might have some small photo-instability but in terms of thermal stability, there is no problem. Most future CDs will have UV cured coatings.*

***Dietrich Schüller:***
*At one point, Jean-Marc, you said that we should beware of long duration CDs. Why is that?*

***Jean-Marc Fontaine:***
*Experimentally, we found that long duration CD-Rs had a higher BLER. We noted that as the data density increased, the BLER increased. The manufacturers increase the duration of the discs by reducing the scanning speed and by narrowing the track pitch. This means that the lands between the tracks are smaller and the light reflection, and, thus, the signal output, is lower.*

***Dietrich Schüller:***
*You also mentioned "Radial Noise". This is not well known. Can you give a brief explanation?*

***Jean-Marc Fontaine:***
*Radial noise comes from the laser tracking mechanism. If dirt is encountered on the disc by the laser, then the mechanical laser tracking system may react to the obstacle. The change in the lateral radial position causes an increase in the BLER. The degree of change of the lateral radial position is measured as radial noise. There is a first level connection between radial noise and BLER.*

***James Hoagland:***
*Do you have any test results on CD-Rs?*

***Jean-Marc Fontaine:***
*We have only recently begun some experiments on CD-Rs. What can be said now is that there are great differences in the performance of the various recorders available. In addition, there are differences in performance between discs made by the various manufacturers. As explained earlier, a third factor is the duration of the disc. But it is too soon to give any definitive information.*

***Ian Gilmour:***
*When we started to examine CD-Rs at the NFSA in Canberra, we found that the reflectivity was lower for CD-R than for moulded or pressed discs. The Red Book sets a minimum reflectivity of 70% and the average for a moulded disc is around 94% - the polycarbonate absorbs about 3% of the light in each direction. The reflectivity of CD-Rs is typically in the low 70s. From the start, there is little latitude for loss even if gold is used as the reflective layer.*

*Most of the research done on CD-Rs by Kodak and others showed that, depending on the particular accelerated ageing regime used, the discs failed either because of mechanical damage to the protective layer or because of the reaction of light, particularly ultra-violet, on the dye polymer itself. Because there are no physical pits, the dye polymer is one extra element that can fail in addition to all the standard problems with moulded CDs. Does this give you ideas for possible further research?*

***Jean-Marc Fontaine:***
*With CD-Rs we need to be much more careful with the recording system. There are at least five different systems at the molecular level. We need much more information about the construction and manufacture of the discs.*

***Mike Turpin:***
*Are the signals that you are talking about compressed or uncompressed? Have you examined compression schemes?*

***Jean-Marc Fontaine:***
*We never used compressed signals. Also, all the discs used were brand new.*

***George Brock-Nannestad:***
*Prof. Lemaire, in your model of what is physical and what is chemical, how would you categorise the following breakdown phenomena? In early CD production, the particular polycarbonate that was used suffered a tendency for stress relief cracks - crazing - to form. The material could not remain as a frozen liquid and became crystalline with total reflectance at the boundaries.*

***Jacques Lemaire:***
*The difference between physical and chemical ageing is very simple. In physical ageing, there are no chemical changes; there are changes in physical characteristics only. All polymers are in a dynamically unstable condition. Polymers are, therefore, always evolving to a new state. Polycarbonates are amorphous materials and the crazing is a strain-relief condition in the early life of the discs.*

***Tulsi Ram:***
*Some of the crazing in polycarbonates could be induced by residual solvents in the polymer.*

***Gerry Gibson:***
*Is it possible to read an uncoated disc - one without layers that may delaminate?*

***Jean-Marc Fontaine:***
*The Digipress disc does not have a reflective layer. It relies on laser power to read the disc. It may, therefore, be possible for disc consisting of only the polycarbonate layer to be played.*

***Gerry Gibson:***
*Is the Digipress system being tested?*

***Jean-Marc Fontaine:***
*I am not testing it and, as far as I know, no-one else is either.*

***David Stebbings:***
*At Sony Music we have done some Arhenius testing of blank de-laminated CDs. We used a modified player and the results indicated that the rate of deterioration seemed to be reduced. The tests were not, however, as long in duration as those performed by Jean-Marc. In fact, we were not able to detect any deterioration in the test discs. The laser power used was about 16dB higher than normal.*

***Gerry Gibson:***
*Does this mean that a CD made only of polycarbonate is feasible?*

***Jean-Marc Fontaine:***
*From what David Stebbings says, it would appear to be theoretically feasible but more study is needed.*

## Session 2:

# Signal and Carrier Restoration

### Chairman: Dietrich Schüller

This session is entitled "Signal and Carrier Restoration". There will be three speakers today - Franz Lechleitner, Hong Zeng and Werner Deutsch.

*Dietrich Schüller was born in 1939 in Vienna and studied Physics at the Technical High School in Vienna. He then studied Ethnomusicology and Cultural Anthropology at the University of Vienna and gained his Ph.D. in 1970. He joined the Phonogrammarchiv of the Austrian Academy of Sciences and became Director in 1972. He retains his links with the University of Vienna by lecturing on audiovisual archives and carriers and phonography.*

*Dietrich has travelled extensively on behalf of the Phonogrammarchiv and UNESCO and has visited over 100 audiovisual archives worldwide. He is the current Chair of the IASA Technical Committee and is a member of the Austrian National Committee for UNESCO. He is the Austrian representative on the Council of the UNESCO General Information Programme and is Chair of the Technical Sub-Committee for the Memory of the World Programme.*

# An Audio Pre-Amplifier Designed for the Transfer of Historical Sound Recordings


## Franz Lechleitner

Phonogrammarchiv, Austrian Academy of Sciences, Vienna, Austria


## Summary of Paper


The re-recording of historical sound carriers like cylinders, acoustical and electrically recorded discs, etc. requires a pre-amplifier which covers the transfer functions of these various formats. The paper introduces such an amplifier which has been specially designed by Erhard Aschinger, Audio Consultant to the Phonogrammarchiv, to meet the requirements of such transfers as defined by the years of practical experience gained by the archive.

There are two switchable two-channel input stages for the amplification of the signal to 0 dBm, enabling the parallel use of two tone arms for a easy and quick choice of the most suitable stylus. The amplified, untreated "stereo" signal can be routed to a recorder to obtain a linear preservation copy. in a second run, possibly after signal enhancement, the signal is returned, and depending upon the requirements, equalised and converted to a monophonic signal.


*Franz Lechleitner graduated from the Technische Universität in Vienna with a Diplom-Ingenieur in electronics. He joined the Phonogrammarchiv in 1973 as the Chief Technical Engineer and has specialised in the re-recording of historical sound carriers. He has also been active in the design and construction of specialised equipment for the archive including transcription desks, cylinder players and dedicated amplifiers. In addition to his work for the archive, he has been asked to re-record several historic collections from other institutions. He has written a number of articles about his work.*

*He is a member of the IASA Technical Committee and is currently Secretary of the Austrian Section of the Audio Engineering Society. He is also a record collector and has a private collection of 78rpm discs.*

# An Audio Pre-amplifier Designed for the Transfer of Historic Sound Recordings

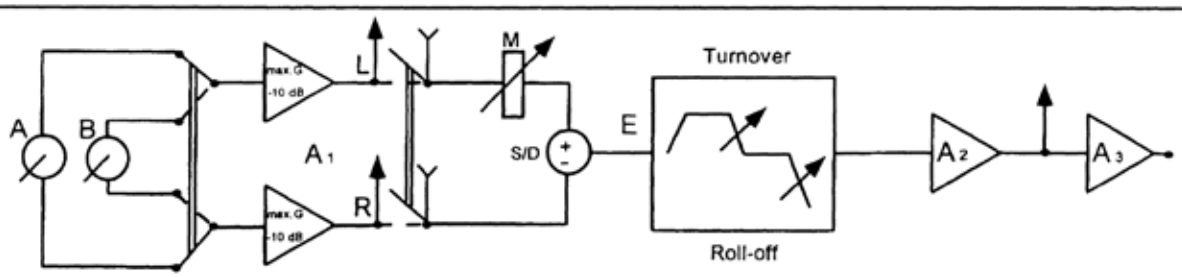

## Franz Lechleitner


The re-recording of historical sound carriers such as cylinders and acoustically or electrically recorded discs requires a pre-amplifier which covers the specifics of the transfer of these various formats.

The Phonogrammarchiv of the Austrian Academy of Sciences can look back on roughly twenty years experience of re-recording. The first preamplifier especially designed for the re-recording of our phonogramms was introduced in 1979. Fifteen years have passed since then, and technical developments and our accumulated experience called for a new pre-amplifier. This has now been designed by our audio consultant Erhard Aschinger in co-operation with ourselves to fulfill our requirements, and offers some particular features which will be pointed out in greater detail.

***Dietrich Schüller:***

*The first speaker is my colleague from the Phonogrammarchiv, Franz Lechleitner, who will be presenting a paper about the design and construction of a "An Audio Amplifier Designed for the Transfer of Historical Sound Recordings".*




A, B - Stereo Pickup
A1 - Two-Channel, Ultra-Low Noise, Switchable Gain Pre-Amplifier (Max Gain: -10dB)
L, R - Left and Right Channels
E - Equalisation
A2 - Output Amplifier
A3- Headphone Amplifier
M - Matrixing Balance Potentiometer
S/D - Switchable Sum/Difference Matrixing Circuit and Matching Amplifier

**Figure 1: Block Diagram of Amplifier**

## Input Stage

Two pairs of input sockets accept two different stereo signals. Either one of them can be routed to the input amplifier by means of a mechanical switch on the front panel. This feature allows switching between the two inputs to choose the better stylus for playback, assuming the turntable is equipped with two tone arms and cartridges.The optimum stylus is the first link in the chain of requirements to get the best sound. The human ear cannot store one sound sample for even a short period of time to compare it with another similar sample played afterwards.

For that reason the archival staff were forced to find the best stylus by means of a very time consuming procedure. The record to be transferred was played back with one stylus and the signal recorded on tape. Another stylus was then used and the signal compared with the recorded tape. If the signal was not as good as the recorded one, then another stylus could be tried. If this was better, then that signal would be recorded to be compared with yet another stylus, and so on.

To shorten this time consuming process, the idea of using two tonearms on one turntable was born, mounted at ninety degrees so as not to interfere with each other. Both fitted with identical cartridges. Assuming a speed of 78 rpm and the styli in the same groove, this gives a delay of about 300mS between the two signals, allowing a very good 'instant' comparison of any two styli which proved to be a much quicker means of optimum stylus selection. Because of fragility and, thus, unsuitability of moving coil (dynamic) cartridges for this type of work, even though they have a generally superior performance with LPs, it was decided to limit the input stage itself to accepting magnetic cartridges only.

The amplification of the input stage is set to 54dB in the 'max. gain' position and is reduced by 10dB by the front panel switch in the "-10dB" position. Thus the requirements of cartridges of differing sensitivity as well as of sound carriers with widely differing degrees of modulation can be accomodated. Because of the very low signal levels retrieved from our phonograms we were aiming for a higher gain than 54dB, but it had to be limited to that for technical reasons. Pre-war constant tone (our HMV set is labelled "constant-note record") records were cut with standard velocity of 8cm/S. The playback level of such records using an AKG PE-10 cartridge gives a reading of around 0dBm after the input stage. After the war, the velocity standard was set to 16cm/s. For these records and other high output material, the "-10dBm" position should be used to prevent overload.

A high level pseudo-stereo (two-channel) signal is available at the output to be used in two different ways:

1. For routing to external equipment.
2. For internal processing.

Generally we use the high level two-channel signal routed to external equipment in our archive since we have started to use this pre-amplifier. Every item is now transferred to R-DAT first. This flat "stereo" preservation copy becomes the new sound source for any further enhancement, both in digital or audio domain. In this way, the original "straight" signal is accessible to everybody for further processing but avoids errors due to wrong equalisation or unknown "enhancements" and further wear of the original record. This working step is essential also for the re-recording of historic sound carriers having a completely different noise floor between channels.

The signal of each channel can be selected either individually or combined for enhancement. This choice would be lost if the "stereo" signal was combined to mono on the first transfer to DAT.

The two-channel signal, whether it is from the lateral or vertical groove information is combined to mono by means of a simple linear sum/difference matrixing circuit. However, the matrixing coefficients are made variable by means of a potentiometer which allows electrical adjustment of the virtual vector angle in order to match the original cutting angle. This proves to be a crucial point with early vertically cut record in general, because many of the discs and cylinders transferred so far suffer from cutting angle error with respect to the ideal 90 degrees. In practice, the potentiometer is adjusted for minimum background noise, which is seldom identical to the calibrated 90 deg. position.

The frequency response equalisation takes place in a special circuit offering the most common turnover and rolloff frequencies as well as flat and 1/f, used for playback of acoustic recordings. The question of how to equalise acoustic recordings seems to be more or less a philosophical one. In theory the membrane of an acoustical cutter head acts like a velocity transducer, calling for flat response. On the other hand such cutter heads seem to cut with amplitude rather than velocity response, therefore 1/f equalisation seems to be accurate for the playback of acoustic recordings by means of a magnetic cartridge. To get round this argument it was decided to build in both settings.

**Audio Heritage Equipment**

**Pre-Amplifier PA-02 Version 1**

| | | | | |
|---|---|---|---|---|
| Switch Position | 1 | Turnover Frequency | 250Hz | |
| | 2 | | 350Hz | |
| | 3 | | 400Hz | |
| | 4 | | 500Hz | |
| | 5 | | 800Hz | |
| | 6 | | 1000H | |
| Switch Position | 1 | Roll-off Frequency | 1590H | -16.0dB at 10kHz |
| | 2 | | 2120H | -13.5dB |
| | 3 | | 3180H | -10.4dB |
| | 4 | | 5200H | - 6.7dB |

**Figure 2: Amplifier Switch Values**

The playback equalisations required for electrically recorded material are numerous and well documented. For technical reasons only the common ones can be selected by front panel switching. On the panel there are no frequencies or time constants, but numbers related to them. Thus it is possible to make individual selection, for example by means of plug-in modules.

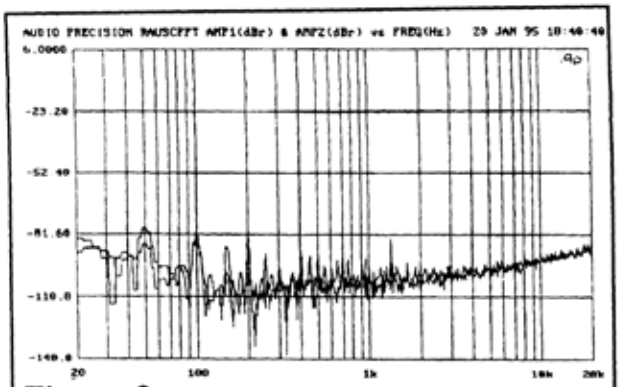


**Figure 3: Left and Right Channels Loaded - Turntable Power Off**

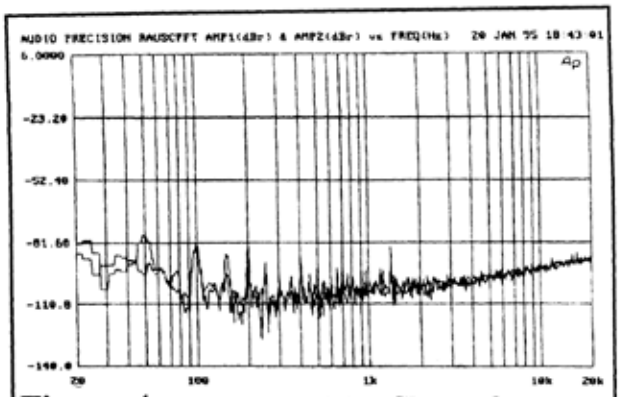


**Figure 4: Left and Right Channels Loaded - Turntable Power On**

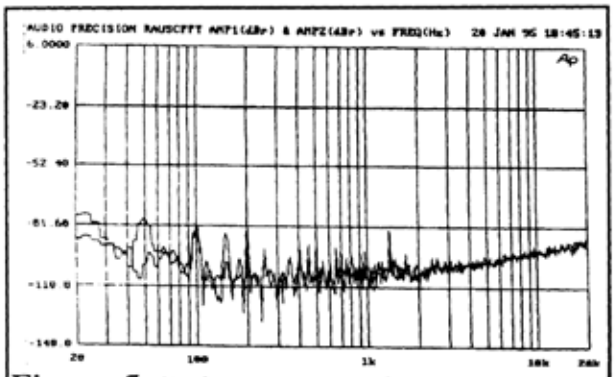


**Figure 5: Left and Right Channels Loaded - Turntable Revolving**

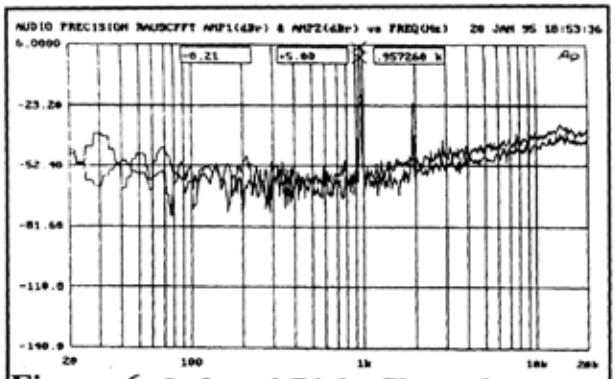


**Figure 6: Left and Right Channels Loaded - Constant Note Record DB 1239 (945Hz, 7.7 cm/s)**

The output amplifier with level control is designed to give +10dBm output level. A LED is set to 6dB below that level to indicate overloads. The signal may be monitored by means of the headphone amplifier with volume control at the very end of the chain.

Much attention has been paid to the power supply. The inbuilt torrodial transformer has been designed to our specification and creates a minimum of stray magnetic fields.

The pre-amplifier is available as a Stand Alone Unit. The front panel carries the operational elements controlling the audio path as well as the mains LED and the headphone output. BNC connectors on the rear panel allow the various audio signals to and from external equipment.

Concerning equalisation people are aiming for a fully stereo model. It is not a question of design rather than of finding closely matched capacitors.

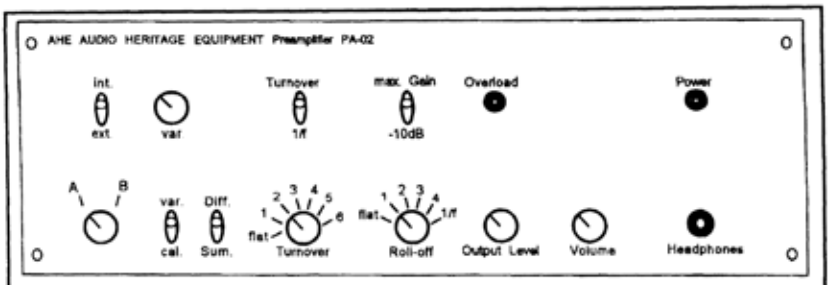



**Figure 7: Front Panel of Amplifier**

***Ian Gilmour:***
*When you are auditioning different stylus assemblies, is it only a question of finding the one that gives the lowest noise or is it sometimes a trade-off between noise and distortion? Accepting, for example, a slightly noisier signal that can produce a better quality signal in later processes.*

***Franz Lechleitner:***
*The preference is to get an undistorted signal. A better noise performance comes, relatively speaking, second.*

***George Brock-Nannestad:***
*When HMV cut discs in the 1930's, they used three tone arms to check the quality. You can spend so much time selecting styli that the disc can be badly worn as a result. In particular, the very loud passages on acoustic recordings.*

*In equipment that I designed recently, I found that a balanced output was very useful. The equalisers that were used in the past were also balanced. A balanced output also avoids any unbalanced noise problems.*

***Franz Lechleitner:***
*It is normally a professional requirement to have a balanced output. With the equipment that we use, however, it was not of help. In general, though, I agree with you.*

***Dietrich Schüller:***
*Thank you Franz.*

# The Restoration of Audio Recordings Using Frequency Domain DSP Techniques Running Under Windows.

## Hong Zeng

Bibliothèque Nationale de France, Université Paris 6,
Villepreux, France

## Summary of Paper

In our project for the French National Library, we needed to build a real-time signal processing system to restore and enhance old, degraded recordings. As the frequency domain noise suppression algorithms proposed for this task were complex, a high speed processor was required.

The decision was taken to construct a multiprocessor using several Motorola DSP96002 boards for PC connected in parallel by a Motorola bus. The number of boards used can be selected with a maximum of four in use at a time. A parallel construction was chosen to allow the system to be developed in the future.

The system is not designed solely for use in audio restoration but also as a research tool. It is, therefore, designed to be easy to use. The use of a Microsoft WINDOWS environment means that the various parameters and coefficients can be easily adjusted with a graphical display.

*Hong Zeng was born in Changchun, China in 1958. He studied at the Changchun Geological College and Graduated as BSc in Electronics. From 1982, he worked on the development of a magnetometer at the Hangzhou Research Institute of Applied Acoustics. He was in charge of a signal processing group on a DSP project for the magnetometer from 1985.*

*Mr Zeng moved to France in 1990 as a visiting scholar studying DSP techniques at the Laboratoire de Mécanique Physique (Université. Paris 6 and CNRS). He began to study for a PhD at the Université Pierre and Marie Curie (Paris 6) in October 1991, with the restoration of historic audio recordings as his topic in a joint venture with the Bibliothèque Nationale de France*

# The Restoration of Audio Recordings Using Frequency Domain DSP Techniques Running Under Windows


## Hong Zeng


### Introduction

*Dietrich Schüller:*

*Our next speaker is Hong Zeng who works for the Bibliothèque Nationale de France and he will be presenting a paper entitled "The Restoration of Audio Recordings Using Frequency Domain DSP Techniques Running Under Windows".*

Our project for the French National Library is to build a real-time signal processing system to restore and enhance old degraded audio recordings. The system will be used not only for audio engineering, but also for research purposes. This is not easy.

First, as some sophisticated technology and algorithms are required, a very large computing power is necessary for processing them. Secondly, for easy access to the parameters the system configuration has to be open and flexible.

Our solution to these requirements is to use frequency domain DSP technique with Windows. We have realised this audio restoration system with multiprocessor options under the control of a system program for Windows. Its real-time performance is satisfying in suppressing hiss, clicks and stationary unwanted sound.

### Limitation of Classical Filtering Method

Most noises in old recordings are broadband noise (white noise). Hisses and clicks are mixed with the wanted signal. Using a general filter to limit noises is the classical method. Its negative effect is signal distortion because of the limited filter band. Yet the noise inside the filter band can not be suppressed. So, with a classical filtering method, it is difficult to separate most noise components from the useful signal. Therefore, the restoration is very limited.

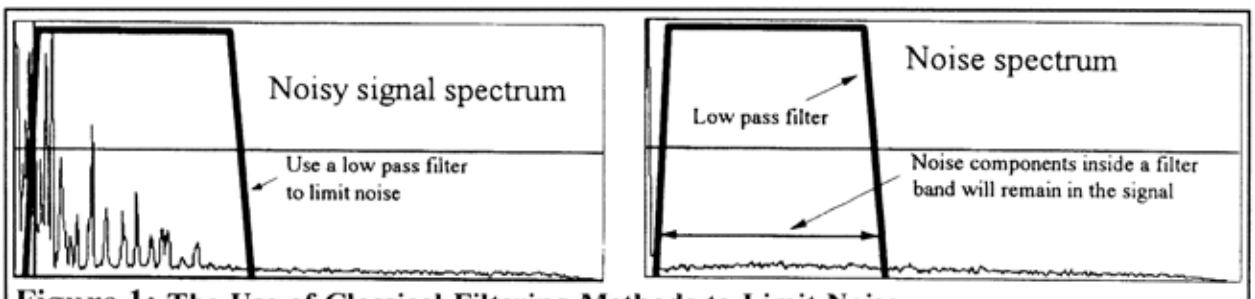



**Figure 1: The Use of Classical Filtering Methods to Limit Noise**

### Frequency Domain Noise Suppression Technique

Some recently developed algorithms can solve many problems in audio restoration. Many of them are frequency domain noise suppression techniques[1][2][3]. It gives us a new point of view,

which is different from time domain filter. These techniques use spectral information to estimate noises, and remove them from the spectrum.

A time domain signal is converted to frequency domain by using short time FFT techniques. First, the spectrum is analysed to estimate the noise components. Then the estimated noise components are removed from the spectrum. After correction, the modified spectrum is used to rebuild the signal under a synthesis process by using an inverse short-time FFT. It is more efficient than high pass and low pass filte, as it can reduce noise in a broad band without noticeable signal distortion. (Figure 2).

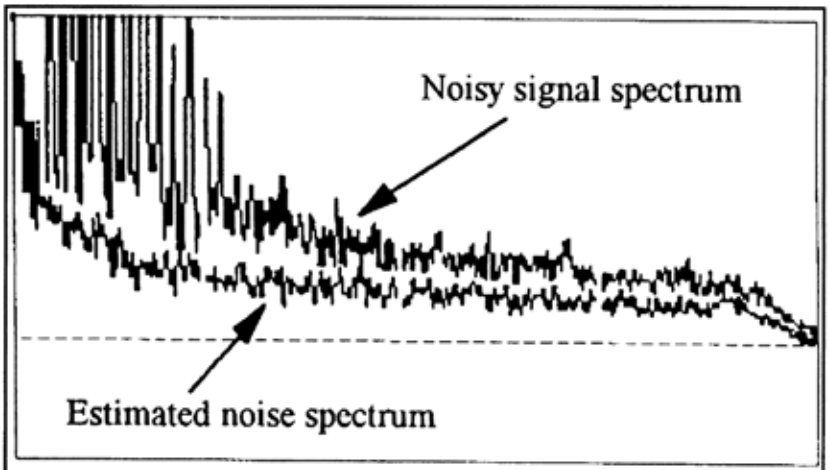



**Figure 2: Correcting Spectrum by Subtracting the Estimated Noise in the Whole Frequency Band**

The estimation is depend on a recognition of background noise. In an audio recording, the noise is mixed with the useful signal for most of the time. The usual method used to obtain this background noise information is previous noise acquisition. This is done by sampling a period of silence at the beginning of the recording before the signal, or in an interval. Then this noise sample (noise spectrum fingerprint) is kept as the reference. The noise type should be constant throughout the recording.

This process uses signal analysis, spectral modification and signal synthesis. A signal sequence is broken into small segments. Each segment is processed by these procedures. The implementation of these techniques for a real-time application requires great processing power to perform the calculations required by the algorithm. For this reason, most of these techniques are still in the laboratory stage with non-real-time processing - the computer has to be left for a considerable time to process a small sequence.

## Implementation

In our project, we chose this frequency domain noise suppression technique as the basic audio restoration method. To realise such a project, our technique solution is DSP + Windows.

The DSP provides the required high speed for signal processing. It is very efficient in realising real-time processing, especially for FFT calculations. In our project, the DSP96002 board has a processing power of 50 MFLOPS[4] - the time taken for a 1024 point FFT calculation is less than 3 ms, which is thousands of times faster than a single PC. Its performance makes our project possible.

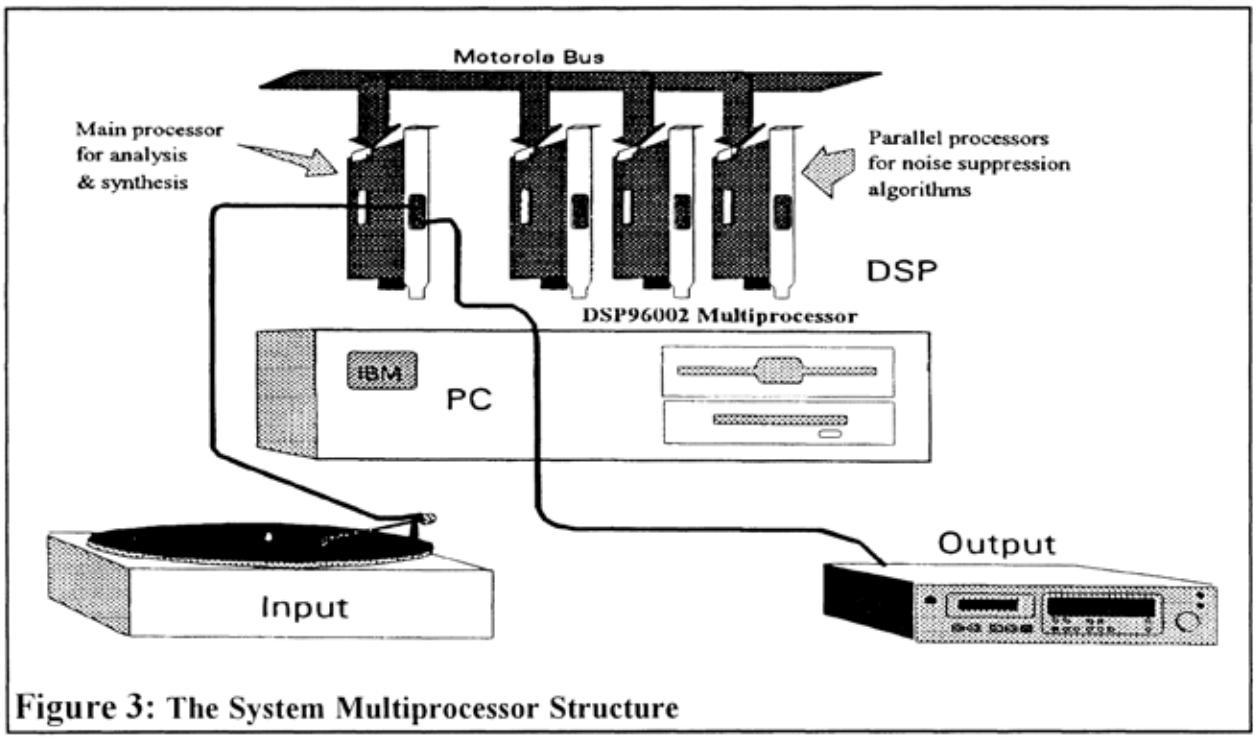



**Figure 3: The System Multiprocessor Structure**

Our system is realised with a multiprocessor structure and tested with 2 DSP boards[5]. It can be expended easily up to 4 DSP boards for more powerful application. This structure is shown in Figure 3. To adapt to the various application needs, the system must be flexible. WINDOWS is a well known human-machine interface. Its graphical features and its multi-task properties make the system easy to be realised.

Some developed applications based on our system have many functions. The following are some examples of available screens:

- Display window & analysis window used to monitoring signal processing and to analyse and compare input and output signals.
- Spectrogram for signal time-frequency analysis.
- Graphical input tool used to design supplementary filters and to input graphical coefficients.

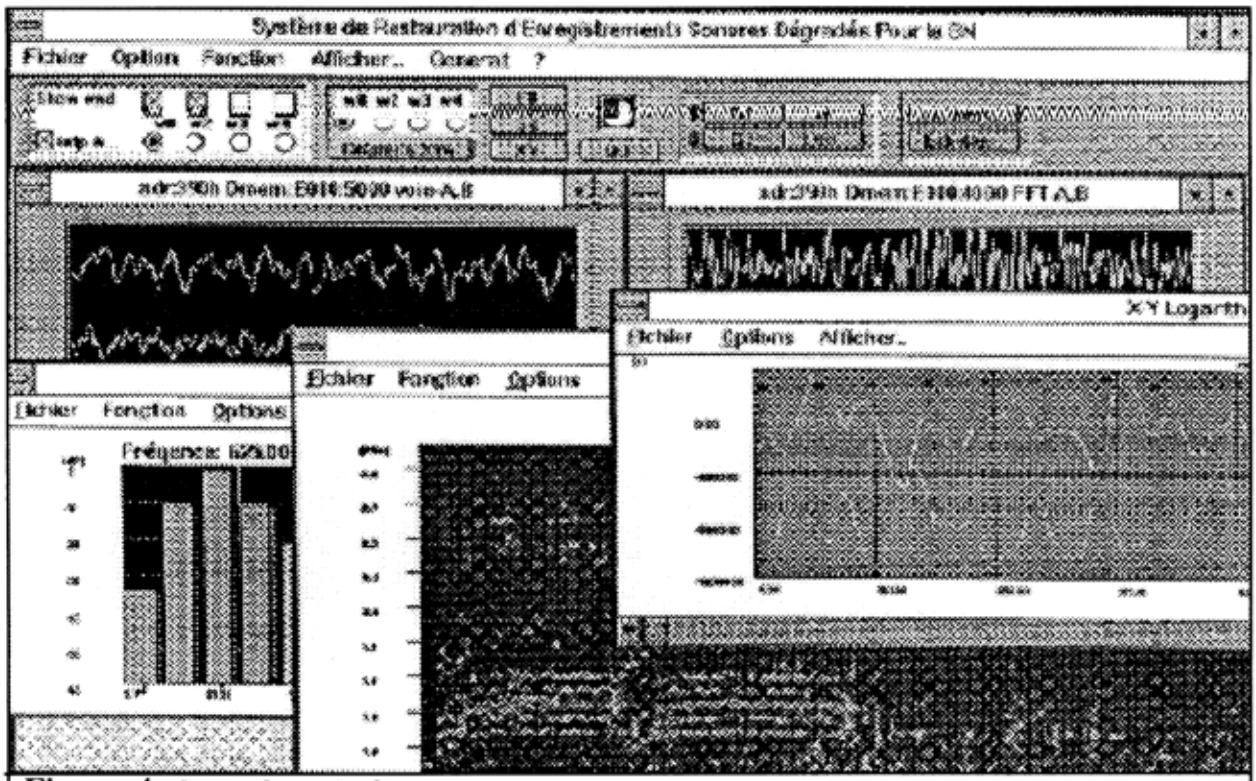


**Figure 4: Some Sample Screens**

And there are also some functions such as:

- Signal simulation.
- Window copying and printing;
- Signal recording and replaying etc.

As well as some developed applications, a system configuration and command panel is used. This is very important for organising some special applications. Its graphical feature makes parameter and coefficient setting very easy (Figure 5). In this configuration panel, one side is DSP options and the other gives PC options. There are three input/output possibilities. They are analogue signal from A/D, digital signal from DSPLK and data from PC. There are also corresponding outputs. Its open structure makes it suitable for many audio processing application.

In addition to using the system for audio restoration, we can use the system configuration panel to set options to perform other processing tasks, for example, spectrogram analysis or for manual restoration of a signal stored in the hard disk.

## Graphic Input Technique

One very important feature of our system is its graphic input technique. It can change most of the parameters and coefficients dynamically. A FIR filter designing tool and an estimating gain generator are two important graphical input facilities. We can use them to draw a filter profile or an estimating gain curve simply by moving the mouse in the window and then load the generated

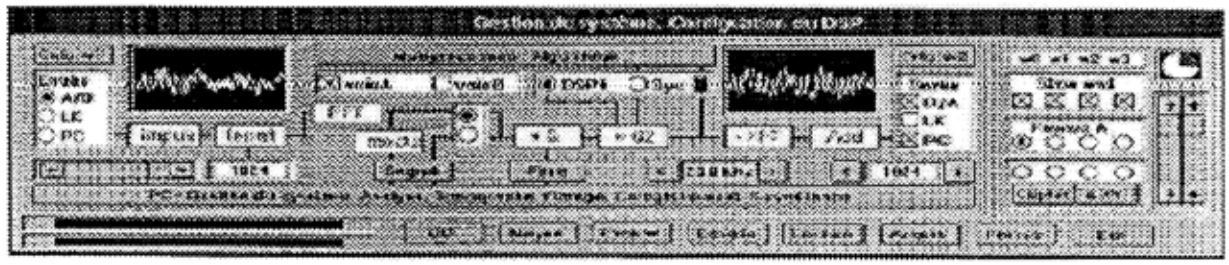


**Figure 5: System Configuration Panel**

data into the DSP without without a break. These additional tools give us more possibilities to study various acoustic processing phenomena and different problems of dynamic audio restoration.

An additional FIR filter is not necessary in most cases but it is used in some serious noisy cases to limit further unwanted sound and some residual noise. This combination of new technology with traditional filters gives us more possibilities to obtain a satisfactory restoration.

In addition to the implemented algorithm for frequency domain noise suppression, the estimating gain generator also give us the possibility of modifying the algorithm features on a large scale. With this option, users, experts or non experts, can change an algorithm feature as they wish.

Based on the spectral attenuation principle, most algorithms give the system a spectral modification gain curve [3], which is spectral attenuation rule followed by the processing. Different algorithms may have different gain forms. So, what will happen if a gain curve is generated as one pleases? Obviously, an arbitrarily created curve would be difficult to describe by a simple algorithm. So its implementation would be more difficult.

The estimating gain design tool is a different form of the same idea. Instead of using an algorithm, we generate the gain curve directly by a manual graphical input. Then we test this gain curve directly. This gives us opportunity to use different kinds of gain curves without the necessity of creating an algorithm. Once a suitable gain curve is found, we give this curve a name and save it for future use. From the research point of view, this capability for modifying the gain curve gives us more chance of finding some desirable special features for solving a given audio restoration problem.

The screen pictures (Figure 6 and 7) are two examples of the use of these tools. Their graphical properties make filter design swift. In the first screen, the horizontal co-ordinate represents frequency, the vertical co-ordinate represents the gain. When moving the mouse in this window with the left button pressed, a filter will be built and sent to the DSP as the mouse passes from one band to another (in this mode, the band width can be one

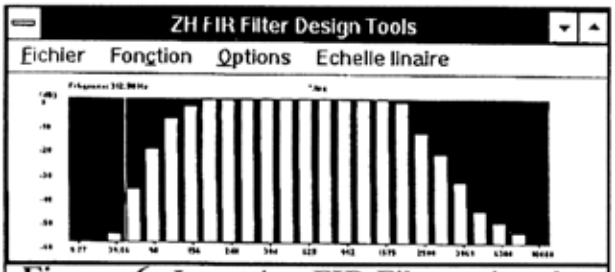



**Figure 6: Inputting FIR Filter using the Graphical Design Tool**

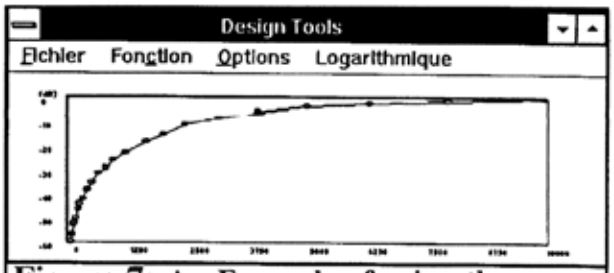



**Figure 7: An Example of using the Graphical Design Tool to Input an Estimating Gain Curve**

octave, ½ octave, 1/3 octave or 1/12 octave). The second mode to input a filter profile is the linear horizontal co-ordinate mode (see Figure 7). In this mode, the filter profile is drawn with lines. After completing the drawing of a filter profile, we can modify it by moving points or adding some points to get the wanted shape and its filtering effect. All the transmissions are done dynamically without stopping the DSP. We can listen to the processing effects immediately.

It is same when using these tools as when using an estimating gain generator, but the horizontal co-ordinate represents signal/noise ratio. Every task of these graphical input tools can be selected through an option in the menu. Once a graphical input is determined, we can save the curve as a standard reference for future use.

## Noise Reference

It is not necessary for the noise reference for the restoration to be searched during every processing. Once a noise reference is found, we can save it as a standard reference - a fingerprint for future utilisation. Some typical noises such as white noise and pink noise can be the most useful standard references. The references are then stored in the library and can easily be recalled using a dialog-box (see Figure 8). A suitable coefficient can be added to adjust the reference level to suit signal conditions. We can change the reference level graphically and dynamically without stopping the operation of the DSP. The reference level represents an estimation quality. If an estimated level is lower than its actual level, the noise suppression would not be complete. In this case, residual noise will appear. On the other side, if reference level is greater, an over estimation effect will distort the wanted signal. So the adjustment of the reference to a suitable level is very important to the processing quality.

## Performance and Conclusion

Under our system program for Windows, the system has been tested with a multi-processor option of two DSP96002 boards. A combination of frequency domain noise suppression techniques with classical FIR filter is implemented. With our graphical input

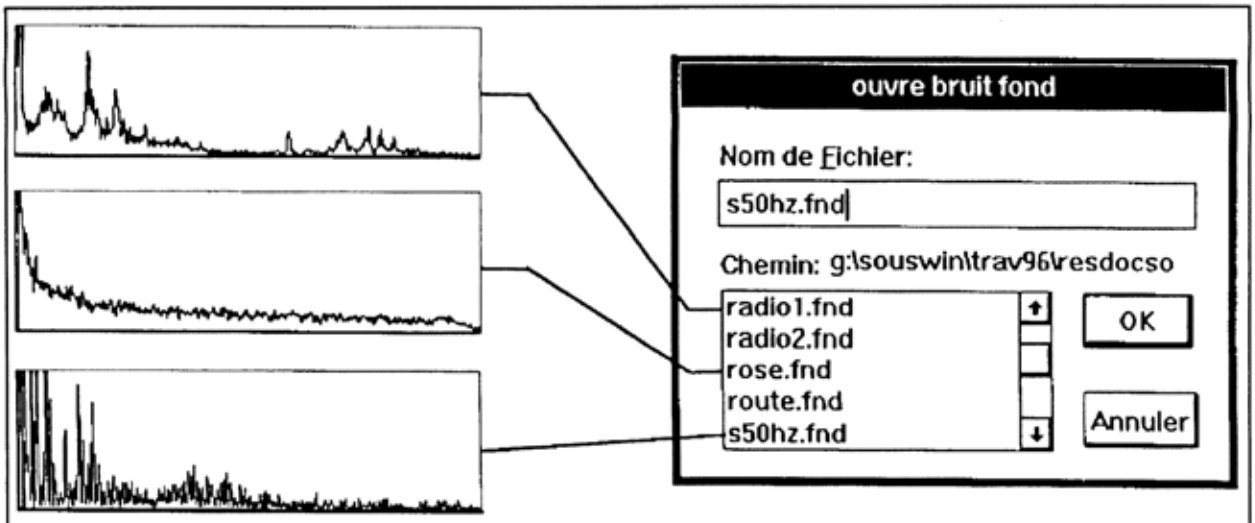



**Figure 8: Noise Reference Library - Noise Spectrum Fingerprints**

technique, most parameters and algorithm coefficients can be loaded or changed very easily to adapt the processing requirements. An important use of these tools is the self-design estimating gain input and FIR filter design. These facilities make our research open to a new field, in which we can study various acoustics phenomena and processing effects related to a spectral estimating gain form and some sensitive parameters of spectral attanuation method in a dynamic way. So very good restoration results can be obtained with our system when processing old degraded recordings. The following are some examples of musical signal restoration.

Figure 9 shows a very good result for the suppression of a fixed tone. The upper trace shows music disturbed by a tone (a stationary square signal of 300 Hz) with an amplitude greater than the music. In addition, there is a background hum of 50Hz and surface noise. After processing, these noises are removed perfectly and the music sounds like the original (lower trace).

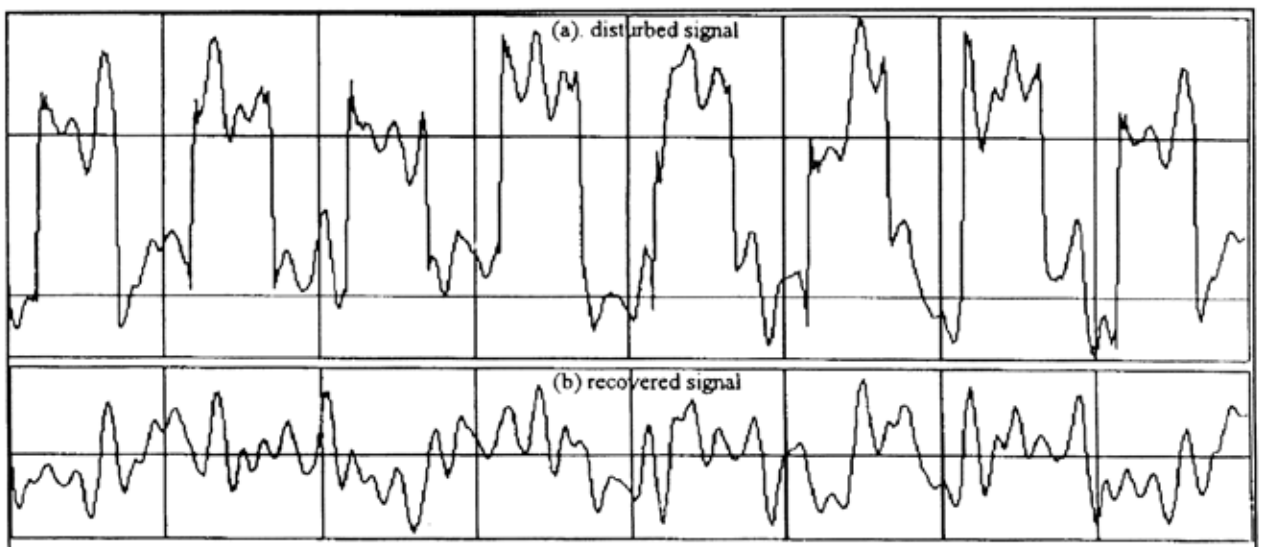



**Figure 9: Example of Real-Time Processing using Spectral Subtraction.**
Upper Trace - Music with Noise Elements. Lower Trace - The Recovered Music Signal.

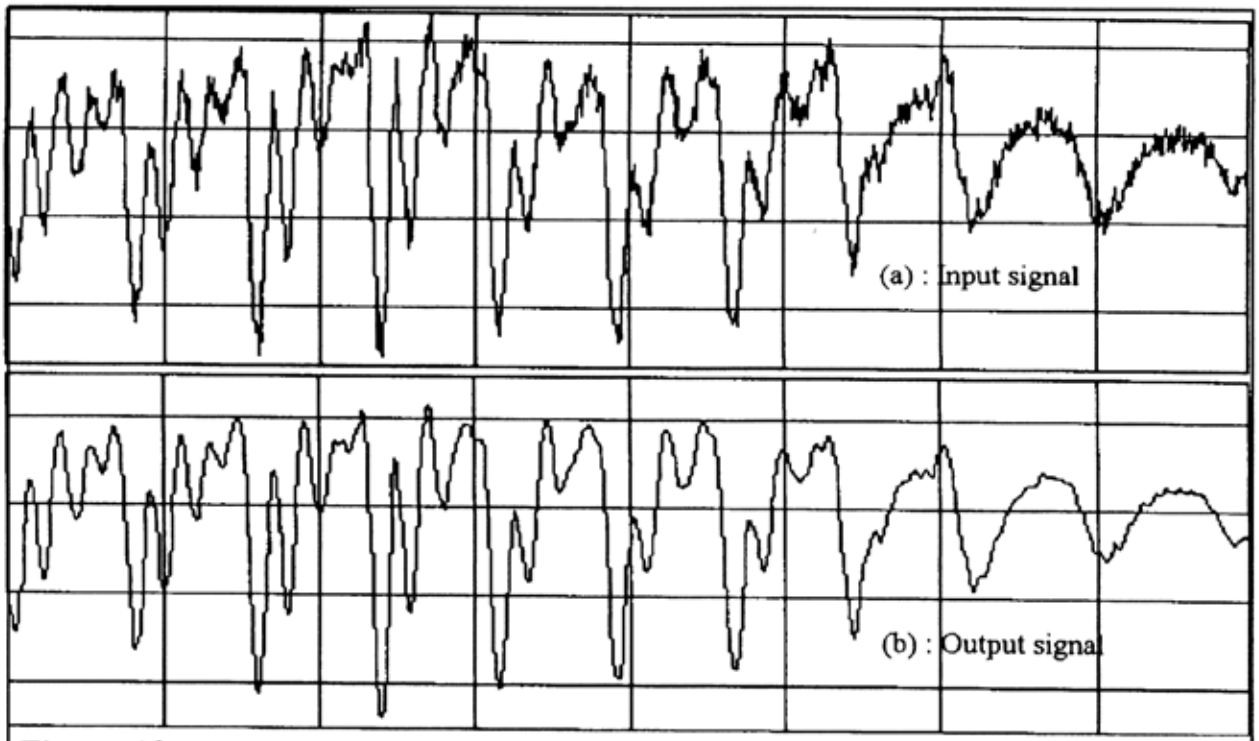



**Figure 10: The System using an Algorithm of Noise Spectral Estimation for Real-Time Processing.** The Upper Trace shows the Input Signal with Noise. The Lower Trace shows the Enhanced Signal after Processing.

Fig. 10 gives a white noise suppression example. The upper trace shows the input speech signal with noise. The lower trace shows the signal after using an algorithm of noise spectral estimation. After being processed, the speech is effectively restored. Fig. 11 shows an example of click removal. After processing, clicks and hiss have been suppressed.

It has been demonstrated that with frequency domain noise suppression techniques, many audio restoration problems can be solved effectively. In particular, many broadband noises like hiss, clicks and steady unwanted tones can be attenuated successfully from the spectrum without noticeable of signal distortion. Its effect in broadband noise processing is very obvious when compared with classical time domain filtering methods. Its progress in PC based parallel processing and its graphical technique under Windows make the system very competitive not only in audio restoration research field but also in DSP product

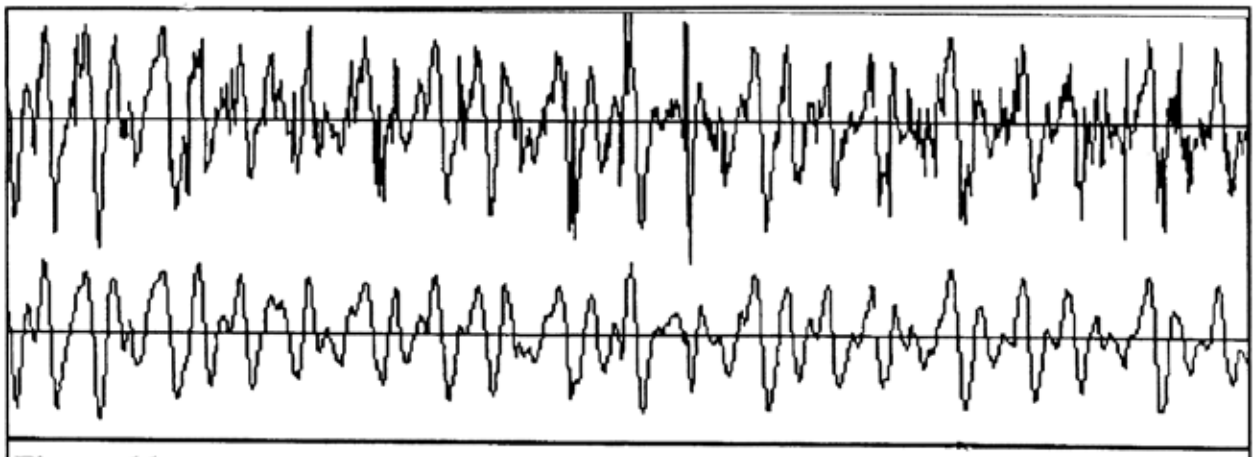


**Figure 11: An Example of Click Removal.**
Upper Trace before Processing. Lower Trace after Processing.

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***James Hoagland:***
*You mentioned that the system can perform real-time processing. Is that after the sound has been stored on the hard disc or can the sound be directly input to the system?*

***Hong Zeng:***
*The signal can be input directly. The output signal can also be fed straight out. We can record to the hard disc but the capacity of the disc is limited. So it is better to use real-time processing.*

***Gerry Gibson:***
*Did you examine the various commercial systems available on the market when it was decided that a digital restoration system was needed? If so, why did you decide not to buy a commercial system but to design and build your own?*

***Hong Zeng:***
*There are two main commercial systems available - No Noise and CEDAR. They have many similarities. Our system is primarily a research tool. The various parameters and coefficients can be changed in a very open way. The algorithm characteristics can be adjusted. The commercial products are closed systems and the characteristics cannot be changed. We use some different principles.*

***George Brock-Nannestad:***
*How do you choose the noise model for a restoration project? Do you check that there are no spectral components left in the chosen sample? For example, a "silent" run-out groove may still have traces of reverberation recorded on it.*

***Hong Zeng:***
*Generally we take the noise model from the beginning of the recording. If this is not possible, we listen to the end.*

***Ian Gilmour:***
*One of the problems with commercial systems such as No-Noise and CEDAR is that they cannot cope with cyclically varying noise as is generated by a eccentrically rotating disc or cylinder. Can your system cope with this noise?*

***Hong Zeng:***
*If the noise is static, we can remove it, but, if it is varying, we cannot.*

***Jean-Francois Consandier:***
*At the end, you mentioned that you can use the system to remove clicks. Can you give some more information about this?*

***Hong Zeng:***
*In principle, removing a click is the same as removing white noise. We take a very long segment - the clicks are seperated in the same way as white noise.*

# Psychoacoustical Models in Signal Restoration and Noise Reduction


## Werner A. Deutsch

Austrian Academy of Sciences, Vienna, Austria.


**It is regretted that is not possible to publish the text of this paper at this time.**
**The Summary and the Debate are included in the Proceedings for completeness.**

## Summary of Paper


The restoration of historical sound recordings has been addressed by several authors considering a number of possible signal processing algorithms representing idealized models of either the noise or the signal source. Inasrnuch as one or both can be estimated accurately, signal enhancement can be applied by adaptive digital filters. An optimum result will be obtained only if an adequate theory is available and if the models fit on the convolving signals. If there is no good model of the time varying signal or background noise available, poor conditioning occurs and the sound quality may drop dramatically, even worse than the unprocessed signal.

This paper deals with a combined approach of approximating a signal model of the time average in the spectral domain and a perceptual model which implements the simultaneous masking function of the ear. Whenever strong signal components are present in the low frequency range, little or no filtering is applied, and the original signal is passed through the process more or less unchanged. Most of the broadband noise components can be neglected due to simultaneous masking.


*Werner A. Deutsch studied psychology at the University of Vienna and joined the Phonogrammarchiv of the Austrian Academy of Sciences in 1968. In 1972, he set-up and became the Head of the independent Acoustical Research Laboratory. In addition to numerous publications, Dr Deutsch and his colleagues have done pioneering work in the field of digital signal enhancement for historical recordings. They have designed and developed "S-Tools" - a digital workstation optimised for sound analysis, processing and storage for use in the fields of musicology and linguistics.*

*Dr Deutsch is currently the Chair of the Austrian Section of the Audio Engineering Society and Vice-Chair of the Working Party on Acoustics of the Österreichische Physikalische Gesellschaft.*

***George Brock-Nannestad:***
*Many of those present are used to listening critically and using their ears but many are unaware of the simultaneous masking that the ears perform continuously. We may be hearing sounds that are not there and not hearing other sounds that are present.*

*We have heard since 1983 a sound like iron-rimmed wheels on gravel whenever you have demonstrated your work. It is a form of phase distortion or phasing - it the mid '80s it was termed the "Viennese Sound" - due to the very low signal to noise ratio. There is very little signal for the processor to work with and the signal does not last long enough for the processor to assess what frequency component it is. An estimate is made but it is very uncertain. The system does not have enough time to analyse the signal.*

*If you adjust the system to the utmost to extract the maximum intelligibility, you will not necessarily get the best sound. Much of the work on signal processing has been done for military reasons, for example, to improve communications in helicopters. Your process uses similar principles to improve intelligibility but, at the same time, artefacts are generated.*

*We heard, for example, a boys choir singing. There was a level fluctuation that is unlikely to have been part of the original recording.*

***Werner Deutsch:***
*There is no restoration or filtering system that can increase intelligibility by removing wanted signal components. The optimum that can be achieved is that the intelligibility does not drop when the noise is reduced. What can be increased is acceptability of the whole signal. I do not claim to increase intelligibility; I claim to increase acceptance of the recording.*

*The slowly varying level in the recording of the boys choir was in the original. The restoration process cannot introduce this effect. We have not implemented a dynamic adaptive filter. The filter that is used is periodically updated and the standard signal comes from the pre-whitened filter response and is then passed through the adaptive filter.*

*If harmonic components are detected in the window by the FFT, they can be filtered. The filter can be updated frame to frame. If a harmonic is not detected, then it lasts for less than 32 or 64 ms. the shortest time that is needed for the pitch of a tone to be recognised is around 3 or 4 periods of the fundemental frequency - that is 20 - 30ms at 200Hz. These systems are neutral; they will not introduce artefacts.*

*As for the "Viennese Sound", there are ways to reduce it. One method is to use a constant Q filter method whereby the FFT points are*

*not linearly spaced over the whole frequency range. This would require greater real time computing power than we currently have in our system. At present, the filter bands are too narrow in the high frequency range and too broad in the low frequency range.*

*The basic aim of the system is that filtering should not be used when the signal is strong.*

***Dietrich Schüller:***
*We do not like the quality of the sound achieved but the application that this type of system is usually used for is the restoration of 78rpm records which have a much better frequency response, signal to noise ratio and dynamic response.*

*In the words of George Boston this morning, this is not an attempt to create an archival copy. This is an attempt to improve the accessibility of the recording.*

*With one recording from New Guinea, the system was able to make the sound of a flute that had previously been hidden in the noise, audible. This was of great benefit to the researchers.*

***Ian Gilmour:***
*At the NFSA, we have found it preferable at times to reduce the amount of processing usec to give a more natural sound quality at the expense of less noise reduction.*

***Werner Deutsch:***
*The sound engineer is the arbiter of what can be achieved and he can continuously adjust the parameters so that the optimum balance between noise reduction, sound quality and intelligibility can be achieved.*

*We have also tried another approach based on the development of the masking function towards an over-masking function. Our intention was to see what happens if we assume that there is more masking present in the auditory system than is given in the experimental data from Zwicke and others.*

*This can easily be done by flattening the masking function. In this case more spectral components fall under the artificial mask threshold. If the signal is split into two parts, noise can be selected out of the signal. One part contains all the signal components that are normally masked and the other part the components that are heard. This is the principle behind lossy Layer III MPEG coders.*

*By changing the mask threshold, we split the signal into two parts which, together, form the whole. In a normal signal, the strongest 5% of the signal partials contain 80 - 85% of the total signal energy. This means that the weaker signal has 95% of the partials but only 15 - 20% of the energy. The weaker part forms the natural sounding background.*

*It must be possible to make a background/foreground discrimination and reduce the noise in the background only. When the two parts of the signal are recombined, a more natural sound should result. We need three or four months more work to achieve this.*

# Videotape Handling Practices 30 Years Later: Did The Recommended Techniques Work?


## James Lindner

VidiPax, New York, United States of America


**It is regretted that is not possible to publish the text of this paper at this time.**
**The Summary is included in the Proceedings for completeness.**

*James Lindner was educated at the New York University Tisch School of the Arts and Graduated with a B.A.(Fine Arts), Film and Television Production in 1975. He studied for an MBA in Marketing at the New York University Graduate School of Business Administration and then moved to Teachers College at Columbia University to study for Doctor of Education, Communications Theory.*

*In 1979 Mr Lindner founded 'The Fantastic Animation Machine": a company to produce advanced computer animations for a wide range of clients. He left the company to join Devlin Video Service in August 1990 as Managing Director of the television facilities. VidiPax was founded by Mr Lindner in July 1991 to provide a service in magnetic media analysis and to restore damaged carriers. The company also specialises in working with obsolete formats.*

*Mr Lindner has received many awards for his work including awards from the Cannes Film Festival and the New York International Film and Television Festival.*

*He is a Member of the SMPTE Committee that is updating the Recommendations for the Care, Handling and Storage of Television Magnetic Tape; a Member of the IEEE; and a Member of the Society of American Archivists.*

## Summary of Paper


Videotape manufacturers and general industry practice have, for some years, recommended certain techniques for tape handling and storage. VidiPax has built a database of Tape Conditions that contains observations from several hundred tapes that have been restored. This presentation will challenge some of the industry standard techniques and point out some techniques that seem to indicate positive results.

# Digital Film Restoration: First Experiences and Results

**Jürgen Ristow**

This paper is about the first experiences of Optronik GmbH Potsdam in the field of digital restoration of archive cinefilms. It is not a scientific lecture but perhaps a contribution to the discussion in this field.

First I want to show you our technological equipment and it's parameters. After that I'll say something about the opportunities for restoration with digital electronic hardware and about the problems connected with the whole process. With some slides, I will demonstrate our first results. Finally I will refer to some of our next projects.

## 1. Technology

The film to be restored is scanned with a scanner from the Oxberry Company (Type 6400) (see Figure 1). This first step is of great importance for the following process. The digitized pictures are prepared for exposure on a Solitair II machine with an Oxberry camera on a high end Silicon Graphics workstation with 2D software from Parallax. With the "Matador" and the "Advance" software it is possible to correct single images and also to create whole sequences.

The deciding factor in choosing this configuration of hard and software was the first class quality which is suitable for the resolution and colour density of today's cinefilm materials. Because of economic factors we renounced the high scanning and exposure speed possible with other equipment.

Figure 2 shows the important technological parameters for an example of a cine picture with Academy Format (1:1.375). The scanner has a resolution of 2000 to 3000 pixels. This means a resolution of 69 line pairs per mm on a length of 22 mm. The system can also handle all other 35 and 16 mm film formats and 9.5 and 17.5 mm as well as 35 mm slide format. The 12 bit colour density gives 4096 steps which is sufficient for cinefilm. Images of about 27 MByte are stored with these parameters on disc and tape and electronically

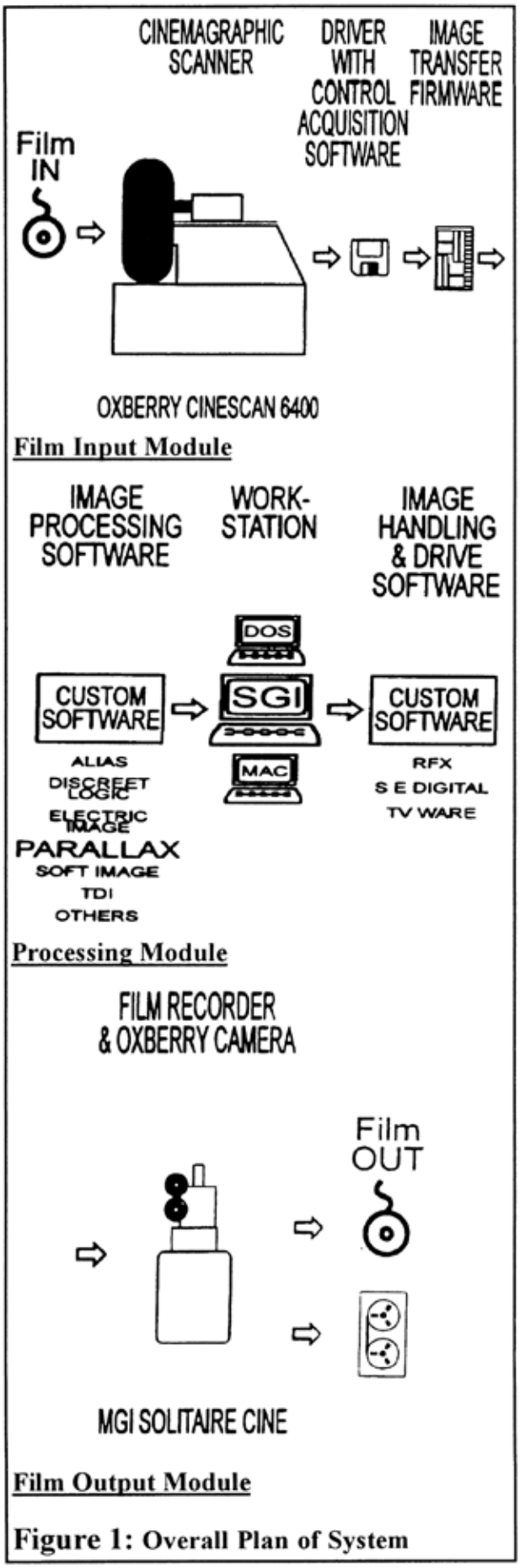



**Figure 1: Overall Plan of System**

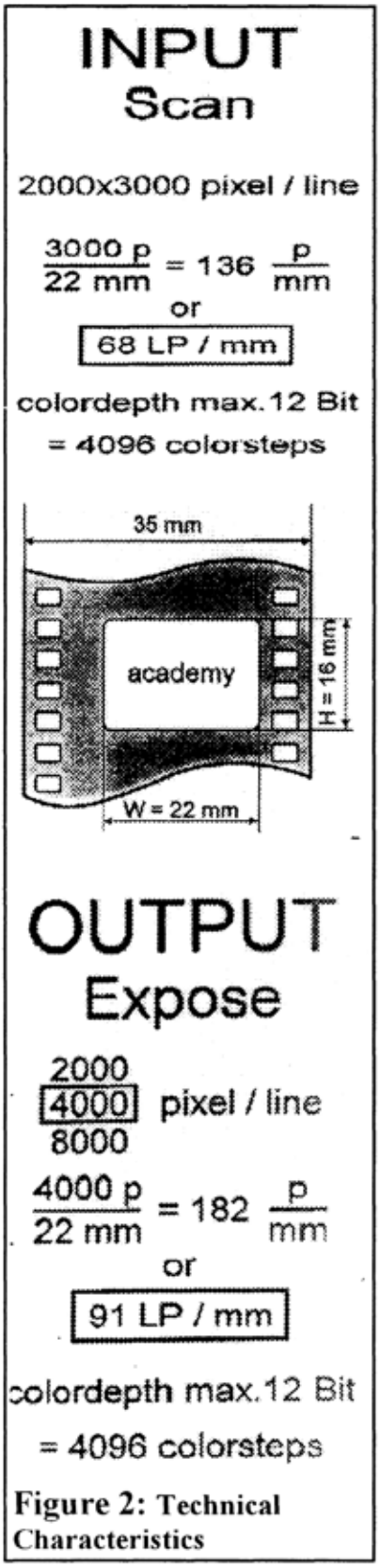



**Figure 2: Technical Characteristics**

manipulated. Exposing with higher resolution is necessary for quenching possible aliasing effects, especially on picture edges.

The electron beam tube works at resolutions of 2000, 4000 and 8000 pixels and a colour gradation of 12 bits. 4000 pixels in the Academy Format give a resolution of 96 line pairs per mm, which corresponds closely to the resolution of colour negative material (for example KODAK 5248). A higher resolution, for example with 8000 pixels, would give much longer exposure times but with no improvement in the pictures. This resolution is needed, however, for exposing photoformats and slides.

## 2. Possibilities of Film Restoration

What is possible with this technology? Table 1 shows a selection of real defects and the technological possibilities of repairing them. The first problem results from various opportunities of manipulating pictures not only with the computer. This gives a multi-dimensional optimising problem that is not trivial.

We found by experience that it is necessary to optimise the scanning process very accurately, while paying attention to the following technological steps. Good scanning makes the subsequent processes more efficient and is the essential basis for obtaining the best possible quality. On the other hand, some corrections can also be done with

| | Defect Removal By | | | |
|---|---|---|---|---|
| **Defect** | **Scanner** | **Computer** | **Camera** | **Laboratory** |
| **Physical and Biological** | | | | |
| Scratches | ✔ | ✔ ✇ | | ✔ |
| Grain Noise | | ✔ ✇ | | |
| Bacterial Attacks | | ✔ ✇ | | |
| Layer Defects | | ✔ | | |
| Mould | | ✔ | | |
| Sub-Titles | | ✔ ✇ | | |
| **Geometrical** | | | | |
| Picture Position | ✔ | ✔ | ✔ | ✔ |
| Steadyness | | ✔ ✇ | | |
| Picture Size | ✔ | ✔ | ✔ | ✔ |
| **Optical and Chemical** | | | | |
| Density Variations | ✔ | ✔ | ✔ | ✔ |
| Gradation Variations | ✔ | ✔ | ✔ | ✔ |
| Colour Aberrations: | | | | |
| Full Frame | ✔ | ✔ | ✔ | ✔ |
| Detail | | ✔ | | |
| Colour Fading | | ✔ ✇ | | |

✇ - Special Software Needed

**Table 1: Possible methods for the Restoration of Film**

exposure or during the copying process in the copying laboratory, for example the gamma-correction and adjusting of colour and density. Later on some reasons!

So I think: The image is only to be manipulated with the computer if no other possibilities of defect removal can be perceived. The complete process with all technological steps has to be considered as a complex system to get optimal results.

## 3. Process Inspection

Each technological part has to be inspected objectivily and subjectively. (Figure 3) The objective inspection starts with the accurate adjustment of the equipment based on the densitometric values of defect material and the material in the recorder. Electronically it is possible through calibration pixel by pixel. Adjustment and calibration have to be done with the highest possible accuracy using reference test slides. A very accurate black and white balance during all process steps and a special grey value table for the final copy positive are very important.

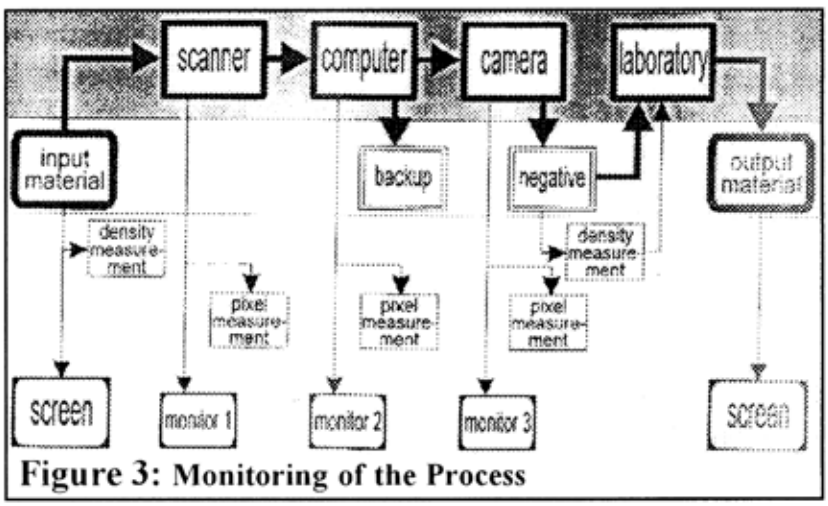



**Figure 3: Monitoring of the Process**

The subjective inspection of input and output material takes place with projection. This inspection is decisive for the result; objective criteria are very complicated to set. At each single production step, inspection is only possible with monitors. Because there are three different monitors, theoretically we would have to balance all three with regard to the final screen projection. This is not possible today. That's why much experience is needed to control. Suppressions are normal also with high accurate working.

So we found that it is essential for the complete process that it is controlled by one team, or better, by one competent person with strong connections with a good copying laboratory.

## 4. Practical Results

We have successfully restored sections of films that have been attacked by bacteria. It would be possible to remove subtitles using the same methods.

It would not be economically possible to restore a complete film in this way because of the cost. It would need too much computer time. That is why we will try to develop special software for automation of parts of this process. The critical aspect of such software is to distinguish between picture details and defects - which sometimes have very similar appearances. A reason for the necessary subjective check-up.

We were honoured to be given the order from the German Bundesarchiv in Koblenz to restore the first Bioskop-films by Skladanowski; the first German films of all. All the pictures have been retouched manually with the computer; density fluctuations have been corrected in the exposure process and the sepia colour of the original pictures comes from exposure of coloured negative film material. The silent film format is nearly the same as the original format of Skladanowski. With motion tracking we tried to correct image position defects, which were introduced by later copying processes, to get better steadiness of images. The titles have been painted following originals of Skladanowski, photographed, scanned and corrected with the computer. Because Skladanowski projected with an image frequency of 12... 13 pictures per second, in our sequence every image was exposed twice to achieve compatability with 24 pictures per second projection, which is today's standard.

A special problem was the reanimation of the sequence "Serpentintänzerin". Only some phase images as fotograf have survived. These images have been scanned with an electronic camera in PAL-format, computed for high resolution exposure and retouched and corrected with motion-tracking. Because only these pictures could be worked with - other phase images are only known from very small printed pictures on paper - we produced the other image between the phase pictures with the computer. After completion in the computer and exposing with a relation of 1 : 1 on KODAK 5248 coloured negative material we got the result you can see in the following small sequence.

*Editors Note: A short sequence of restored film was shown at this point.*

At this point I would like to thank the Bundesarchiv Koblenz for its encouragement and especially for the very intensive engagement and the active help of Mr. Brandes.

## 5. Further Projects

Another type of damage that has been successfully restored was a very bleached movie. This is a very complex problem. The manipulation of colour values is only possible with special software, which is very complicated to develop. In this context I have to admit to the fact that some detailed problems are still unresolved. Fundamentally we think that they are resolvable. For retouching of scratches, some very effective special software already exists. We are also working in the field of developing special software to repair bacterial attacks and for removal of subtitles.

Thank you for your attention.

*Jürgen Ristow was born in Swinemünde in 1935 and studied Electrotechnics and Acoustics at the Technical University of Dresden. After Graduating in 1959, Dr Ristow was a Science Assistant at the University until becoming the Chief Manager of the Film and Television Development Department of the DEFA Motion Picture Studios in 1965. In 1991, he moved to the Institut für Medientecnik in Potsdam. He was appointed Manager of OPTRONIK GmbH Potsdam in 1992.*

*Dr Ristow is a member of the Fernseh und Kinotechnische Gesellschaft, the Physikalische Gesellschaft and the Acoustic Engineering Society*

# Digital Restoration of Film: The Kodak Cineon Digital Film System

**Paul Watkins**

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## Summary of Paper

Digital technology has greatly enabled the development of powerful new tools and working methods for the restoration and preservation of the motion picture legacy. This paper describes the basic steps involved in converting film images into digital data, the specific techniques involved in repairing and renovating images using computer manipulation of data and the re-conversion of these data back to film output.

The Cineon Digital Film System, developed by the Eastman Kodak Company, was initially designed for application in the realm of visual effects in feature films. The system will be briefly described, with additional comments on unique software extensions developed by Kodak which are specific to digital film restoration.

The successful restoration of Walt Disney's Snow White and the Seven Dwarfs by the Kodak subsidiary Cinesite Digital Film Centre marked the first commercial digital restoration of a full length feature film. Some examples will be shown and the experience gained will be described in the context of its influence on further product development. There will also be some discussion of the need to consider the detailed nature of film images when undertaking restoration projects.

Equally important in large scale restoration projects is the working methodology. Use of computer stations in selected configurations to set parameters and appropriate process steps allows a high level of automation to be applied to the task, thereby allowing creative talent to be applied much more productively and Cost effectively to the more demanding sections of the project. The paper will conclude with some discussions of these production options.

*Paul Watkins joined Kodak Ltd in 1992, working for the Motion Picture and Television Imaging Division, after gaining an Honours Degree in Business Administration from the University of Bath. Initially he was Sales Representative to the motion picture laboratories, film archives and optical effects houses before becoming Sales Executive for the Cineon Digital Film System in the United Kingdom.*

# The Digital Restoration of Feature Films: The Kodak Cineon Film System

**Paul Watkins**

In the past few years there have been major advances in the capabilities and performance of digital imaging systems, of which the Kodak developed Cineon range is a prime example.

I aim to explain how these new techniques might be used to complement traditional techniques in the restoration field. A key point is that digital methods are not going to replace existing practices overnight, on the grounds of both cost and practical operations. However, development is so very rapid that a combination of new and well tried restoration practices will soon provide exciting possibilities in this important field.

Just as important as describing the technology is to have an understanding of some practical production issues, and so both will be key features of my talk. I will be speaking about the conversion of film images to digital data, manipulation and correction of the data, and finally the recording of the adjusted images back onto film. I will be setting my words in the context of image restoration projects, which are of significantly larger scale than the more common use of digital imaging in the world of film and video special effects.

I would like to begin by taking a short look at the history of the Cineon program. The Cineon Digital Film System was developed by the Eastman Kodak Company to provide high resolution digital image manipulation capabilities for motion picture film. A major contributor to the development of the Cineon system was the unrivalled fund of imaging science knowledge within the Kodak research laboratories. This technology flow relentlessly continues as the product develops further, and is a key differentiator between applications developed primarily for video imaging and those for theatrical display.

Like all imaging solutions the Cineon Digital Film System has an input, a storage and manipulation, and an output stage. These are the Genesis Digital Film Scanner, the Cineon workstation, and the Lightning Digital Film Recorder respectively. I will be looking in greater depth at the benefits provided by these Kodak solutions later in the presentation.

In September 1993 Kodak opened the Cinesite Digital Film Centre in Burbank, to provide services for the scanning, digital manipulation, and recording of motion picture images. This not only more quickly enabled the spread of digital imaging activities, but it also provided Kodak with the means to gain rapid field experience of the emerging needs of digital

practitioners, and to drive future product development. In January of 1994 Cinesite (Europe) was opened in London in order to provide the same kinds of services to the growing European marketplace. Although the initial thrust for digital film techniques came from the features post production and special effects communities, the application of the technology to restoration was a natural extension.

The experience of becoming involved in the first digital restoration of a complete feature film (Walt Disney's 'Snow White and the Seven Dwarves') gave Kodak the direction to develop software tools that address the specific needs of film restoration. That experience has been invaluable in the development of Cineon as a restoration application, both in technical and production considerations.

Of course, the application that we will be discussing today is but one of four main possibilities for the utilisation of Cineon software. The others are; feature film special effects, the removal of rigs, wires and safety harnesses from movie scenes, and the building of libraries of digitised footage.

The imaging demands of restoration work are very different from those of special effects. In a majority of cases special effects sequences involve a number of shots of a few seconds length. In contrast, restoration projects can involve digital manipulation of whole movies. By way of an example, the restoration of 'Snow White' by Cinesite required the digitisation of nearly 120,000 35mm film frames, creating 15 terabytes of data! So, with potentially vast amounts of image data to handle on a restoration project serious thought must be given to the questions of how to store it, move it around, and work on it, in order to achieve the greatest efficiency, highest quality solution.

Hence the first consideration should be that of the scope of the project - it will point towards the most effective hardware and software solutions to get the job done productively. In the restoration of large portions of movies productivity is the key word.

The specific types of problems to be tackled within the project must be determined. Image defects can be classified by variables such as size, frequency, colour, severity, and other characteristics to enable the best combination of software tools to be chosen. In a large restoration project there will probably be a number of different problems to deal with. Typically there will be the need for:

- The removal of scratches, dust , dirt, and other artefacts
- The stabilisation of flickering images
- Colour grading and contrast adjustment
- Hand retouching

There is unlikely to be a single solution to each specific problem. A combination of software tools will help the artist to gain the best quality result in the most productive way. Computer skills are relatively easy to teach, but aesthetics and an eye for film take time to learn. A digital artist, like his more traditional counterpart, must understand how best to apply the tools available.
So, how does Cineon help to maximise productivity? While it is important not to reduce the vital role of the creative artist in the success of the restoration project, the scale of the task means that it is essential to gain the maximum assistance from computer power to provide high productivity and performance.

Perversely, the very repetitive nature of a computer following a set of instructions provides a much more uniform result than frame-by-frame painting. In the more traditional way of approaching the job, the artist retouches every frame by hand, which is time consuming, requires far more human intervention, and is therefore costly. The brush strokes of even the best artists will differ from one frame to the next, showing up on the screen as a kind of bubbling granularity.

The true way to success is to enable the creative artist to set the rules and guidelines for the computer to follow, test and refine the available parameters until the result is satisfactory, then ask the computer to process the instructions over the selected frames. This methodology provides a productivity breakthrough. Not only can the job now be broken down into sections, and the creative tasks shared amongst lower capacity workstations, but the data processing (or rendering) can be done without the need for the creative artist to be present, typically overnight. Thus the maximum value of creative time is gained, and the repetitive tasks are left to the computer, without the need for costly artistic involvement.

Cineon achieves this semi-automation through its flowgraph method of job construction. On the flowgraph are a series of logically grouped tools, or 'nodes'. The artist can select the appropriate process for the problem at hand via his or her choice of nodes on the flowgraph.

Every node has a window that, when opened, gives the artist the ability to alter key parameters. For example, telling the Cineon software what size and colour of dust particles to remove from a scene using the 'Dust-busting' node. Changing parameters such as defect size and colour within the dustbusting nodes' window leads to differences in the digital detection matte pulled from the original footage, and so to the number of defects removed from the scene.

Whatever the process being applied is, the artist must find the balance between removing the greatest amount of unwanted defects from the image, and the point at which true image information starts to be removed. In particularly difficult cases

the artist can define regions of safety to prevent a processing node from altering a particular area. Revisions can be made to the node parameters at any time, and can also be animated over time to take account of variations in the images being restored.

The linking of process nodes to build up the job flowgraph also means that a number of operations can be carried out concurrently. For instance, in restoration jobs alterations to both colour grading and contrast levels are likely to be needed over large amounts of the project.

The effect on the image of fine tuning the node parameters can be previewed on the computer monitor very quickly, which has been especially calibrated to the colour temperature and contrast characteristics of Eastman motion picture films to aid judgement.

When happy the artist can commit to the batch processing of data, perhaps even scheduling this processor-hungry rendering for a slack period, such as overnight, when the power of the computer is not required for more interactive work. Creative time is then maximised and the equipment used more cost-effectively. After checking the results, perhaps with the client, the much smaller percentage of hand retouching work that now remains can be carried out. Cineon has a paint palette-style Retoucher application that allows individual sections of frames to be digitally manipulated and repaired.

So, by using the flowgraph nodes in combination the artist retains creative control of the process, but many of the routine and repetitive tasks are avoided - greatly improving productivity. We now have a firm view that this concept of working is the only realistic way to succeed in the restoration of full length feature films.

I would now like to look in a little more depth at the hardware aspects of the Cineon Digital Film System and in particular how they are configured to answer the challenges of large restoration jobs.

Our input, the conversion point from analogue film to digital data is the Cineon 'Genesis' Digital Film Scanner, capable of scanning 500 35mm frames at full 4k resolution in an 8 hour shift. Importantly, Kodak colour scientists found that by sampling at 10 bits per colour logarithmically the full colour fidelity of motion picture film can be captured, well into both the highlights and shadows of a scene. This level of quality is maintained throughout the whole system, and is the only way of digitally matching the imaging capability of film. The artist has the information at hand to do the very highest calibre job.

For instance, it means that we can effectively capture the grain characteristics of the input film roll, and if so desired reduce it, or perhaps strip it completely and replace it with the grain of a recognised Eastman film stock - by use of the degraining and

regraining nodes in the flowgraph.

The creative workstation is typically a 4 or 8 processor Silicon Graphics 'Onyx' supercomputer, capable of batch processing several hundred full resolution frames per shift. However, when considering the various workstation configurations that can be applied with the needs of restoration in mind, I have already suggested to you that advantage is gained from a more distributed way of working.

Consider the two distinct production activities; firstly, job flow construction and parameter setting, and secondly the batch processing of data. A network consisting of a number of smaller computer seats connected to a powerful central server gives the flexibility to assign batch processing over a combination of the total number of processors in the system. The restoration job can then be more efficiently broken down into tasks that are automatically handled by the computer and those more difficult scenes that require intervention by the creative artist. Job flowgraph creation and parameter setting can be performed by a number of operators on low cost seats such as the Silicon Graphics Indigo$^2$, at the rate of around 125 full resolution frames per hour. The more processor intensive retouching and rendering work can be carried out on the larger Onyx machine at the centre of the network.

The open architecture approach used by Cineon provides complete freedom to input images from a number of sources and to carry out the job with greatest flexibility. It enables us to provide a 'Developers Toolkit' interface to Cineon, so that users can integrate their own nodes with the software to add, modify, or combine processes in light of experience built up on projects.

Output of the finished restoration work back onto film is handled by the Cineon 'Lightning' digital film recorder. Unlike any other film recording system in the world this laser-driven machine outputs onto the ultra fine-grained Eastman EXR intermediate film 5244. Use of this particular stock prevents extra levels of unwanted grain being added to the image, giving the artist control over the type of grain he or she wants on the resulting film clip from within the Cineon software. Lightning can record approximately 1200 full resolution frames per 8 hour shift, which is a comfortable match for the work coming in from the networked workstations.

When considering the cost implications for investing in this type of technology the prices of the film scanner and recorder are easily quantifiable, but the cost of the creative workstation is dependent upon several factors:

Total number of workstations dedicated to project.
Ratio of high end (Onyx) to low end (Indigo²) workstations.
Configuration of individual machines;
- Number of processors
- Size of memory - RAM and image discs
- Number of calibrated monitors
- Number and type of network connections
- Tape archiving and Input / Output solution

To summarise, we have seen how the Cineon flowgraph method of working enables a large job to be broken down into two parts, one creative, the other repetitive. The batch processing of image data yields significant increases in productivity and more consistent levels of quality, leaving creative people free to carry out creative tasks.

By utilising Cineon on a network of lower cost computers, served from the centre by a powerful rendering machine, the job can be further broken down between the creative artists and the computer processors. With experience users can strengthen their approach by adding their own modified solutions to the Cineon software in order to address their specific imaging challenges.

We have seen a number of ways in which the Cineon Digital Film System not only gives the ability to digitally restore films at the highest levels of image quality, but also has the approach which is most flexible and most practical in achieving a productive and economic solution to the demanding requirements of digital restoration.

The Cinesite restoration of 'Snow White' was a world first in the digital repair of full-length feature films. Less well publicised is that the Cinesite team in Hollywood have recently completed another ground-breaking project - the first digital restoration of a sequence of 65mm film.

The film in question is 'My Fair Lady', and the specific job was to give a 'digital facelift' to four shots from the famous Ascot scene of the movie. The shots were digitised on a 65mm version of the Kodak 'Genesis' film scanner, along with the 26 title cards from the movie. Much of 'My Fair Lady' was restored by traditional photochemical processes, but the project leaders felt that the brightly coloured Ascot scene would not have seemed as vibrant if the colour correction, dust, dirt and scratch removal, were not achieved digitally. I think this example illustrates how traditional and digital restoration methods are co-existing happily at this point in time, and for a good time to come, each

route having its cost and quality merits.

Digital technology, effectively used, WILL become a major contributor to the work of film restoration. Production considerations will be just as important as creative ones for all but the very shortest of projects. Kodak believes it has developed both of these key needs into the Cineon product range, and that development will continue to provide more and more effective solutions.

# Digital Techniques in Film Image Restoration - The Human Touch

## David Scammell

Quantel, Newbury, United Kingdom

*David Scammell Graduated with a B.Sc. Degree from Brunel University in 1978 and joined Quantel as a Research and Development Engineer. In 1981, he moved into Product Support and has been responsible or many broadcast products from the original DPE 5000 effects unit to the state-of-the-art Harry. In 1988, he was appointed Senior Product Manager with responsibility for Quantel's entire broadcast range.*

*In 1991, Mr Scammell moved to the USA to take up the position of Vice-President Engineering, with responsibility for developing a Product support organisation in the USA for all of Quantel's products for the broadcast, print and film industries. During this period, he developed a particular interest in new market areas, particularly those of High Definition Television and mixed media. He introduced Quantel's first product for the film industry - Domino - to Hollywood and returned to the UK in 1994 to become Marketing Manager, Film Products.*

*Mr Scammell is an active member of the SMPTE, ITS and several other industry organisations and is a regular contributor to conferences around the world. He is particularly motivated by the issues surrounding new technology and how it is applied in a creative environment.*

## Summary of Paper

Digital technology now provides the ability to scan film images, manipulate them in a digital form and then place the images back on to film in a transparent way. The opportunities that this provides for the restoration and repair of damaged material is enormous and this has become an area of significant interest for the film industry.

The method of application of this technology is, however, vital in determining the quality of the results that can be achieved. One approach with apparent appeal is to use computer programs to analyse the images and to automatically repair them - "dust-busting" and similar algorithms. Despite the instant interest of such an automated process, the results of these techniques can be very disappointing and are clearly unsuitable for large scale restoration.

An alternative approach is to use a human operator to visually inspect each digital frame of the film to decide what is required to improve the image using his or her skill and artistic control. This may, at first, appear more time-consuming but need not be so if the equipment has been designed with this human interface in mind. In practice, this method of restoration has been found to be significantly more productive than any automated system and has the all important benefit of providing a much more pleasing and visually perfect result.

The presentation will examine these aspects in more detail and will demonstrate with examples what can be achieved by a well designed system.

# Digital Techniques in Film Image Restoration - The Human Touch

David Scammell

## Introduction

For many years the possibility of storing feature films in a digital environment has been researched and examined. The applications for this technology are quite far reaching, involving possibilities for alternative transmission techniques, long term archiving, multiple format production, special effects, and film repair and restoration.

In this paper I will be taking a close look at one particular aspect, that of film repair and restoration. I will, however, be pointing out the very close relationship between this application and that of special effects. This I believe is important, since many of the techniques that produce stunning visual effects can be used to provide equally stunning repairs to film material that might otherwise be considered past saving.

This link is easily overlooked by those considering film restoration techniques, since a common misconception is that once the film can be digitised, computers can now look at these images and automatically fix them. However, this approach ignores the fact that the human brain is still the most sophisticated computer available. Provide a human operator with the correct tools that have sufficient speed and flexibility and the results will not only outpace a computer, but will provide infinitely better results.

This paper will look at how these techniques are applied, their advantages, and will illustrate with some practical results. First, it is important to look at the technology that makes this possible.

## Technology Overview

It is imperative that for successful restoration the system must be transparent. Extensive tests have been carried out, and much has been published, about the resolution required for digitising 35mm motion picture film. Quantel has over 20 years of experience in digital images, covering everything from electron microscopes through broadcast to the very demanding standards of the print industry. During this time we have become expert in recognising the value of digitising images in an appropriate manner. Insufficient information will obviously provide poor quality results, but what is often overlooked is that too much information also provides poor quality results, due to the

overheads introduced in storing and manipulating excessive amounts of data.

We applied the same thorough but realistic techniques when approaching the problem of digitising film. I could at this point produce a long technical discussion about exactly the number of pixels (3000 x 2000), bit depth, colour space requirements etc, but I decided that since it is the results we are all interested in to show you instead - after all every picture is worth a thousand words. Here are a couple of quick examples comparing a print from a Domino Digital negative with one from the original.

*Editors Note: The presentation included several short film clips.*

Domino is a complete system, carefully matched to ensure that results that you have just seen can be reproduced every day with the minimum of fuss. To do this meant designing our own film scanner and output recorder, and I would like to talk very briefly about these.

The Domino Film Scanner has been custom designed by Quantel for maximum flexibility and maximum throughput, without compromising image quality. Equally important is that the system is simple to operate, and extremely reliable. It utilises a standard Oxberry film transport, and a pin registered Mitchell gate.

Stability of scanned images is important as will be seen later in the paper. The scanner uses a custom 6000 pixel ccd linear array, and three oversampling passes are made for RGB. Total scan and record time to the disc storage contained within the scanner hardware is 15 seconds a frame continuous.
The Domino Film recorder is also custom designed by Quantel, to the same set of parameters - particularly reliability. For this reason the proven CRT based approach was chosen, with some extensive patented improvements to remove flare and improve resolution and dynamic range. Again, storage is integral, and operating as a completely autonomous unit, the Film recorder can output at 50 seconds a frame onto standard 5245 camera negative stock.

A major problem with digitising film images is the large amount of information that has to be stored, both for transfer and archive purposes. Computer tape formats may seem an obvious choice, but they are slow, require the equipment to view what is on the tape, and are not easy to edit. Instead we looked at how we could provide a fast, simple and visible medium, such as we are used to in the video world with videotape. The solution is extremely simple and straightforward.

We use a standard Digital Video Recorder, and break down the film information so that it looks like a series of digital video frames. In this way each film frame takes up 16 digital video frames, hence we call the format D16. It must be stressed that there is no compression or other losses of any kind in using this format, however it is very fast, and has the added benefit that tapes can be viewed on any 625 line video monitor. The tape transfer speed is 3 frames every 2 seconds for a full film resolution file - this contrast well with computer tape mediums where transfer times of a minute a frame are considered good.

This D16 format is an integral part of the Domino system, it being used to transfer images from the scanner to the workstation, and from the workstation to the recorder. This automatically provides an archive of the original scanned images as well as an archive of the restored images.

I have discussed the film input and output, and the tape archive format, however the most important part of the system is the workstation. This is the unit on which the majority of the actual restoration work will take place. The premise of this paper is that a human operator can easily out perform a computer. For this to be true, however, the operator has to have the right information at his or her fingertips or, perhaps more appropriately, in front of their eyes. Quantel again has enormous experience in this field, and our products have evolved to provide the most natural user interface available. Control is based on a pressure sensitive tablet and pen, which provides a much more direct and natural hand to eye co-ordination than a mouse.

The speed of operation is paramount; it is essential that the system keeps up with the operator to avoid disturbing a natural rhythm. Most importantly, all the film information must be available instantly, with a full resolution real time replay. This is essential for this type of work, since it is impossible to tell if a restoration technique is working unless the result can be reviewed in real time. This contrasts with computer systems, where single frame or low resolution previews are all that is possible. To achieve this type of flexibility the Domino workstation is custom designed by Quantel, utilising hardware specifically designed for these tasks, including a unique disc array, called Dylan, which is capable of storing 2 minutes of full resolution film images, all with true real time random access playback.

## Applications and Techniques

The basic techniques that the equipment employs for film restoration are, in principle, quite straightforward. Each frame of the image can be examined for areas that are flawed; this could be dust, scratches, watermarks, or in extreme cases tears. Adjacent frames in the same scene are then also examined to see if the flaw is fixed or is moving around - covering a different part of the image. In most simple cases, such as dust, tears, and watermarks, these move around the image, and it is a simple case to "paint" through the dust to a clean area on an adjacent frame. For this technique to be effective it is vital that both the frame before and the frame after are instantly accessible, and that complete freedom is afforded the operator to choose based on the material, movement in the image, and the degree of restoration required.

There are, of course, many cases when this simple adjacent frame technique does not work. For instance, many scratches will run down the film covering up much the same part of the image on all frames. There are two alternative techniques which then come into play. One is generically called pixel cloning, or in Quantel terms "Copy Brush". In this technique part of the image is copied over the scratch, using a soft edge airbrush. Usually the area adjacent to the scratch is used, although parts could be copied from anywhere on the image if it is more appropriate. Again, it is vital that the operator has full control over the area to be copied, and even the density of the copy, which may only have to be quite shallow for fine scratches. For more dense or thicker scratches a similar technique to wire removal can be used, where adjacent parts of the image from each side of the scratch can be copied and blended together to provide a smooth transition where previously there was none.

In all these techniques the operation is at full resolution, even zoomed into the image if necessary, but the repair takes place as the operator moves the pen, there is no waiting. Even with quite poor originals a skilled operator will repair several frames a minute using these techniques on the Domino system.

For more complex problems the more sophisticated tools in the system come into play. A common problem is when one particular part of a scene is quite badly damaged over many frames. In this case it is possible to cut out a good area, and literally paste it over the rest of the scene, again with a soft edge so that the join is invisible

In another example there may be some excessive movement between frames - intentional or due to poor registration. Image stabilisation is provided by ALF (Auto Lock Follow), which can be used to reposition parts or entire images if required.

In all of these cases the grain which is an integral part of the image will be copied in exactly the same way as the rest of the image. This ensures that there are no 'flat' areas of image where the grain visibly changes texture or becomes static.

It may be useful at the point to take a quick look at a couple of scenes that made use of this techniques. These scenes are part of a test that we carried out recently for the Swedish Film Institute - the results you see took about two hours to achieve. Watch particularly for the watermarks in the second scene - these are particularly difficult and are almost impossible to detect when viewing individual frames - the real time replay of the images at full resolution is essential for this type of problem.

Another aspect of the restoration process is colour adjustment of one form or another. Domino has a number of different ways and tools to help in this area. A common problem is excessive fade in one or more of the colour dyes. Since the Domino scanner makes a separate pass for R, G, and B we have an enormous amount of control over any imbalance in this area. This has several advantages; firstly we can keep the noise level down that might otherwise be caused by increasing gain in the channels once scanned, secondly the entire process takes place at the scanning stage, with no additional time penalty over a regular scan, and thirdly the result can be seen even before the scanning takes place - the Domino scanner has a colour corrected real time monitor displaying the full resolution of the scanned image. Of course it must be remembered that this process does fall down if one of the dye layers has completely disappeared - if there is no colour information left at all then we are unable to bring it back - although artificial colouring tools may be considered at this point.

I have outlined here just some of the tools and techniques that we have incorporated into Domino that make it such a powerful restoration tool. I explained at the beginning of this paper that there is a huge synergy between the requirements for restoration and that of special effects, and I am sure that you are aware that Domino has already established a name as one of the leading special effects systems for film makers.

However you may ask of our background in restoration, and how am I able to make these claims? The answer is that our video equipment, built for broadcast special effects, has been carrying out this work for many years. Originally the Paintbox was used by Post Production houses as a clean-up tool, but in the last 5 years products such as Harry, and especially Hal, have been used to restore large numbers of films at video resolution for video release, both here in London and in California. Our experience with these customers has led us to develop an increasing number of tools to deal with this application, and Domino has reaped all the benefit of this.

Incidentally it has also transpired that video, although a lower resolution medium than film, is a much more demanding medium for restoration, since videos are watched over and over again - especially those aimed at children, and viewers like nothing more than still framing to spot an error or omission. Films restored for cinema release, where they are typically viewed only once, have in fact been re-restored for video release on our equipment to a much greater quality threshold.

I would like to finish my presentation, however, by showing you a practical example. We were approached last year by BAFTA to see if we would help to produce a film to celebrate 100 years of British Cinema for the UK LA festival. This required us to scan images from films of all ages (the oldest from 1917), and all formats - negative, I/P, I/N, and even prints, both colour and black and white. All the different framing formats then required resizing and positioning to provide a common 1:1.85 aspect ratio, and finally colour correction was required to provide a smoothly flowing look, whilst retaining the authenticity of the original material.

Of course, every scene required some restoration work - sometimes just some dust and scratches, other times much more extensive. As an example of what we had to do, here is a selection of the material, all shown full frame, in their native formats.

*Editors Note: A short video sequence was shown at this point.*

As you can see, there was a fair amount of work. Finally the opening titles and end credits were added, and I am now very proud to be able to finish my presentation with an example of what can be achieved with digital restoration, carried out with the human touch.

# HDVS as a Digital Motion Picture Archival Medium

**Milan Krsljanin**

Sony Broadcast and Professional, Europe, Basingstoke,
United Kingdom

## Summary of Paper

A High Definition Video System - HDVS - with about five times the information of standard video formats and a picture quality, when projected, comparable to that of 35mm film, offers some interesting possibilities for the archiving of motion picture productions.

A particularly interesting aspect is digital recording. By using this method, the recorded information is robustly protected and any number of digital clones can be made with no degradation of the picture quality. Another interesting aspect is the availability of a wide range of tools for image restoration. Furthermore, interfacing with computer graphics work stations allows the exchange of data with data recorders and also the use of a variety of softwares for sophisticated picture retouching when required.

Material converted to digital HDVS tape is suitable for electronic projection and also for conversion to any existing video format for TV presentation. In addition, a very sophisticated system for the transfer of material from digital HDVS tape to 35mm film is available. This system produces images as a single strip monochrome separation from which a number of identical negatives of pristine quality can easily be obtained.

HDVS as a real-time digital medium will play an important role in preserving many valuable motion picture productions with superb quality and unique flexibility.

*Milan Krsljanin is the Manager of the Sony HD Facility, Europe at Sony Broadcast and Professional, Europe. After Graduating with a Degree in Electronics from the University of Belgrade, he worked with TV Belgrade for nine years in various positions, mainly in television production.*

*Mr Krsljanin joined Sony in the United Kingdom in 1985 and the HDVS group in 1987. One of his first tasks within the HDVS group was to support the editing of the first feature film to be shot and post-produced entirely in HDVS - Julia and Julia - and produced by RAI.*

*In 1989 he was appointed project leader for the installation of the Electron Beam Recorder (EBR) system for the transfer of HDVS images to 35rnrn film. He was appointed Manager of the facility when, in 1991, the EBR project was transformed into the HDVS facility incorporating post-production and media conversion capabilities. He supervised the transfer of a full-length feature film - Phantom King's Diamond - from digital HDVS to 35mm film for theatrical release in 1993.*

# HDVS as a Digital Motion Picture Archival Medium

## Milan Krsljanin

***Dietrich Schüller:***

*Let me now call Milan Kryljanin from Sony Broadcast and Professional to give his presentation entitled HDVS as a Digital Motion Picture Archival Medium*

The previous speakers have done an excellent job in explaining the basic concept of digital restoration of film. My presentation will include a short video sequence to illustrate the work that we have done at Sony Broadcast and Professional.

Modern technologies are offering a variety of methods for preserving the audio-visual heritage. Digital techniques are one of these tools. Magnetic tape is the most economic and robust medium for storing information, particularly digitally encoded information. As such, its position will be unchallenged for many years to come. The information stored will be easily transferred to any new medium that may be developed in the future. Digital data can also be easily transported along the new information super-highways.

The new HDTV formats offer a larger and a higher fidelity picture than the 525 and 625 line systems currently used for television broadcasting. The quality of the Sony High Definition Video System (HDVS) exceeds that of 16mm film and approaches that of 35mm film. The Sony Digital Betacam is increasingly seen as an alternative to 16mm film and as an archival medium for 525 and 625 television. For higher quality needs, a range of data recorders are available that can record digital information in a compressed or an uncompressed form. Depending on the requirements, the compression can be set to give optimum recording time on the tape or the optimum fidelity of data. Data recorders can also be used to provide a range of resolution requirements.

For 35mm film, HDVS can be considered as a recording and storage medium. In addition to the obvious advantages of instant playback and ease of copying, the quality is excellent. For example, the HDVD 1000 data recorder offers a data rate of 1.2 GB per sec - this is nearly six times the data rates achieved by the D1 video format. This opens up a number of interesting options including the use of HDVS as an alternative to 35mm film.

Depending on the quality of the film transfer equipment (telecine) used, the initial transfer from film to video can also be the first stage of restoration. Electronic restoration software offers a number of realtime devices that can, for example, correct colour errors including saturation and colour balance, adjust contrast and remove scratches and dirt. If necessary, the video image can be cloned a number of times without the degradation that would occur with an analogue original.

These HD techniques are increasingly being used by the film studios in Hollywood as an effective but economic method of creating the graded prints required for distribution to the cinemas.

For the restoration and preservation of films and videos, a range of work stations with software components for the digitisation and treatment of films are available. Research at the Sony High Definition Picture Centre in Culver City are working to develop more sophisticated tools that will repair images and restore the original film quality. The aim is to be able to automatically repair image degradation. This will not only require great computing power but also high quality film to HD video and HD video to film transfer equipment.

I would like to show some examples of the work now being carried out. The material arrived in the UK on HDVS at 2000 lines and, for convenience, it has been transferred to BetaCam SP.

*Editors Note: Mr Krsljanin showed a video sequence at this point.*

The most important points from these examples are that the final restored sequence from the Electron Beam Recorder (EBR) must match the balance of the original picture and that computer time must not rise above one minute per frame.

A high quality HD Telecine operating at 2000 video lines enables films to be digitised without loss of quality. This will make it easier to provide access copies at a variety of standards as well as making clones of the original film by means of an EBR.

*Editors Note: Mr Krsljanin showed a video sequence at this point illustrating the operation and use of an Electron Beam Recorder.*

Another advantage of digital copies of films, videos and audio is that it is possible to provide automated access to the material. Automated Library Systems (ALS) are available to make effective use of such systems. Such systems are in operation today using data recorders or Digital Beta recorders. Future systems will enable 35mm films to be digitised and stored on cassettes without loss of quality for use in such automated libraries.

*Editors Note: Three sequences showing the same HDVS clip transferred to VHS tape, to BetaCam SP and to 35 mm film ended the presentation.*

***George Brock-Nannestad:***
*What is the equivalent resolution in lines per mm on a 35 mm film of your electronic transfers?*

***Milan Krsljanin:***
*2000 pixels by 1000 pixels per frame.*

***Ralph Montague:***
*Higher definition film stocks have been developed - the fine grain Super 16 stock that is increasingly being used to shoot film material for television with a view to a future transfer to HDTV. Have you any comments about this practice?*

***Milan Krsljanin:***
*The people from Kodak may be able to answer this question better. I can only say that NHK in Japan do not consider that Super 16 is suitable for HDTV.*

***Dennis Kelly:***
*I am from Kodak and work on the Cineon project. The question is really one of format aspect ratio. The same stock is used for both Super 16 and standard 16 mm film. The difference is the area of film exposed. It is clear that if quality is the criteria, then 35mm must be used. There is no one simple answer. It depends upon the balance of quality against expense.*

***Mike Croll:***
*The data recording machines that were shown in the presentation have been around for a few years. They are fairly expensive to operate. Are there any plans for the manufacture of more economic machines suitable for HDTV recordings?*

***Milan Krsljanin:***
*I cannot add anything to the reports in the press. It is planned to have a range of HDTV recorders suitable for use by broadcasters available in time for the Olympics.*

***Clyde Jeavons:***
*Can you give some indication of the likely costs of a HDTV transfer station?*

***Milan Krsljanin:***
*I can only give you the list prices quoted in the rate card for the Sony High Definition Facility that I manage. For a transfer from HDTV tape to 35 mm film, we charge £35 per second for short sequences. For a 90 minute film, it would be about £50,000. Colour grading with real time capability is in the region of £600 per hour. Other companies will have other rates.*

***Paul Watkins:***
*Cinesite would charge in the region of £4 per frame for scanning, £5 per frame for recording. For buying a system, the lowest Cineon system is the Indigo 2 which does not have the rendering power needed for large scale projects and costs a little over £100,000. The Genesis scanner is about £250,000 and the Lightning Recorder is around £1,500,000.*

***David Scammell:***
*To put a slightly different perspective on the discussion, at Quantel we manufacture the equipment and do not provide a service. We have, however, some knowledge of rates charged by some of the companies that we have supplied equipment to. The rate will depend upon your commitment to the service provider. If you go along and say that you have this 10 seconds of film that is giving you problems then you will be quoted rates of between £500 and £1000 per hour.*

*If, however, you ask for quotes for long term restoration projects, you will get rates around £125 per hour. You then have to discuss how many frames an hour can be treated, the level of restoration required and similar factors.*

*However, if you have the level of work that will keep a digital facility busy, then you should also carefully consider investing in your own equipment. To purchase a complete system from scanning to recording will cost around £1,000,000.*

***James Lindner:***
*At Vidipax, we charge £50 per hour for any restoration work and typically work for three or four hours per hour of original material.*

***Milan Krsljanin:***
*You can compare this situation with that of digital effects. I have been quoted rates between £1,000 and £25,000 per shot.*

***Henning Schou:***
*In the Berlin JTS in 1987, we took a feature film and cut it into 25 sections. The sections were sent to 25 archives for restoration using the archives normal procedures. The sections were joined together on return and projected in parallel with an unrestored copy of the film. This proved to be a most illuminating experiment.*

*I would like to suggest that a group of archives make up a similar test reel for you to restore.*

***Milan Krsljanin:***
*Franz Kraus of RF Film Services has already conducted such a test. He can supply you with the results of their tests.*

# Experiments with Optical Scanning of Negatives of Edison Cylinders


## Susanne Ziegler*, Gerd Stanke**, Michael Bottlinger*** and Reinhard Kohius***

*Museum für Völkerkunde, Berlin
**Gesellschaft zur Förderung angewandter Informatik, Berlin
***Deutsches Institut für Lebensmitteltechnik


## Summary of Paper Presented by Gerd Stanke


The Ethnomusicological Department of the Museum for Ethnography in Berlin, founded in 1900 as the "Berlin Phonogram Archive", holds one of the most famous collections of Edison-cylinders of traditional music from all over the world. While other archives and sound collections used the originals for play-back purposes, thus causing deterioration to the quality of the recording, copper negatives (called "Galvanos") were produced in Berlin from the original wax cylinders. These negatives then served as matrices for new wax copies to be made in unlimited numbers.

After a nearly 50 years' odyssey through Eastern Europe, following the evacuation of the collection during the Second World War, the holdings came back to the Museum for Ethnography in 1991. 14.000 copper negatives, more than 95% of the pre-war holding are waiting to be heard again.

Before developing a method for the casting of (positive) cylinders for traditional playback an attempt is being made to devise a method for the optical pick up of the sound directly from the negatives.

The paper describes a first attempt: the inner surface of the cylinder negative was scanned circularly by a matrix camera in 72 steps of 5 degrees each. The parameters of the optical system were set to cover approx. 15 tracks and capture about 4 to 5 sec of sound. The hypothesis is that, with the correct lighting conditions, the physical profile of the tracks can be transferred into a grey scale profile from which the waveform can be derived digitally.

The first experiments have shown that it is possible to trace the tracks successfully and to generate a signal proportional to the grey scale by image processing. The comparison of these preliminary results with the signal obtained by conventional means from a wax moulding of a negative demonstrates the imperfectness of the first attempts. The work does, however, show sufficient promise to justify further systematic approaches to the optical scanning of this important and unique collection.


*Susanne Ziegler studied Musicology, Ethnomusicology and Slavic Languages at the University of Köln and gained her Ph.D. With a thesis on Folksongs in Yugoslavian Macedonia. She worked as an assistant in the Institute for Comparative Musicology at the Free University in Berlin from 1983 to 1988 while continuing her research on Caucasian Music.*

*Since 1990 she has specialised in historical recording and in 1993 she joined the Department of Ethnomusicology at the Ethnological Museum in Berlin. Dr Ziegler is in charge of the wax cylinder project of the former Berlin Phonogramm-Archive.*

*Gerd Stanke studied cybernetics in Prague before moving to the Department of Discrete Mathematics at Humboldt University in Berlin. From 1971 to 1981 he worked in the field of Artificial Intelligence developing simulations of neural nets, character recognition and learning algorithms.*

*After 1981, he carried out research work in applied image processing at the Academy of Sciences of the GDR. He has worked on a number of projects within the ESPRIT Programme including VASARI, MUSA and VAMP. Since 1991 he has worked on the application of digital image processing to industrial quality control and for historical and cultural projects.*

# Experiments with Optical Scanning of Negatives of Edison Cylinders

## Susanne Ziegler, Gerd Stanke, Michael Bottlinger and Reinhard Kohlus

### Introduction

Our paper describes a first attempt to find a method for converting optical signals generated from the tracks inside the negatives of Edison cylinders into sound. The problem connected with this attempt was that no real technical effort was available. All parties involved agreed to use the existing technical equipment, though constructed for completely different purposes. The aim of the study was to carry out the first investigation in reconstructing the sound from the negatives of Edison-cylinders by means of an optical method and to compare the results with the existing mechanical method. In any case, an optical solution of the problem has two advantages: first to get direct access to first generation copies (music or speech) by circumventing the production of new copies, and second the optical way is a non-destructive one.

### The Material

The Berlin Phonogramm-Archive, founded in 1900, holds one of the most famous and most comprehensive collections of Edison-cylinders. It consists of traditional music recorded all over the world between 1893 and 1943. Berlin was the only place where copper-negatives (so called galvanos) were produced from the original wax cylinders by galvanisation. During this procedure the originals were normally destroyed, but the galvanos served as matrices for new wax-copies in unlimited number.

After an odyssey of nearly 50 years' through Eastern Europe following the evacuation of the collection during Second World War, the holdings came back to the Ethnographical Museum in 1991. We counted more than 30.000 cylinders, including about 2.700 originals, 13.500 wax copies and 14.000 galvanos, which is probably more than 95 % of the pre-war holdings. Based on the assumption that the galvanos preserved the original information in the best possible way, we are trying to establish a re-recording project based on the galvanos.

The original method of producing copies from the galvanos has not been preserved - a new method has to be developed. The first results of a pilot study of a new optical-digital method will be presented.

*Reinhard Kohlus studied Process-Engineering and Techno-Mathematics at the University of Clausthal-Zellerfeld and gained his Masters Degree as a Chemical Engineer. Since joining the Deutsches Institut für Lebensmitteltechnik he has worked in the field of image acquisition, picture analysis and the measurement of small and medium sized particles in images. He is currently Head of a Research and Development team.*

*Michael Bottlinger gained his Masters Degree from the University of Karlsruhe. To prepare his Ph.D. thesis, he joined the Department of Chemical Engineering at the University and worked in the fields of image processing of frame structures, process control for quality assurance and mechanical process engineering. He joined the cylinder project because of his experience in acquiring images of mini and microstructures.*

## Considerations Before Starting the Investigation

The first question was:

> Is there something to be seen inside the negatives that represents the sound track?

Tests under a microscope as well as with a video-camera showed that the profile of the sound track can clearly be detected (the video is available from the authors). In any case, an optical way promises two advantages:

- To make audible something where, up to now, there is nothing to hear.
- The optical way is a non-destructive one.

From the theoretical point of view three optical methods are under consideration:

1. Normal grey level images using appropriate lighting conditions (indirect method)
2. Structured light by a simple line (more or less direct measurement)
3. A variation of 2. with extended light structures, grids etc.

For technical reasons and in order to start the test without construction of a new acquisition system, method 1. was chosen. We will see benefits and the drawbacks.

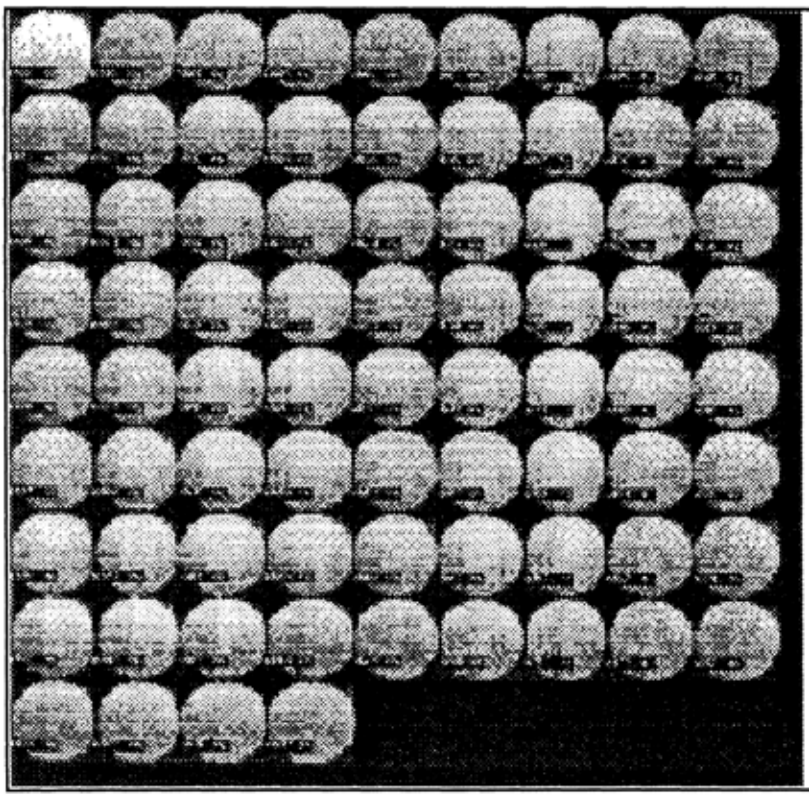


**Figure 1: An Example of a Set of Acquired Images**

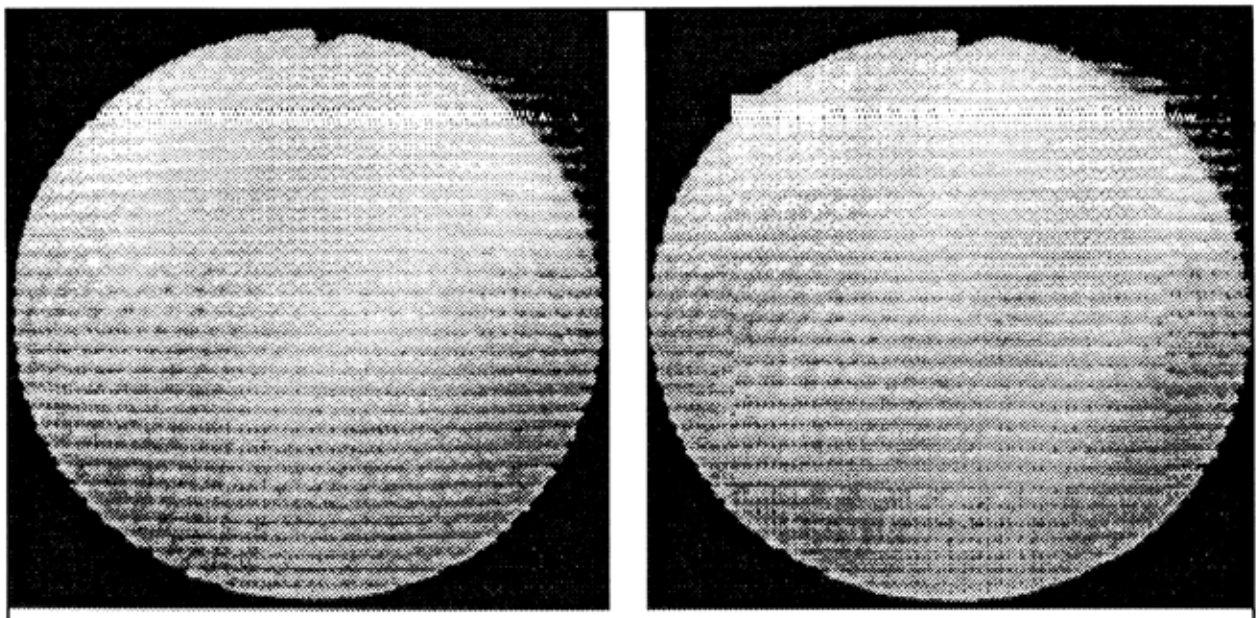


**Figure 2: Images under Consideration before and after Geometric Correction**

## The Image Acquisition

The acquisition system available was an endoscope with a simple cold light source that allowed light to be projected into the cylinder at an obtuse angle. A turning lath was used to hold the cylinder and to rotate it in 5 degree steps. This simple set-up guarantees to cover about 15 tracks at once, in the axial direction, and provide an overlap of about 20% between neighbouring images in the perimetrical direction.

Altogether 72 images of the inner surface were acquired by a matrix camera. This corresponds to 4 or 5 seconds of sound depending on the original turning frequency of the cylinder. It should be noted that due to the imperfectness of this simple set-up, some image segments were lost and others were captured twice. Figure1 shows a sequence of captured images.

## Geometric and Shading Problems

The optical and geometric relationships between the objective and the distance to the inner surface of the cylinder caused some geometrical distortions. These distortions had to be corrected. This was done using the knowledge that all the tracks are parallel but overlaid by a simple interactive waveform (Figure 2).

After this geometrical correction all 72 image segments were assembled to form one continuous image covering the whole perimeter of the cylinder. Using correlation procedures and the knowledge of the approximate size of the overlapping areas did not cause any problems. But one additional effect had to be taken into account. The axis of the cylinder was slanted a little to the axis of the turning lathe - the provisional character of the set up

did not allow a measuring device to be fitted. Because of this slant, we got a macro weaving of the tracks in the completed continuous image (Figure 3). We had to compensate for this weaving and this was done during the process of correlation for fitting the image pieces together.

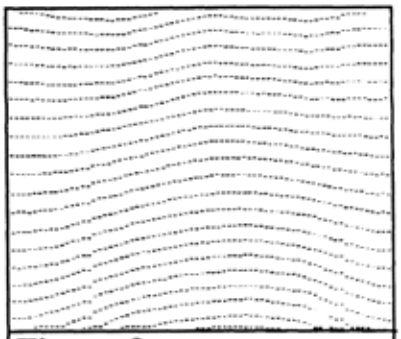


**Figure 3: Macro Weaving of the Audio Track**

A shadowing overlays the images. This was caused by the lighting conditions and caused some troubles. In general, the central areas of the images are illuminated more than the border regions. It was necessary to correct this shading. The information for shading correction was obtained by summarising all the image segments into one normalized background image which was used for correction. The correction procedure assumed a multiplicative shading.

## Transferring the Optical Signal

The hypothesis underlying the transformation was that, by using appropriate lighting conditions, the physical profile of the tracks can be transferred into a grey level profile in the images acquired. It means that there exists some relationship between the brightness of the pixel areas representing the hills and valleys of the track and the real physical dimensions of the track curve. Assuming this for a first step, the areas of the tracks, or rather, the centre lines of each track were found using a searching image processing procedure. In a second step, an operator window evaluating the grey level conditions is moved pixel by pixel along the centre lines. The resulting place/value represents the instantaneous amplitude of the signal. Following the track around the perimeter, the wave could be reconstructed step by step. The resulting sampling frequency (velocity) of the digital wave differs by about 20% from the original one but this is not a real problem.

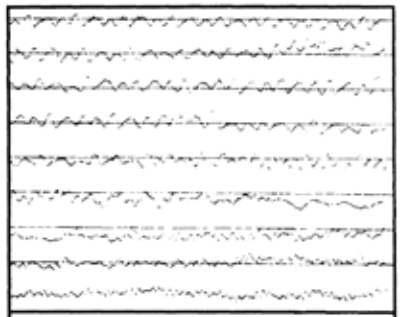


**Figure 4: Samples of the Waveform showing the Widely Differing Qualities Obtained**

## Comparison and Outlook

A comparison of the original sound taken from a positive wax cylinder copy and of the signal obtained using the optical method was carried out by specialists of the Austrian Academy of Science, Vienna (thanks to Dr. D. Schüller, Dr. W. A. Deutsch and Mr. F. Lechleitner). The result is not good but at least there is something to hear. For the first time in the world, we hear something that corresponds to the original sound. The main result of the work under discussion is that there is something audible which can be criticised and improved. A clear plan of what must be changed in a systematic investigation exists and is given in Table 1.

| *what happened* | *actual problem* | *what to do* | *improvement of the sound quality* |
|---|---|---|---|
| pieces of images where lost | no | automatical instead of the current manual manipulation | yes |
| image shading yields to overlaid low frequencies | no (lightening problems) | design a setup allowing homogeneous lightening | yes |
| imperfect fitting between stepwise acquired neighboured images (wave) pieces | no (connected with lightening) | - new set up<br>- improved geometric correction<br>- fitting not only of the complete images pieces but track by track | yes |
| false sampling rate | no | correct | yes |
| true profile of the track | yes | to study the relation between the images acquired and the actual high of the track profile | sure |
| | | to choose method b) or c) | yes |
| dynamic of the signal | yes | improvements mentioned above; better resolution etc. | sure |
| | | to choose method b) or c) | sure |

**Table 1: What Needs to be Done to Overcome the Current Imperfections**

## Summary

An attempt was made to derive the sound signal from negatives of wax cylinders galvanos by using an optical method. Because no special construction for the system illumination-camera was used, the images were overlaid by a shading which strongly influenced the signal. In addition, the distortion was direction dependent and a geometric distortion also had to be eliminated. Nevertheless, the track was followed in the images and a signal proportional to the grey levels seen by the camera was generated.

Clearly, this signal currently reflects the imperfectness of our attempt which represents only a few weeks effective work. But there is, at least, something to hear. The main result of the pilot study is that, in a systematic approach, the physical profile of the cylinder-negative was transferred into sound by optical means.

***Peter Copeland:***
*May I begin by congratulating you on the results achieved in such a short time. There have been a number of attempts to use optical methods to read grooved tracks and none of the systems have achieved results as good as yours.*

*More importantly, I have not been able to see how the existing systems could be improved. In contrast, just sitting here, I have thought of several possible ways that the system demonstrated here might be improved.*

***George Brock-Nannestad:***
*Have you considered that your system is highly adapted to the requirements of reading an interior curve? The curvature of the cylinder matrix assists the optics in obtaining a good in focus image of the centre track of the section being photographed. It may not be possible to adapt the system to read a wax cylinder pressing.*

***Gerd Stanke:***
*In principle the system will work on the exterior curve of a cylinder. It is a question of modifying the processing of the images.*

***George Brock-Nannestad:***
*In the example that you played, which was the signal obtained from your optical system and which was from the wax cylinder? It is difficult to make a judgement because the signal processing may bring the sounds nearer together.*

***Dietrich Schüller:***
*The brighter, hissier sound was the mechanical playback of the cylinder without any equalisation or treatment.*

***William Storm:***
*I would also like to compliment you on the work that you have done. This could be a very productive project if you look at lateral cut discs.*

*I suspect that one of the problems that you are facing is that you are trying to decode a vertical motion component. This means that the centre of the depth of focus keeps moving.*

*If the same technology was applied to lateral cut discs, I suspect that the signal to noise ratio would improve dramatically.*

***George Brock-Nannestad:***
*You are using only ordinary light to illuminate the inside of the matrices - not a laser?*

***Gerd Stanke:***
*Yes, standard light. We are still experimenting with the illumination of the interior to get the best definition images. It may be that a laser would be better but we have yet to try such a device.*

***Dietrich Schüller:***
*What I find fascinating about this project is the possibility of being able to read the sounds recorded on the 15,000 galvanic matrices without having to make positive copies.*

*What has also been found during the experiments is that the sound obtained from the matrices is very close to that of the original cylinders where they still exist and much better than that obtained from copies made from the galvanos.*

## Session 3:

# Access to Sounds and Moving Images

## Chairmen: Crispin Jewitt and William Storm

*Crispin Jewitt is Director of the British Library National Sound Archive (NSA). He has spent his working life in the British Library, taking up the post of Assistant Director at the National Sound Archive in 1988, and becoming Director in 1992. He is responsible for holdings which include over a million discs in various formats, 180.000 reels of tape, the full range of early audio carriers, and unique video material.*

*Having worked in the field of international co-operation in collection development before joining the NSA, Mr Jewitt has been able to build on this previous experience by involving the NSA in European Commission funded research programmes. As a partner in Projects Jukebox and Paragon, the NSA has been able to develop, working with overseas colleagues, knowledge and expertise in the fields of new services and information management.*

*William Storm was the Director of the Belfer Audio Laboratories and Archives at Syracuse University for many years. The core of the archive consists of the cylinder collection of Thomas Alva Edison and his family.*

*In 1992, Mr Storm left to join the Digital Equipment Corporation to develop ideas for the use of computer mass storage systems for the preservation of and access to sounds and images. He has since left DEC and has formed his own company - Media Equipment International - to develop the concept of the use of computer storage for the long term preservation of information of all types.*

# Access to Moving Image Collections

**John Abbott**

This paper consists primarily of the visual presentation of an image catalogue of over 300 film and video programmes. The catalogue consists of the film and television programmes in abstract form and stored on one side of a video-disc in a sequentially organised quad-split format groups of four images presented in sequence on the screen simultaneously. The quad assembly was created by running the film past a frame grabber instructed to sample frames at preset intervals.

The frames of the disc are associated with a simple, keyword driven database which allows extraordinarily rapid access to the images. If you know the title of the programme that you want to see, type in the first few letters, press "Enter" and there it is on the TV screen. Alternatively, key in genre, theme, programme length and language to scan the abstracts which appear immediately.

Hit another key and an information box gives you a textual synopsis and commercial information. Tap backwards or forwards manually and the content of the production is revealed - four sampled images from the film per videodisc frame. Tap another key and the images advance automatically, almost sureally, and this is the moment when you begin to get a feeling for the unsparing honesty of the sampling technique and its awesome speed.

A complete feature film, sampled at 5 second intervals, can be assessed in about in about a minute. A spark of interest? Call for a tape of the complete programme. No interest? Move on to the next item. In half an hour you can make an initial visual assessment of about 45 hours of real-time programming - a compression ratio of 90 to 1 - and the equivalent of about 900 hours of original material a day.

That would be Dalek torture, of couse, but the practical point is that confident REJECTION of unsuitable material is very much facilitated. In a normal film research pattern you have to spend more time finding out that you DON'T want images than finding out that you do. This kind of abstract preselection saves innumerable hours of negative work and, when you become accustomed to the quad-splits flashing past your comprehension and you stop trying to look at individual pictures, it reminds you that the human mind is a wonderfully adaptable machine.

The disc demonstrated at JTS95 was developed jointly by The Image Bank and Euro Aim and contains a visual catalogue of the European productions available at the '94 Donostia Screenings. The "electronic storyboard" confused some buyers at first and

*John Abbott is a writer and documentary film make of over thirty years experience. Born in Australia, he was attracted into the industry after working on the Brando version of the "Mutiny on the Bounty" in Tahiti in 1961. He wrote drama for all the Australian television channels broadcasting in the '60s and 70's but was best known for his public affairs documentaries.*

*By the time that his series "The Russians" was released in 1980, he had moved to England to read Law at the London School of Economics. He specialised in Intellectual Property Law - winning the Kenneth MacKinnon Prize for Revenue Law.*

*During this period, John supported his family by working part-time as a film researcher. This led to his interest in the preservation of archives and improving user access to them which informs his consultancy ARAMS. His major clients for the past two years have been The ImageBank and Euro Aim and he is involved in distance-marketing projects with INA, SVT and Reuters.*

some producers were uncomfortable about the clinical impartiality of the abstracts the system presented.

As soon as the mind-set required for viewing in this abstract way clicked into place, most buyers began using the system in conjunction with the printed catalogue as a preselection tool to refine their selection lists for viewing in real time. Some also used the disc as a POSTproduction tool. Having seen three or four minutes of a production, they would come to us for a quick overview of the rest of it - does the action at the start hold up; does it relax into "talking heads"? On the last day, some buyers completed heir lists by sighting programmes that they had not had time to sample in real-time.

The significance of the system lies not in its software and hardware configuration - both are simple and relatively "old tech" and digital versions are under development anyway - but in the interaction of the quad-split abstract of images and the human mind. This results in an immense increase in the capacity of an archive user to find, absorb and assess imagery.

# The Experience of Six Years of Automatic Access to the Audio-Visual Collection of the Centre Audiovisuel de Paris

## Philippe Boulanger

Centre Audiovisuel de Paris, France

## Summary of Paper

For more than six years, the Vidéothèque de Paris has been using an automated audiovisual consulting system. It will be presented as follows:

The System Description
- Purposes and the original system
- Capacity and volumetric data
- The particular nature of its functions

The Users
- Typology
- Frequency of use
- Behaviour

Statistical Data
- Information about the type, duration, themes of documents consulted
- Consultation sessions
- Failures and defects of the system
- Aging and replacement of the carriers

*Philippe Boulanger gained the Baccalauréat A7 in Arts Plastiques in 1975. He gained the Diplôme de décorateur option cinéma de l'Ecole Nationale Supérieure des Arts Décoratifs in 1981.*

*He worked for several years in television and cinema for a number of companies - winning in 1980 the Prix JVC France at the Festival Vidéo de Tokyo for "Nina Hagen Band" - until he joined the Centre Audiovisuel de Paris in 1982 as the Director of Production. By 1990 he had produced or co-produced over 200 titles - 300 hours of programmes.*

*He was appointed Technical Director in 1991 with responsibility for the exploitation, maintenance and development of the services.*

# The Experience of Six Years of Automatic Access to the Audio-Visual Collection of the Centre Audiovisuel de Paris

## Philippe Boulanger

I have been asked to take part in this meeting in order to explain the choices, the solutions and perhaps also the uncertainty of the Vidéothèque de Paris, whose main objective right from the start, has been to offer to the general public access to the moving picture.

### What is the Vidéothèque de Paris?

Situated in the heart of Paris, the Vidéothèque de Paris is a cultural non-profit making organisation which opened its doors at the beginning of 1988. It is not only dedicated to the moving picture, but is also a place where one can reflect upon urban phenomena and social events in general.

The Vidéothèque de Paris has gathered a collection of audio-visual archives about Paris where the city is the theme as well as the setting of the action. It is a documentation centre supported by an original technology for individual interactive access to the moving picture. It is open to the general public and offers daily programming via five public screening rooms equipped with all types of movie projection and video facilities.

Today, I will focus on describing our automated consultation system, rather than public programming which is the usual access to the moving picture ...

### The System from a Public Point of View

For members of the public, access to the moving picture at the Vidéothèque de Paris is childsplay. It involves the following:

**Payment:** The entrance fee is either at a daily rate or by monthly or annual subscription. This allows unlimited access to all screenings as well as the use of the consultation facilities for 2 or 4 hours.

**Reservation:** The subscribers can reserve a viewing station two weeks in advance via telematic means (ie minitel system), consulting a timetable and selecting the date of their choice.

**Installation:** The public viewing room offers 40 viewing stations. It is not "self-access", but is managed by Vidéothèque staff. A central computer supervising each station offers all

users, including long distance subscribers, up-to-date information on the availability of a viewing station.

**Selection:** The non-specialised public is offered 5200 titles which means more than 3300 hours of viewing time. Selection can be made thanks to four simple characteristics of the retrieval system:

1. It is "full text", which means that each word describing a movie is a key word.
2. The user can ask for what he or she wants in everyday language.
3. It is ergonomic, thanks to a basic Videotex screen and Minitel keyboard.
4. It is practical as users can ask questions by telematic means via the French Minitel system.

**Obtaining the Picture:** The documents are recorded on 3/4 inch high band video cassettes. Two robots manage the storage of 10000 cassettes. They choose the cassette required and insert it into one of the 80 video cassette players. The sounds and images of the film are sent to the viewing station via a switching matrix.

**Viewing:** The same screen is used to retrieve the document through the data base and to view the selected film.

**Listening:** The sound is transmitted to the user via a infra-red system. There are no cables, nor head-phones. The sound is heard via two small speakers fitted into the frame of the seats.

**Sharing:** A station can accommodate several users around the same screen. For example, students working on the same project, children accompanied by adults, ...

**Controlling:** The user can control the viewing using a remote-control in the same way as for a classical video-player (play, fast-forward, rewind and pause).

**Programming:** The user can make up his own program from several different films and organise them to his liking at the moment of viewing.

## The System from Behind the Scenes

We are living in an era in which video consultation is becoming more and more familiar by moving from cultural domain to that of television, ie from the video library to video-on-demand. I would like to ask you to bear in mind that the Vidéothèque de Paris belongs to the age of video library - it opened to the public at the beginning of 1988. Remember that all the technical solutions I am going to talk about were defined or specified in 1986. In view of this, some of them may appear rather basic...

## The Life-Cycle of the Film

Our collection has been built up from nothing by buying the non-commercial show rights of films. In general, we negotiate the rights for a ten-year period. It is not our business to safeguard the original films. We are concerned with making a copy and having free disposal of it in order to use our rights in the best technical and artistic conditions.

At the Vidéothèque de Paris, we use two operating methods, each one with a different medium.

- Release print for the public programming. Our principle is to project films in the original format at the original frame rate.
- Copies on video cassette for individual viewing.

## The Viewing System

It goes without saying that the automation of the viewing system is largely facilitated by the standardisation of the medium on which information is recorded. The choice of medium determines the quality of sound and picture. It conditions the access time to the film and is of considerable importance for the life span of the system and the cost of managing it.

In 1986, the notion of audio-visual consultation could obviously not be dissociated from the characteristics of the physical recording medium. For large collections, the same problem of medium still exists in 1995 and this will probably be the case as long as magnetic tapes are the solution in terms of size, cost and density of data storage. There is, to date, no standard solution. In fact, the choice of the perfect medium depends on the size of the collection, the number of viewing stations and on the expected volume of screenings.

Now, I would like to develop one aspect of our project which highlights the influence of the choice of medium on the performance and the specifications of the system.

## Influence of Video Recording Format

When the medium, the format and the standard for public consultation have been defined at the Vidéothèque, there were only three possible choices:

- Videodisc
- Home format VHS
- 3/4 inch (low or high band)

We have chosen 3/4 inch high band because of its:

- Good picture quality.
- Ability to support Time-code control.
- Technical stability.
- Wide availability.
- Low cost of duplication.
- Its broadcast capability.

But this choice also generates its own limitations and influences other parts of the system.

## Statistics

Now, let's look at some the statistics generated by 7 years of of use of the system.

### About the Collection

The collection consists of more than 5200 titles, making a total of 3300 hours of viewing time, with an average duration of 37 minutes per title. We increase the collection by purchasing around 300 new titles a year.

You can see that our collection is extremely diverse. Most of the titles are documentaries. It consists of:

Documentaries (58%)
Fiction (22%)
News (10%)
Advertising (5%)
Broadcast events (3%)
Variety (2%)

The collection has been gathered from various sources including cinema, TV, company films, amateur films. period represented covers the entire history of cinema. The documents from the photo-chemical domain are predominant.

### The Retrieval System

Our full text data base is asked around one thousand questions daily. It goes without saying that a tree-like enquiry system with multiple levels and criteria always generates one thousand answers to one thousand questions asked.But in our case, of these 1000, 140 are repeated questions by the same users. From the remaining questions, 765 get a reply and 95 remain unanswered because part of them are out of context, some of them are valid but not dealt with in our collection, some are due to spelling or typing mistakes and some to unexplainable manoeuvres.

# About the Technical System

## Size of Facilities

80 video players to serve 40 stations may appear excessive. There are three reasons why we need so many:

The real number of stations on line is 65 (including staff and group stations within rooms designated for that purpose). The necessity to change from one cassette to the next when viewing a long movie requires the system to have a second player available which is reserved and loaded a short time before the switch-over point. This generates the need for at least 10% more players than users. In case of technical failure there are spare players installed and available for use.

## The Organization of the Cassettes

The 5200 titles of the entire collection are recorded on 4300 different cassettes - an average of 1.21 title per cassette.

We have three methods of organization:

- One title per cassette (the simplest method for the making of the cassette and for the technical management of the viewing).
- Two or more titles assembled on one single cassette (the time needed to wind the tape to the right title causes delays and it means also that the other titles are unavailable when one of them is already being viewed).
- One title split onto two or more cassettes, (which requires switching over and makes one entire title unavailable when one of its cassettes is being used).

## The Organization of the Storage

Because of the need to resolve simultaneous demands on a title, almost the entire collection is duplicated onto two copies. The monthly average of requests for the most popular title, Jean-Luc Godard's "A bout de souffle", is 30. With two copies, the risk of conflict is statistically very low. By using the viewing statistics we often decide to add more copies of the most popular titles. The highest number of requests for one title in a month is 120. With four copies, the risk of conflict is considerably reduced during this time

In this way, we can cope with an influx of requests from, for example, a group of school children asking for Richard Lester's "Superman II"! You shouldn't be surprised that this film is included in our collection - the Eiffel Tower is a big part of the screen play.

Today, the storage is organized as follows:

Duplicate copies of 4900 documents.
Single copies of 230 documents.
Triplicate copies of 68 documents.
Quadruplicate copies of one document.

## The Viewings

The data provided by the system has only been available since 1990.

## Consultation Capacity

The viewing room is open to the public from 12:30 to 8:30 PM, six days a week with one late opening until 10:00 PM, for fifty weeks of the year. Its capacity is therefore 100000 viewer/hours per year.

Obtained by:

(40 stations * 8 hours) = 320 hours per day

(320 hours * 6 days) = 1920 hours per week

(1920 hours + 80 evening hours ) = 2.000 hours per week

(2000 hours * 50 weeks) = 100000 hours per year.

However, considering the phenomena of the progressive arrival and departure of the users and the gaps between the sessions on the same station, it is impossible to reach this capacity. Last year, 35000 consultants came and used 60000 hours of viewing time. This occupation ratio of 60% seems very difficult to exceed.

## Use

A consultant covers almost three viewings per visit (2.9 exactly). During an average session of 1h 45 minutes, a viewer allocates: 15 minutes to retrieval through the data base and 90 minutes to viewing audio-visual documents, (that means 5 minutes of retrieval per one viewing).

Last year, more than 100000 requests to view documents were made. Subscribers represent 40% of the consultants. The average numbers of visits per subscriber is ten.

### Viewing Sessions

Each viewing session made is recorded on a statistical data base with information about the requested movie, the date, the user, the duration of the viewing and a code which gives details about the viewing (the cassettes viewed in full, only partly viewed or not viewed at all). The most valuable information for us is when no cassette is viewed. It can be due to the fact that:

- there was no cassette available.
or - there were technical problems.
or - the user changed his mind before getting the first picture.

The ratio between the number of requests and the number of pictures obtained is very important for us. It indicates the rate of dissatisfaction of the public (dissatisfaction expressed or non-expressed ...). We are trying to keep this ratio at 7% - that is 93 pictures obtained for 100 requests.

## The Collection and the Requests

How does our collection meet the demands of the general public? You won't be surprised to learn that, from a collection of this size, where all documents are equally accessible and where no choice is influenced by marketing means, a small number of titles are the object of the majority of the requests.

More precisely, 20% of the users requests are for the 2% of the titles and 60% of requests are for less than 20% of the titles. We observe, therefore, that, every month, more than half of the titles in the collection are requested.

# Conclusion

I will end this presentation by talking about our biggest enemy, which is delay. There are two causes of it at the Vidéothèque de Paris:

- The number of actions already memorized on the robot's list.
- The time needed to wind the cassette to the beginning of the required movie.

The delay is inevitable because the request cannot be anticipated. The delay also depends on the situation: it is not known by the system before the request. Our system takes at least 45 seconds from receiving a request to providing the first picture of a film. We notice that the average delay is 90 seconds and in some extreme cases it can exceed 4 minutes. When people use any

standard interactive system, if there is no answer or feed-back within three seconds of the request, they feel they are being kept waiting. Today the public is in an environment where audio-visual means "instant". At home, obtaining a picture requires simply pressing a button on the TV remote-control.

However, we don't find our public particularly impatient. We have observed that our consultants can wait minutes for a film. This is because requests are made to satisfy a real individual need.

Thank you for your attention.

# VideoScribe: Combined Image and Text Store to Describe Moving Image Documents


## Philippe Poncin and Vincent Prost

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**It is regretted that it is not possible to publish the text of this paper at this time.**

**The Summary is included in the Proceedings for completeness**

## Summary of Paper


The purpose of VideoScribe is to describe audiovisual documents. The overall structure of the document is analysed in detail and each section or shot is described. The document is represented by a series of images on a story board, each shot being represented by a sample frame identified both by a time reference and a textual description.

The time references are the SMPTE timecodes stored on the video tape. This creates a link between the data base and the video tape recorder and permits rapid access to extracts identified from the descriptions in the data base. This is achieved by either selecting an image from the story board or by using keywords to search the textual descriptions and the attached timecodes.

The ergonomics of the information interface are designed to make the inputting of the description rapid and precise. For the video tape machine operations and the capture of images, the system uses original functions to achieve a first cut of the document by automatically detecting changes of scene. The creation of the story board and of the textual descriptions is done by a simple editor and keyboard.

The story board of images also forms a permanent description of the document which is useable as a summary of a series of production rushes or as a consultation document in a library. It is also possible to export the data to form a catalogue of items in store.



*Philippe Poncin was born in Paris in 1948 and completed his training as a Civil Engineer for Telecommunications in 1973. He joined the Institut Nationale de l'Audiovisuel in 1977 as the Head of the Technical Department for the Archives Directorate. In his present post of Deputy Director of Audiovisual Archives, he is responsible for the planning of buildings for the storage of material and for the technical services involved with the restoration and exploitation of the sound, video and film documents in the archive.*

*Vincent Prost was born in Lyon in 1967. He qualified as an Electronics engineer in 1987 and as a Master of Image and Sound in 1 990. He joined INA in 1990 as a Research Engineer in the Audiovisual Archives. He has worked on several projects including the restoration of old recordings, the analysis of video signals and access to video documents.*

# Project JUKEBOX: Remote Access to Sounds

## Birte Christensen-Dalsgaard

Computing Centre for Research and Education,
Aarhus, Denmark

*After obtaining her B.Sc. in Denmark, Birte Christensen-Dalsgaard studied at Cambridge University, England from 1975 to 1977 for her M.Sc. in Mathematics and Physics. She then worked for two years at the Institute of Chemistry in Liege, Belgium before moving in 1980 to the Joint Institute of Laboratory Astrophysics, Boulder, Colorado, USA to study for her Ph.D. in Theoretical Atomic Physics. This was followed in 1984 by a period of post-doctorate study at the Institute of Chemistry, H.C. Oersted Institute, Copenhagen, Denmark.*

*Birte joined UNI-C, the Danish Computing Centre for Research and Education, in 1985 as a Senior Consultant and a member of the CADICAM and Super Computing Group. In 1987, she was appointed Assistant Professor at the Institute of Physics at the University of Aarhus in Denmark. In 1990, she spent six months as a Visiting Scientist at the University of Southern California, Los Angeles, USA. She re-joined UNI-C in 1991 and has been working on Project JUKEBOX as the Technical Manager since the start of the Project.*

**It is regretted that it is not possible to publish the text of this paper at this time.**

**The Summary and the Debate are included in the Proceedings for completeness**

## Summary of Paper

Project JUKEBOX is a European Union supported project testing and evaluating international access to sound archives via the public telephone network (ISDN). The background for the project is that, even though Europe has a large cultural heritage in the form of music, interviews, folklore etc., the public access to this audio material is very restricted.

The recent developments in digital technology, sound compression and telematics makes it realistic, from a technical point of view, to offer access to a high quality copy of sound from everywhere in Europe. In JUKEBOX, three sound archives (the State and Media Archive, Denmark; the National Sound Archive, England; the Discoteca de Stato, Italy) offer access to a limited selection of their material to users in four countries (Denmark, England, Italy and Norway).

With the advance of possible solutions to the technical problems, the problem of copyright becomes greater.

The presentation will describe the technical solution employed for the archive and the user stations and will give an account of the results so far. Copyright problems will be raised but will not be the main topic of the presentation. If a suitable connection can be provided, it is intended to demonstrate the system on-line.

***James Lindner:***
*Why did you not use the World Wide Web as the communications system? The Web is in place and is widely accepted.*

***Birte Christensen-Dalsgaard:***
*The decision to use ISDN was made after considering all the options including the World Wide Web. The problem with the Web is that the HTTP protocols behind it make temporary copies of the files on the users PC. This was not acceptable to the copyright owners. In addition, the Web does not support the data rates that are required by the Jukebox project.*

***George Brock-Nannestad:***
*Why did you use the XLR connector for the headphones? It is not a standard headphone connector.*

***Birte Christensen-Dalsgaard:***
*The XLR connector was fitted to the equipment. It was far easier to fit an XLR plug to the headphones than to modify the equipment. It also makes the headphones less attractive to collectors.*

***George Brock-Nannestad:***
*There are various search fields provided but not one for "Performer". Can this be provided? Many people will want to search for a particular artist.*

***Birte Christensen-Dalsgaard:***
*You can choose between searching the "Composer" or a "Performer" text files. The facility that you desire exists.*

***James Hoagland:***
*Is the catalogue of common terms available?*

***Birte Christensen-Dalsgaard:***
*It can be supplied if you request it from the Jukebox office.*

***Uffe Lumholt Madsen:***
*You mentioned that there was a data rate for the audio of 112 kB/sec. Should that have been 128 kB/sec?*

***Birte Christensen-Dalsgaard:***
*Ideally, we would have liked to achieve 128 kB/sec - that is two B channels. We are actually achieving 112 kB/sec because of limitations in the system. Tests that we carried out showed that 112 kB/sec was acceptable to the users.*

# Software Tools for Moving Image Archives: Access, Indexing and User Interfaces

**Philippe Aigrain, Philippe Joly, Philippe Lepain and Hae-Kwang Kim**

Institut de Recherche en Informatique de Toulouse, University Paul Sabatier, Toulouse, France

## Summary of Paper Presented by Philippe Aigrain

*Philippe Aigrain graduated in Computer Science from the University of Toulouse and holds a Ph.D in Computer Science from Université Paris 7. In 1982, he was a post-doctoral research fellow at the University of California at Berkeley.*

*Since 1983, he has specialized in research on automated processing of image and sound media and its applications for the access to image banks and sound archives. He has been managing a research team on these topics at IRIT since 1986. He has written many technical papers and has been internationally active as an expert for large image and sound archive projects and research programs.*

This paper will focus on the approach that has been developed by IRIT to the building of generic software tools and methods for audiovisual archives- These tools and methods will be presented at the applications level and from the users point of view. The tools exploit data produced by automated or computer-assisted content analysis and the written version of the paper will refer to this work in detail. In the presentation to the Symposium three software tools will be presented:

- A shot-by-shot automatic visual cataloguing software tool with camera work analysis-based choice of representative images for each shot.
- A discrete manipulation visual user interface for the access to video material, including sound image relation analysis and representation.
- A computer-assisted speech sound-track transcription or shot-by-shot annotation tool for video.

*This research was supported by the Ministere de la Culture et de la Francophonie and Bibliothèque Nationale de France.*
*This work has also benefited from ideas raised by the TV Legal Deposit Access Working Group organized by the Institut National de l'Audiovisuel.*

# Software Tools for Moving Image Archives: Access, Indexing and User Interfaces[a]

**Philippe Aigrain, Philippe Joly, Philippe Lepain and Hae-Kwang Kim**

## Introduction

Following research conducted by our team[b] on automatic analysis of audiovisual documents, we have developed a number of generic software tools for access to video in audiovisual archives and libraries. Our tools exploit data produced by automated or computer-assisted content analysis. We give references to papers describing the analysis techniques we are using, or methods which have been proposed by other researchers to achieve analogous results. This paper presents three of these software tools at the application level and from the user point of view:

- A shot-by-shot automatic visual cataloging software tool.
- A discrete manipulation visual user interface for the access to video material, including sound/image relationship representation.
- A computer-assisted speech soundtrack transcription or shot-by-shot annotation tool for video.

It should be noted that we aim at developing software tools up to the full prototype level, where they can be used in realistic contexts in audiovisual archives and become the basis of actual access systems through technology transfer or specifications of future systems. The software described below are not commercial products, but are protected under software copyright at the software and visual interface level. The software names are only provisional.

## 1. Underlying Technology

### 1.1 Processing and Analysis of Video Contents

The software presented below is based on the existance of data describing the document contents. In particular, the existance of time segmentation of these contents and, in some cases, labelling of time segments into simple categories (for camera work and soundtrack, for instance). It is well known that time segmentation of video documents is a long and tedious process. Our software can prove to be useful only if a large part of the time segmentation data can be acquired by an automatic and efficient processing. This is indeed the case for our software, but we have not yet reached a full integration of various pieces of analysis software.

***William Storm:***

*A popular view of an archive is that it is a place where well-meaning people have gathered a vast amount of information which it is impossible to gain access to. People such as those gathered here have had the foresight to gather information together and, contrary to the general perception, we have made great investments in space and facilities to make it accessible.*

*Yesterday, we discussed methods of transferring and cleaning up old material and how expensive such work appears to be. Set beside the cost of not having good access to information, the cost of keeping the material in good condition and in a readable form is quite low.*

*We are privileged today to have two speakers who are working to facilitate access to A-V archives. The first is Philippe Aigrain from the Institut de Recherche en Informatique de Toulouse at the Université Paul Sabatier, Toulouse. The second speaker will be Werner Deutsch from the Austrian Academy of Sciences.*

*May I now invite Dr Aigrain to present his paper.*

- The software described in Sections 2 and 4 of this paper use only segmentation in shots. Shot change detection is now a mature technique: it can be achieved in real-time[c] even when shot change occurs through a progressive transition (dissolve, wipe, etc). A full description of our technique can be found in Reference 2. Let us note that detection of progressive transitions is essential even if they are less frequent that cut transitions, because, in many cases, they are likely to introduce important subject changes. We have also proposed an efficient method for the analysis of camera work and segmentation of sequence-shots in segments defined by homogeneous camera work. [5,4] This type of analysis produces data which is very useful for choosing which image will be used as a representative image in the icon built for a given shot. It can also be used to build representations of camera work in the icon. In the software presented in Sections 2 and 4, we do not use data produced by camera work analysis. A new version of our software will be developed this spring which will integrate camera work analysis into the choice of representative images for a shot.
- The user interface software for video presented in Section 3 is based on the existence of a much wider range of descriptive data, including:

  - Macro-segmentation of video in sequences,
  - Detection of speech, music and loud noise segments in the soundtrack.

We have proposed methods for the automatic segmentation of a video in sequences (consecutive sections of a video which share a similar setup or subject)[3], and other researchers have done so for specialised types of content[8], but it has yet to be verified that these methods are sufficently reliable. In our present software the macro-segmentation in sequences has to be achieved by the user from the segmentation in shots or starting with an arbitrary division into segments of equal duration. This is not a big problem since it does not take very long to produce such a macro-segmentation. On the other hand, definition of speech and music segments in the soundtrack is a relatively tedious process. It is thus critical for us to be able to achieve efficient automatic speech and music detection even when they are combined in a noisy enviromnent. We have been working on a method for achieving this, but in the software presented in Section 3, the soundtrack data has been created manually. [d]

A full review of state-of-the-art processing techniques for video is given in Reference 1. It should also be noted that all of our software applies the same principles of user interface design for audiovisual documents, which have been described in Reference 3 and also applies to our work on interactive listening to musical recordings.

### 1.2 Technical Context

The software runs on Sun®, SparcStationTM II, 10 or 20, with the X-VideoTM board from Parallax Graphics®, under Sun-OS 4.1.3+ and X Window System. The next version will run under Solaris 2.3+ and X/Motif on the same hardware.

## 2. Visual Cataloging

VIDEOBOARD is software which performs digitizing to the AVI M-JPEG format of Parallax Graphics®, automatic shot segmentation and production of "storyboards" which can then be either printed (see Figure 1) or used for relevance assessment during on-line access to video databases.

Before printing or storage, storyboards can be corrected by the person in charge of indexing (see Figure 2). Such a correction might be necessary for the following reasons:

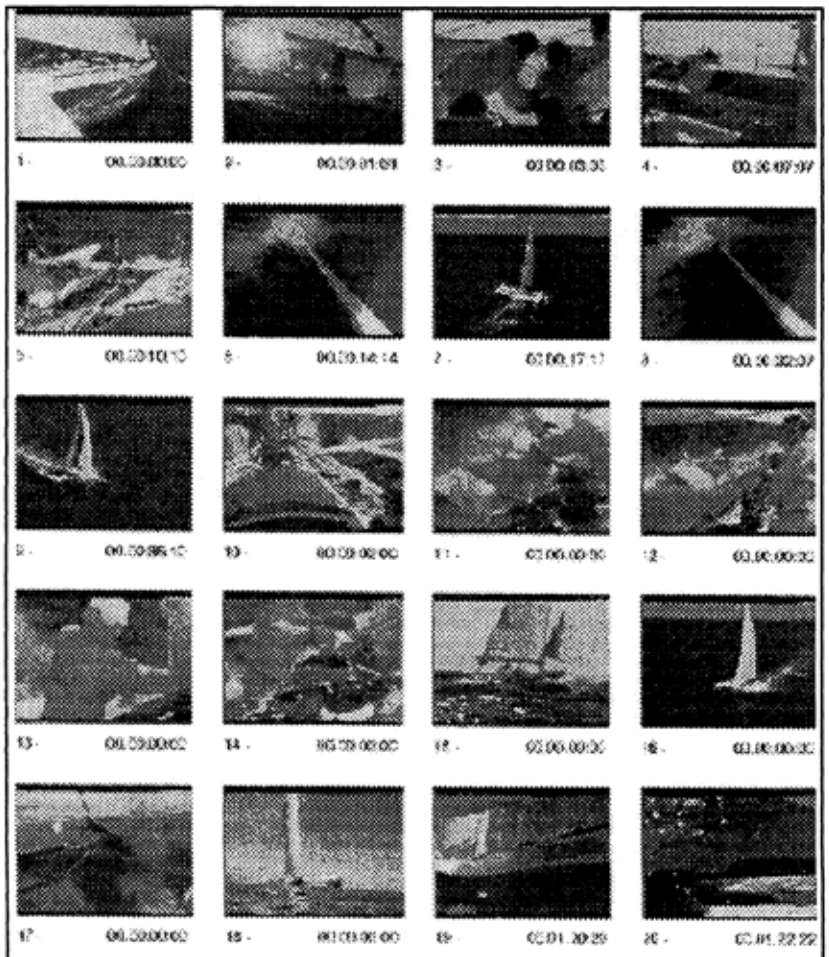


**Figure 2: Automatically Generated Storyboard for Video "Ariège" Laserdisc**

© D.G.T. 1982.

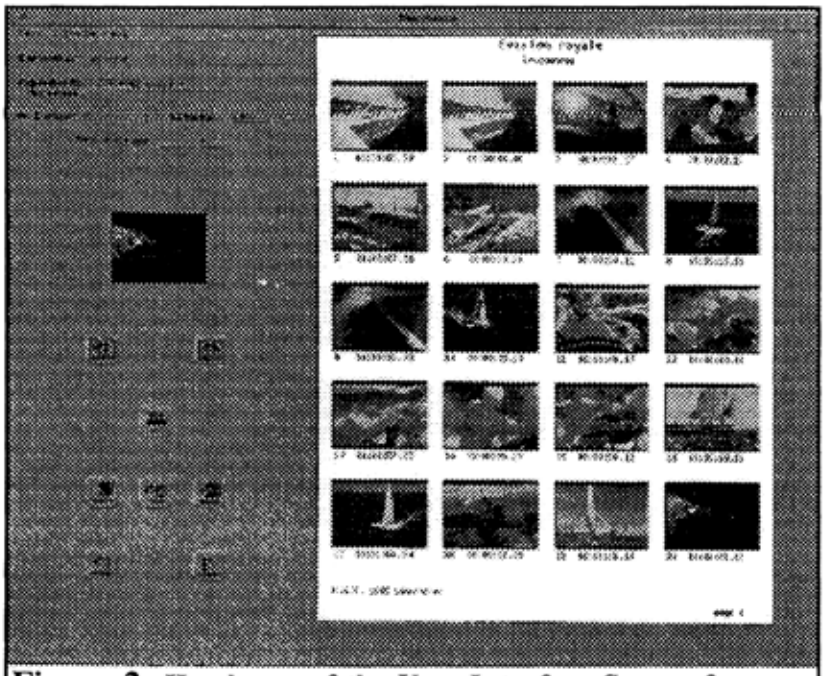


**Figure 2: Hardcopy of the User Interface Screen for Storyboard Correction**

- In rare cases a false detection of cut change may occur because of sudden lighting effects, water projected on the camera or the like. It is then very quick and easy to remove these false shot change detections by visual inspection.
- As mentioned above, in this version of our software, we do not use camera work analysis for the choice of a representative image for each shot: we systematically use the second image in the shot. One may want to modify this choice manually, which is possible at the correction phase, but unfortunately time consuming.

We have chosen not to represent transition effects in storyboard produced for visual cataloging, though transition effects are detected and recognized as cut, dissolves, wipes, and unrecognized. This is because we want the viewer to be able to browse very quickly through pages of the storyboard and thus prefer to limit as much as possible visual interferences. Shot are numbered and time-coded, but the time codes are intemal time codes in the digitized video and not actual time-codes in the source document[e].

## 3. User Interface for Analytic Perception of Video

The main concern of our research team is with user interface for interactive viewing and listening to audiovisual documents. It is our opinion that properly designed visual interfaces may have a very significant impact in allowing the same type of analytical, comparative, arguable perception of contents for video or music which has long been possible for text and which largely defines academic work. It is also our opinion that the cultural value and economical potential of such interfaces goes far beyond the limits of academic access to audiovisual archives. We hope to contribute to a type of access to audiovisual documents which will be useful and enjoyed also in production, schools and even the home.

The VIDEOLINE software is only an intermediate stage in a long term effort to build what we call discrete visual manipulation interfaces. As stated above, the user or the audiovisual archive curators still have to manually define a number of time segments, in particular for the soundtrack representation, before being able to take full advantage of the software functions. Nonetheless, VIDEOLINE offers a platform for potential users to experiment with.

VIDEOLINE offers a two-level view on the document contents (Figure 3). On the top right, the sequence window gives a global view on the full document (here a 16 minutes documentary). We are not satisfied with the present state of the sequence window.

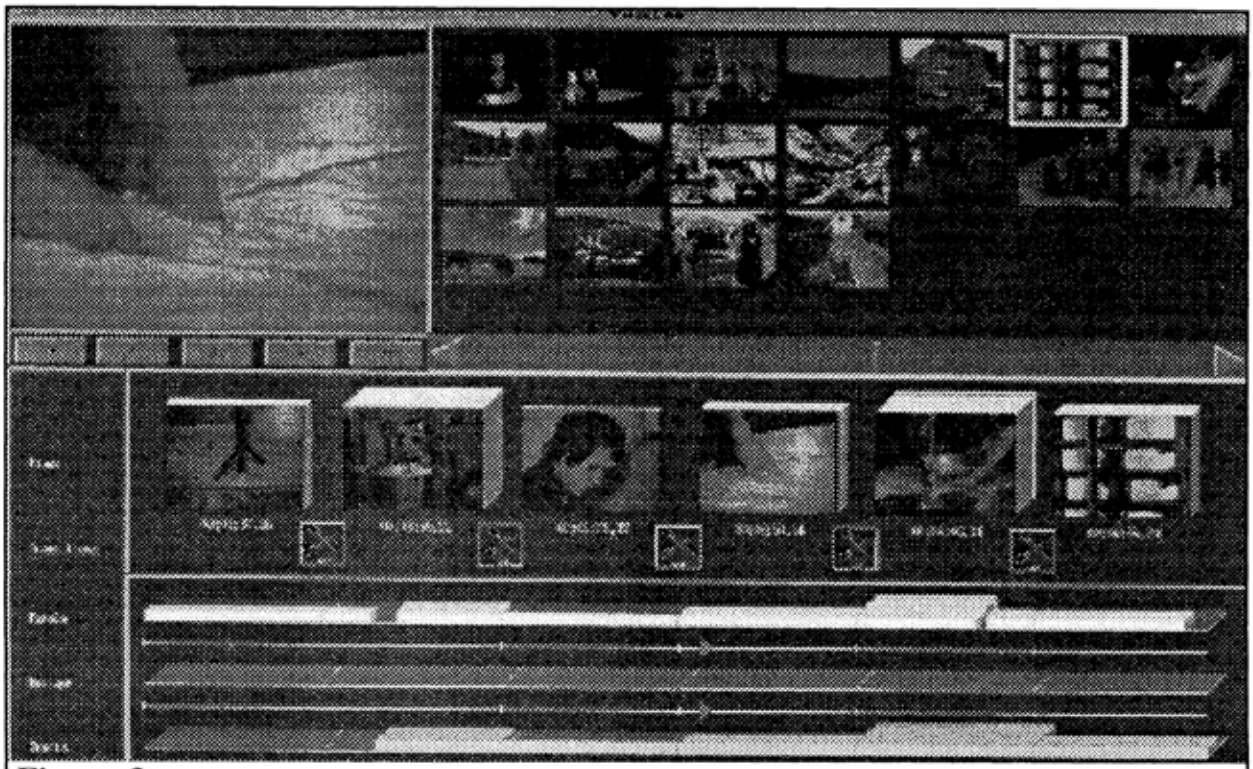


**Figure 3: Hardcopy of the VIDEOLINE User Interface Screen**
Video "Ariège" Laserdisc © D.G.T. 1982

We are planning to organize it in order to display the durations of sequences and to better represent the contents of each sequence by associating it with an icon built from two different images extracted from the sequence. This last point will be made possible by our method for automatically recognizing sequences. It is thus subject to confirmationof the reliability of this method.

The core of VIDEOLINE is the work view organized in horizontal strips. The first two lines are for the image part of the video and the three last lines are for the sound component. We are planning extra lines for user annotations, which will consist of:

- Short textual annotations,
- Graphical signs,
- Icons selected from a pre-defined icon palette, as in the system developed at MIT Media Lab by Kenneth Haase[6].

The first image line is the shot line, which displays six shot icons. "Depth" of the icon indicates the duration of the shot, and the time-code of the shot start is also indicated. The second image line is the transition effect line. The three soundtrack lines display time segments respectively of speech, music, and loud effects and actuality. The depth of the corresponding pseudo-parallepipedic icons indicate the duration of the segment relatively to the shots. Though this representation may seem complicated, its meaning becomes evident when playback occurs.

The most important facts about VIDEOLINE and any other discrete visual manipulation interface are that:

- Any displayed time segment may be selected (by a single action) and "played".
- During playback there is synchronization between the video and the representation display, through cursors and paging.

The user of VIDEOLINE can position himself in the document either through the sequence window, which gives direct access to each sequence, through use of the global scrollbar which gives access relative to the global duration, or through scrolling and paging of the work view. Time segments in the work view or the sequence window can be deleted, added or their types or limits modified. Of course such user modifications affect only the user's access copy of the descriptive data and do not modify the initial data provided by the archive, unless an administrator decides so.

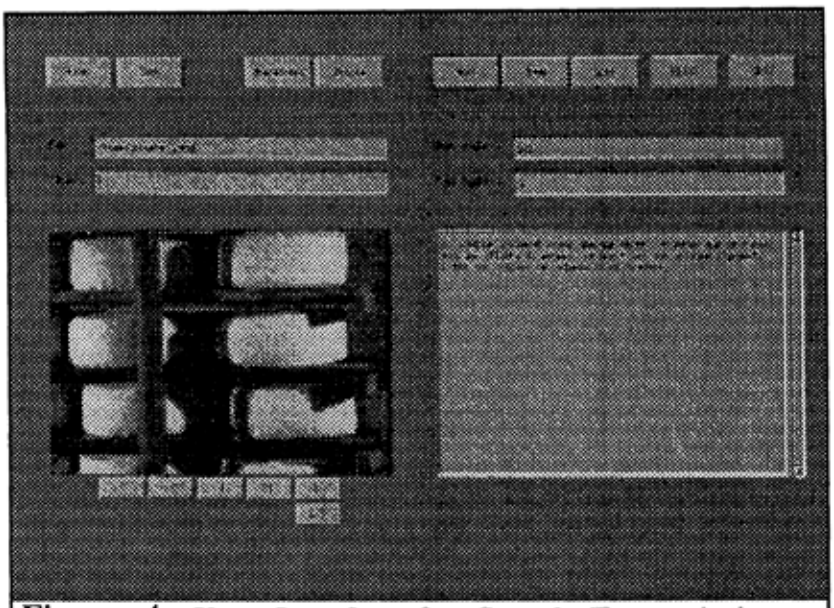


**Figure 4: User Interface for Speech Transcription or Shot-by-Shot Annotation**

## 4. Assisted Transcription and Shot-by-Shot Annotation

The VIDEOSCRIPT software makes very simple use of the segmentation in shots data, in order to offer an ergonomical interface for speech soundtrack transcription or shot-by-shot annotation, two of the basic time-consuming operations in audio-visual libraries and archives. VIDEOSCRIPT is composed of two parts, the data acquisition interface and the script printing module. The data acquisition interface (Figure 4) is composed of an image window and a text window (and of a number of buttons for playback control and time segments selection and modification). The user can:

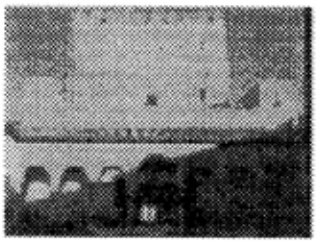
- Play the currently displayed time segment in loop while typing transcription or annotations which will be associated with time segment.
- Play the video from the current point, with synchronization of the text window.
- Modify the definition of time segments by merging segments from the initial segmentation in shots.
- Request printing of transcription or annotations.

An example of a printed transcription built with VIDEOLINE is given in figure 5. Automatic layout is done to keep the proper relationships between text and images. From our observations with a few users, VIDEOSCRIPT is sometimes used for producing a text-oriented transcription, for which image are mere illustrations, or, on the contrary for producing strict shot-by-shot transcription keeping track of the relationship between shots and dialogue.

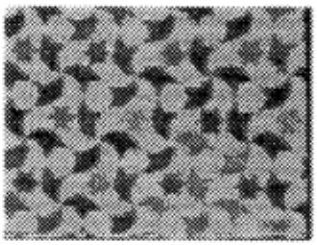
## Simmetria e tasselatione



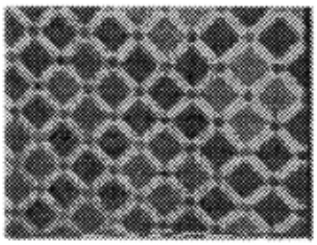
SPEAKER : We have seen that there are 17 groups of plane symmetry. This would seem to impose a limit on the imagination, but just taking a look at the famous mosaics of the Alhambra will convince us that this is not so. The Alhambra was built during several different periods by the Moors on a hill which dominates the town of Granada in Spain.



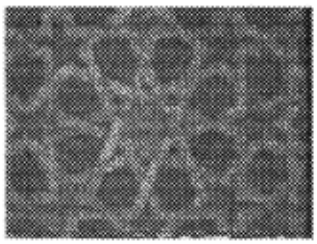
The word "Alhambra" is derived from the arabic word "Qal'aj al Hamra" which means "red fortress", the name that was given to the fortress because of the colour of its towers. But the mosaics are not the only attractions of the Alhambra. The buildings and courtyards of the palace are a marvel to see.



Muslims were not allowed to reproduce living things as decoration; thus islamic artists were forced to confine themselves to geometric decorations, and therefore used the group of flat symetry, using them empirically, without knowing that there where only 17 and no more.



This number was only discovered at the beginning of this century, which did not at all inhibit the fantastic results we see in mosaics of the Alhambra.



While looking at the mosaics in the Alhambra, it's worth while remember the word of the mathematician Herman Weyl, author of a famous essay on symetry: "It is a vast subject, important to art and to nature. Mathematics is its root and it would be difficult to find a better field in which to demonstrate mathematical thought as a work of art".

**Figure 5: One page of a Speech Transcription for the English Video Edition of "Simmetria e Tasselatione", a film by Michele Emmer.**

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8. Hong Jiang Zhang, Yihong Gong and Stephen Smolian. "Automatic Parsing of News Video." In *Proc. IEEE Conference on Multimedia Computing and Systems*, Boston, May 1994.


## *Notes*

*a. This work has been funded by the French Ministère de la Culture et de la Francophonie and has been conducted in collaboration with the Audiovisual Division of the Bibliothèque Nationale de France. It has also benefited from the user input in the "Consultation Audiovisuelle" group of the Direction of Legal Deposit of the Institut National de l'Audiovisuel, which has experimented with software developed by Olivier Koechlin and Vincent Prost [7].*

b. *The Applications Culturelles et Artistiques de l'Informatique (ACAI) research team in the Institut de Recherche en Informatique de Toulouse (IRIT) has been created in 1986 jointly by the Ministère de la Culture and Mff. It is specialized in research on user interfaces for access to image and sound documents, and related processing and analysis of document contents.*

*c. "In real-time" means during digitizing or transfer, or by processing an already digitized and compressed video with a duration of processing lower or equal to the duration of the video.*

*d. Using the software itself, since all segments can be created, deleted and modified in our user interface software.*

*e. Due to limitations in the video control software associated to the X-VideoTM board.*

# Tools for Sound Data Acquisition, Transfer, Segmentation and Storage

## Werner A. Deutsch

**Austrian Academy of Sciences, Vienna, Austria**

**It is regretted that it is not possible to publish the text of this paper at this time.**
**The Summary is included in the Proceedings for completeness.**

## Summary of Paper

Many sound archives and libraries are considering transferring their sound documents into digital formats in large quantities. The range of software and hardware tools which have been developed ranges from simple sound card solutions to complete audio workstation clusters with large audio archive servers. A variety of data formats and compression methods can be considered. Computer assisted level control, signal analysis and equipment control are valuable features of integrated systems. Segmentation, labelling and indexing provide the implementation of different possible data base interfaces.

This paper reports an experience gathered from the implementation of a speech data base holding 300.000 speech and music sound segments with transliteration, phonetic and musical transcription. Further development will include still images and moving images.

*Werner A. Deutsch studied psychology at the University of Vienna and joined the Phonogrammarchiv of the Austrian Academy of Sciences in 1968. In 1972, he set-up and became the Head of the independent Acoustical Research Laboratory. In addition to numerous publications, Dr Deutsch and his colleagues have done pioneering work in the field of digital signal enhancement for historical recordings. They have designed and developed "S-Tools" - a digital workstation optimised for sound analysis, processing and storage for use in the fields of musicology and linguistics.*

*Dr Deutsch is currently the Chair of the Austrian Section of the Audio Engineering Society and Vice-Chair of the Working Party on Acoustics of the Österreichische Physikalische Gesellschaft.*

## Session 4:

# Digital and Computer Technology in A-V Archiving

## Chairman: Philippe Poncin

*Philippe Poncin was born in Paris in 1948 and completed his training as a Civil Engineer for Telecommunications in 1973. He joined the Institut Nationale de l'Audiovisuel in 1977 as the Head of the Technical Department for the Archives Directorate. In his present post of Deputy Director of Audiovisual Archives, he is responsible for the planning of buildings for the storage of material and for the technical services involved with the restoration and exploitation of the sound, video and film documents in the archive.*

# Digital Instead of Analogue: Experiences with the Modernisation of the "Deutches Spracharchiv"

## Peter Wagener

Deutsches Spracharchiv, Mannheim, Germany

**Summary of Paper**

The Deutsches Spracharchiv (Archive of German Language) holds the world's largest collection of spontaneous Spoken German language recordings made for linguistic research. The archive is part of the Institute für Deutsche Sprach (IDS), the central research unit in the field of Germanic linguistics. The greater part of the 12,000 analogue recordings in the archive are between 30 and 40 years old and their long-term viability is becoming questionable. 1994 marked the start of a digital transfer project to CD-Rs which will be made accessible by a network-integrated CD-jukebox holding, initially, 3000 CDs.

*Peter Wagener studied Germanic and general linguistics, gaining his Doctorate with a thesis on German dialectology. He was a Research Fellow at the University of Göttingen from 1980 to 1990 when he was appointed Director of the Deutsches Spracharchiv.*

# Digital Instead of Analogue: Experiences With the Modernization of the "Deutsches Spracharchiv"

Peter Wagener[1]

## The Analogue History of the Deutsches Spracharchiv (DSAv)

It would be carrying coals to Newcastle if one argued in this circle that the future of sound archives is not be destined to be on analogue sound carriers. Sooner or later, they will be entirely in the domain of digital media. That does not mean that analogue recordings are no longer of any importance - the case is quite the reverse: they will be protected and preserved in archives as an increasingly scarce data format until the end of their life span.[2] Exactly this problem - the limited durability of tapes - faced a comparatively small sound archive. How the modernization of the collection was undertaken, I will now report.

The Deutsche Spracharchiv, founded in the thirties, has made recordings of German dialects and colloquial speech since 1955. Thses recordings were meant to serve as a basis for research of present-day spoken German. In the first group of recordings that the interviewers of the Deutsche Spracharchiv made, nearly 6.000 dialect speakers from almost 1.000 villages in the old FRG were recorded. This corpus of recordings is called the "Zwirner-Corpus" after the founder of the archive, Eberhard Zwirner. Besides this corpus, the DSAV has recorded or received from other research workers 26 more corpora and stored them properly.[3] By these means, the DSAV became the biggest scholarly collection of sound documents of spoken German. At the moment, the archive administers about 12.000 sound recordings with a total duration of 3500 hours. Today, the archive is no longer an independent institute, but it is integrated in the Institut für deutsche Sprache in Mannheim, the research center for German linguistics.

## Why Digital?

For a scholarly archive with a central function for the linguistics in Germany, the DSAv is a huge institution. In comparison with other sound archives, however, in, for example, the field of broadcasting, a stock of 12.000 sound recordings is rather small. But you have to keep in mind that the resources for research in the humanities are very limited. Thus, it is a big problem for us to modernize our archive and to transfer the recordings to a new sound carrier. A large part of our collection is 30 to 40 years old,

which means that the analogue sound carriers of the original recordings have nearly reached the end of their life span.

An acute problem arose in 1992 when we - as part of the process of the German reunification - had to take over the sound archive of the Akademie der Wissenschaften of the GDR. To be more specific: the Central Institute for Linguistics of the Academy was integrated in the Institute for German Language (IDS) in Mannheim. This corpus, originated in the sixties, was not stored very well all the time. Some of the recordings on C-tapes (Cellulose-Acetate bases) show such strong traces of decay that it will be hard to save them, especially as some of the tapes are on rusty - in a few cases on completely rusted - metal cores.

We had to act We could not wait until sufficient experience with digitization existed. We realized very fast that our unique, high value archive material must not be digitized using technical methods that employ data reduction. The digitization had to guarantee that the full analogue sound signal was transmitted. Thus, we decided to digitize 1:1, without any processing of the sound. Beyond the saving of the sound recordings the digitization allows modernization of the archive in three respects:

- Conversion into an "eternal' record that can be edited by modem means.
- Modernization of archive management and services by improvement of access to the digitized data of sound recordings.
- New opportunities for computer-based linguistic researches on a huge corpus of spoken German, particularly union with the modern instrumental phonetics and integration in a system with similar oriented research institutes.

As you know, sound archivists have begun to talk of "everlasting database" instead of "everlasting data carriers".[4] For this purpose, a mass storage system is required which has a fast copy function with high data transmission at its command. Based on this, it is possible to create a self controlling and renewing archive that keeps abreast with the breath-taking development in digital audio techniques and that does not need to renounce to recent modernizations.

It is important that the expenditure that is needed for the transition from the analogue to the digital data structure is required only once. We expected from the equipment that we had to configure not only a single function of digitization. Beyond that, it should also be the technical-instrumental basis for the further development of the DSAv. This is only possible in a modular system of archive-, sound adaptation-, editing-, and output units. For all these modules, there are practicable solutions that have been confirmed according to the purposes of the DSAv.

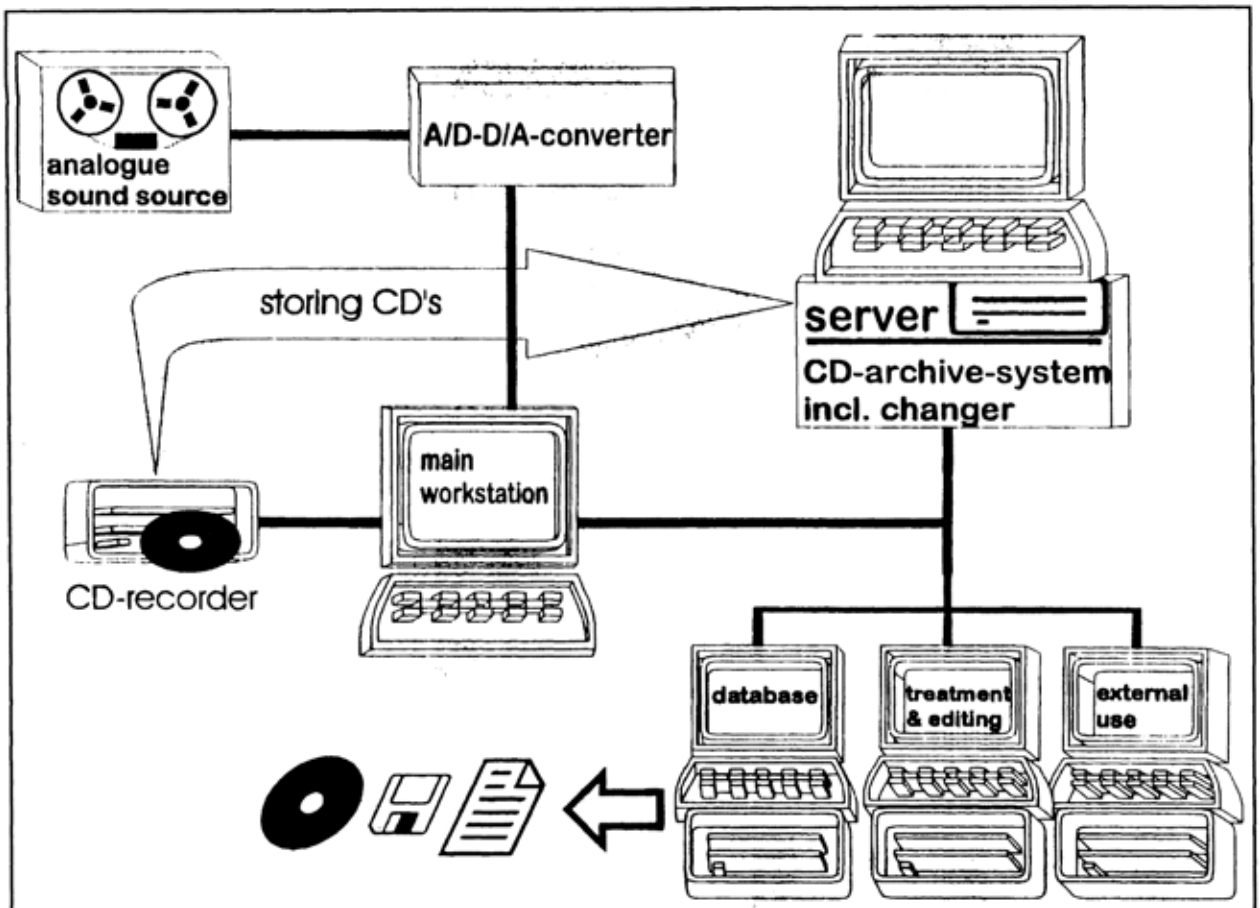



**Figure 1: Organisation of the Equipment for Digitisation**

## The Configuration

The core of the system is the workstation based on an Apple Macintosh Quadra 650/4/16O/CD. With this workstation which has two hard disks of 516 and 1032 MB, we digitize and process the analogue reels. The analogue players we use are a Tascam 122 MKII and a Tascam MKIII tapedeck as well as a Studer A816 Master Recorder, which can operate at the common speeds of 9.5, 19, 38 and 76 cm/s (3.75, 7.5, 15 and 30 ips).

These analogue machines are connected with the Pro Master 20 BIT Audio Interface, designed by the Digidesign company. The interface serves as an A-D and D-A converter, i.e. the analogue input signals are transferred into the digital binary code and vice versa, and places the digital signal into the intermediate storage in the Apple Mac. In order to provide the best possible level adjustment we have interposed the mixing console, a Studer 0980 MK2, between the analogue source and the PC.

The digital data of the sound recording can be edited with software. The DSAv also uses programs such as Sounddesigner II from Digidesign for eliminating noises, such as crackle and excessive hiss, and distortion. The transfer of the original

analogue tape is effected without any further processing as we consider it to be desirable not to abolish the authenticity of our recordings.

Having transferred all the data from the hard disk of the Apple Mac to the CD-recorder CDW 900E (Sony), the Audio-CD is cut in real time (the maximum recording capacity of a blank disc is 74 min.) with the course of the recording controlled by the program Toast CD-DA from Astarte). An alternative program, Toast CD-ROM Pro, is available to manufacture CD- ROM'S.

The recorded Audio-CD will be stored in a CD-auto-changer system controlled by a server (a PC with complete network capability). All the CD's contained in the jukebox can be retrieved from any of the four connected PC-workstations, i.e. the CD requested is carried to one of six CD-ROM drives and is listened to directly at one of the workstations through loud-speakers. At the same time, important recording data about the speaker, contents, language classification, etc. is available through the database management system 4D (4th Dimension from ACI), which has been specially designed for the needs of the DSAv. The database facilitates specific queries about the digitized recordings by keying in precise searching criteria. Obviously, there is no need to argue on the positive effects this has on compiling sound documents for scientific purpose (makes it easier and speeds up working on this huge material). In a further step the German standard transcripts are to be added to the corresponding record. The simultaneous play of the speech and the written text is not yet possible.

## The ALL-IN-ONE-ARCHIVE-SYSTEM

The digital archive system of this kind in the DSAv is a prototype construction designed by Computer Media Service (CMS) company of Ludwigsburg, who have been concentrating on digital word and image processing with Apple Macintosh systems. The archive system is installed into a 19" cabinet with a storage capacity of approximately 3000 CDs and it is equipped with 12 Double Speed CD-ROM drives. The server and the necessary software is integrated (i.e. the terminal emulation TELNET, the file system NPS and the network system ThinEthernet). The all-in-one archive system operates as follows:

- Writes the data of the AUDIO-CD onto the server hard disk.
- Reads the TOC of an AUDIO-CD (which the database makes use of).
- Enables requests for single CDs or recordings (with CD and track number as parameters).
- Audio track hard disk buffer (appr. 650 MB).

At the moment we are working with a smaller test-version of the server with a capacity of almost 300 CDs and five CD-ROM drives, but it is expected that the complete all-in-one archive system will be in full operation by the middle of the year.

## The Technical Sequence of Operation

In the following I will outline the sequence of operation for the digitization of analogue recordings and their safety device on Audio-CD's (Red Book):

**1. Preparation of the Analogue Tapes**

- Bringing the tape from the analogue archive.
- Determination of the duration of the recording.
- Writing the list of the recording on the tape.
- Placing the register numbers.

**2. CD Premastering**

- Re-wind the tape four times to reduce the print-through.
- Programming the skimming, i.e. setting the strength of the current of erasing
- Digitization using the Audio-workstation and interim filing on hard disks.
- Compiling of the running-order and saving as a playlist.

**3. De-noising (optional)**

- Determination of the noise frequency bands and any other correctabledistortions.
- Digital treatment of the signal.

**4. CD Production**

- Drawing up the CD lists
- Checking the transfer rate
- Writing of the CD

**5. Archiving and Documentation**

- Registering the recordings in the catalogue
- Feeding the database putting the CD into the jukebox

The experience we have gained in the first six months of working with this system confirm the correctness of this sequence of operation. Compared with the duration of the recording, the time needed to produce one CD is between five and six times, i.e. the production of a CD with a total running time of 74 minutes

requires about six hours of working time. We also have to consider that there are rejects as not every blank CD disc is satisfactory and not every recording procedure runs well. We can now see that it is advisable to install measuring facilities in order to test the CD's after recording.

## Notes

**1.** I would like to thank Christoph Staffa, Patrick Kaul, and Wolfgang Rathke for their great help with the writing and the English translation of this paper.

**2.** Werner Singhoff, *Langzeitstabilitdt der Bild- und Tonaufzeichnung auf Magnetband.* Mannheim 1995. (Working Paper of the BASF Magnetics company).

**3.** The main stock is listed in *Gesamtkatalog der Tonaufnahmen des Deutschen Spracharchivs.* Edited by Waiter Haas and Peter Wagener, 2 vols. Tübingen 1992 (PHONAL. Vol. 38 - 39).

**4.** Dietrich Schüller, Behandlung, *Lagerung und Konservierung von Audio- und Videoträgern.* In: Das Audiovisuelle Archiv, 31/32 (1992): p. 21-62 (published Sept. 1993).

# Digital Media-Management System


## Hans-Dieter Queren


This paper is in two parts. The first part will examine the problems currently facing sound collections and the general specification for any replacement system. The second part of the paper examines the particular needs of Sonopress.

The work group "Archivsysteme" (English: "Archive Systems") was founded in order to find solutions for future archive forms in the music industry. This group consists of representatives from the sectors of music publishers, the producers of audio and data storage media, broadcasting institutions and system suppliers.

The goal of this work group is to draw up a specification for an integrated automated media archive. The system includes components for the recording of audio, video, layouts and data material and should have elements at its disposal enabling the archive to be coupled to the production environment. On the basis of this specification, conventional archives can be replaced by a "Digital Media Management System" in a multistage concept.


*Hans-Dieter Queren was born in Hanover in 1941 and studied Radiotechnology at Nuernberg. After Graduating he worked in a number of theatres until joining Polygram in Hamburg as a sound engineer. In 1984 he was appointed Head of Audio and Data Premastering with SONOPRESS in Guetersloh.*


## The Current Situation

In the music industry at the moment, the U-Matic system from Sony is effectively the standard for archiving and for data transport. U-Matic is a video system which was adapted for recording digital music data and has been in use since the end of the seventies.

Problems and weaknesses inherent in the system are now increasingly coming to light. These take the form of time-and cost-intensive work sequences:

- Maintenance-intensive tape/disk drive systems.
- Expensive stock keeping due to low storage capacity.
- Low copy speed (real time only).
- Discontinued support from the system suppliers.
- Recopying process necessary for mastering.

To invest the finance needed in an archive based on U-Matic would cause progressive price increases due to increasing data stock. Therefore, the question of a suitable replacement system which best fulfils the sum of all future requirements arises.

## System Requirements

The archive system forms the basis of all media-related activities. All activities which are currently necessary in connection with this, or which are foreseeable in the future, have to be reflected in the conception.

**Storage Systems:**

In order to achieve long-term archiving of the data without costly recopying processes, the strategy followed until now of searching for the "eternal storage medium" has to be put aside, and the storage as an "eternal data set" striven for instead.

Future storage media will have a shorter product cycle than systems used in the past.

For this reason, simple, fast - and, therefore, favourable from a costs point of view - transfer procedures onto new media are necessary. For reasons of investment protection, any one storage system must be able to be combined with another.

**Integration into the Production or Transmission Environment:**

The reaction times to customer requests are becoming increasingly shorter and this brings with it demands for the integration of an archive in an automated production sequence. In addition, all necessary accompanying files (label data, track lists, ISRC, etc.) are to be incorporated. The necessary effort for manual handling is to be kept to a minimum, and multiple entries of the same data in different electronic data processing systems are to be avoided.

**Reduction of Archiving Costs:**

The effort involved in maintaining the archive and the space required by it must be considerably reduced. Copying processes and quality analyses of the archived data stock must be capable of being performed without great demands on the personnel.

**Shortened Processing Times:**

Input/output processes and the transfer of contents to the work places must be possible in less time than currently usual. In future, the development of faster mastering speeds on the LBRs must be capable of being performed independently of special input media in order to be able to use the technical potential available to the full.

## Solutions

The stipulated requirements can be solved by a modular system based on electronic data processing.

**Mass Storage:**

Automated tape libraries provide storage capacities for more than 200,000 hoys of music in CD quality. Such systems have a spatial requirement of less than 15 m and permit an access to an individual title in less than two minutes.

**Data Bank:**

Data bank systems meeting the SQL standard permit an open structure. Planning and performance accounting systems within a company can communicate with the archive via standard data bank interrogation methods and incorporate this in an automated production sequence.

**Network:**

Fibre optic networks (ATM or FDDI) achieve data transfer rates which allow the transfer of one hour of music in CD quality in 1 - 2 minutes.

## Advantages

A series of advantages result from the state of affairs listed above. These are itemized as follows for the areas concerned:

**Archive:**

Different storage systems can be combined with one another. The archive is thus not fixated on the media of a particular manufacturer and extensions can be carried out flexibly according to the performance characteristics required.

The securing of data and quality control are carried out automatically. Manual activities are limited to maintenance and the removal of defect data storage media.

Data can be copied on to new data storage media at considerably greater speed (up to factor 50), in case a system change should become necessary.

**Premastering:**

Automated access to the entire data stock.

Titles, or parts of titles, can be loaded directly from the archive to the work station. A copying procedure on to a special data storage medium is no longer necessary; the manual handling of data storage media becomes unnecessary.

**CD Mastering:**

Errors in the data structures delivered or inconsistent data no longer cause breaks in the mastering procedure due to built-in plausibility controls.

All CD derivatives can be mastered at the highest possible speed.

All data stored in the archive are directly available. Data storage media need not be recorded on, controlled, and transported to be mastered.

All accompanying data such as, for example, track lists, ISR codes or UPC/EAN codes are available in the archive. A renewed manual entry is no longer necessary.

All data for the production are held in the archive during the guarantee period. If post rerecording is necessary, the data can be reaccessed without loss of time.

**Label Printing:**

In future, automatic systems for screen printing preparation can be supplied with layout data directly from the archive. In particular, the provision of continually recurring basic patterns simplifies the preparation of this kind of layout. Suppliers can be connected by telecommunication means, so that transport of data storage media is unnecessary.

**Audio-Visual:**

Connecting the archive system with an automatic productions sequence, which is controlled by SIPUS/Sono2000, guarantees the availability of contents and the necessary accompanying data at the right time and at the right place. Manual priorization can be reduced to a minimum (e.g. in case of unexpected events).

## New Perspectives

The availability of music, including all accompanying data, in an electronically accessible system permits entirely new characteristics and distribution forms.

**Acoustic Searches:**

Music and accompanying data are accessible via data bank searches. Not only title information such as, for example, the interpreter, can be called up, the contents can also be played on each authorized work place. These search functions are also available externally via ISDN.

**External Data Exchange:**

In the near future, the transfer of music via wide-band ISDN or Corporate Networks will be made possible. Time costly transport to and from production installations will thus become unnecessary.

**Warehouse Systems:**

Advertising and customer information systems use different multimedia data for product presentation. All the necessary contents for this are stored in the archive and can be made available in optional compression steps.

**External Access:**

The access to parts of the stocks via telecommunication routes can be permitted for authorized user's. These can be broadcasting stations, for example, which can call up musical compositions - authorized for transmission by the license holder - for the arrangement of their programs, directly from the archive.

**New Forms of Distribution:**

The archive system forms the basis from which new electronic distribution forms can be directly supplied. The connection to pay-radio, music-on-demand and video-on- demand systems is conceivable.

## System Components

The integrated, automated archive system is divided into groups of functions, which correspond to the tasks in a production environment or in a transmission environment. The actual core for the storage and administration of all data is extended by certain components that make the processing and transmission of the data possible.

**Input/Output Stations:**

The input and output of the contents (audio, video and data) of different storage media via stations with individual tapeldisk drives or swapper systems.

**Premastering:**

Supplying the processing stations with contents or data for the suitable processing of audio and data storage media, and for the preparation of compilations.

**Mastering:**

The conversion of the contents and accompanying data into the bit sequences used by the target data storage medium, as well as the control of the mastering equipment.

**Label Printing:**

The supply of the printing equipment with layout data for the preparation of the print labels or the screen for the printing process.

**Internal Communication:**

Connection to the internal electronic data processing periphery for the communication with production planning, work sequencing and performance accounting systems.

**External Communication:**

The transfer of contents and accompanying data to authorized users by means of telecommunication.

# The Sonopress Example

## Why a New Archiving Concept is Needed

The SONOPRESS tape archive has expanded from its initial 140 $m^2$ to a current size of 300 $m^2$ in the last ten years. An average increase of 40 tapes daily means an annual increase of 10,000 tapes or around 15 $m^2$. Staff requirements have changed in the same period from one person to four, assisted by occasional seasonal staff. The total costs for the 93/94 business year amounted to DM 610,000. Space, cost and the age of the stored tapes were the major reasons for considering a new archiving concept.

The limited life cycle of current tape media makes urgent consideration of methods of conserving tape archives that are now fifty years old and more essential.

Some stored analogue tapes have already become useless due to separation of the magnetic coating from the carrier material.

Digital tapes are now up to twenty years old and the limited life cycle of current storage systems means that a new "standard" must be adopted quickly.

U-matic systems are nearing the end of their life cycle, making consideration of new archiving concepts both logical and timely. The periodically recurring cycle of format conversion experienced in the past should be avoided in future. This makes a data format of lasting validity the goal to be attained, one that makes the storage of large quantities of digital data possible. Rapid, flexible data transfer is one of the most important prerequisites here. High data security is guaranteed by the drive quality of modern computers and the data format specially developed for archiving with its high error correction capacity (CRC) and permanent backup.

## Tape Archive Requirements

### Storage for Large Quantities of Data

The average storage capacity per CD is about 700 MB (up to 1 GB for the complete data set including booklet and inlay card). Approximately 64 TB (terabytes) are available in our archive.

Just as a yardstick, this quantity of data is enough to play music continuously for 10 years, making it quite obvious that trying to convert the entire archive to a new system would be absolutely pointless. Note, however, that institutions devoted to the preservation of culturally valuable acoustic compositions are confronted with this difficulty.

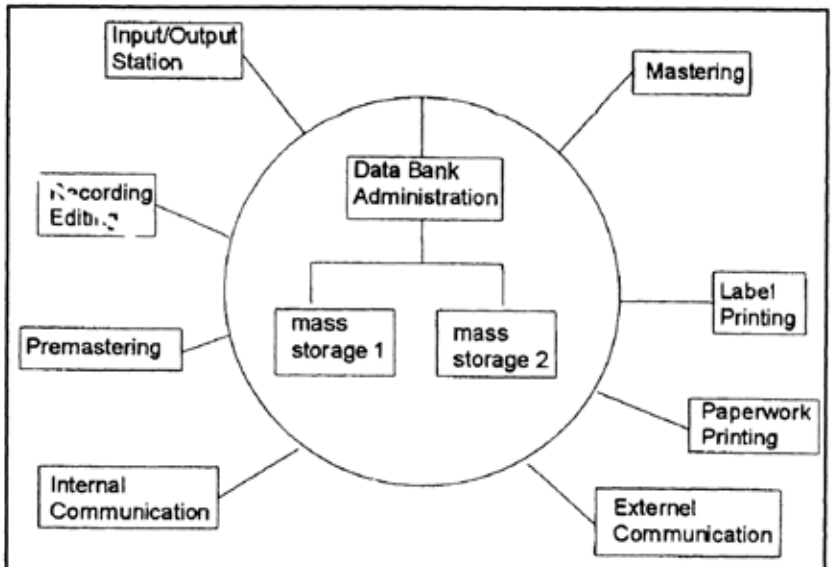



**Figure 1: Structure of a Digital Media Management System**

### Storage with Unlimited Expansion Capacity:

In creating a digital system for CDs, the fact that this product consists not only of music but also of text and graphics must be allowed for. Video clips and CD-ROM control data must be storable together with the relevant music in the multimedia age. This can include multiple-track data. Storage restricted to 16-bit data is inadequate for today's production processes: data up to 24-bit standard must be storable.

### Low Space Requirement:

The Storagetek company's computer, with a storage capacity of 145 TB, needs 12 $M^2$ Of space (example: 64 TB are equivalent to 10 years of continuous playing time).

### Fast Copying and Transfer:

10,000 audio hours (16.bit, 44.1 kHz) can be copied in 24 hours at 72 Mbit/s.

### Modular Design:

As different users have different storage capacity and content requirements, mass storage design must be modular. SONOPRESS would initially like to use the production line - Premastering - Archiving system - Mastering. This begins with the digital storage in the archive being fed primarily during normal daily operations. Experience shows that old tapes from the current archive are often needed, which are accepted into the digital system via this route. Targeted BMG marketing activities can make it necessary to transfer tapes on a one-off basis. The old archive should be superfluous within the next 10 years. This seems to me the only viable method, as all others are too costly and take too long.

### Defined Interfaces:

It should be possible to allow a variety of different hardware companies to connect components to the storage system. This means the interfaces must be defined to make connection trouble-free.

### Connection to Current Data Systems:

Current data systems must be able to correspond with the archive storage to make control of future production processes possible.

## Main Aims of a Digital Archiving System

### Creation of a Digital Media Archive:

A digital archiving system comprises not only the storage of media data but a limited range of data processing methods as well. Concentrating exclusively on the storage is thus too narrow a view. Differing media, including AUDIO, VIDEO and ACCOMPANYING DATA SETS are also administered. It is thus more accurate to call it a "Digital Media Management System".

### Integration of All Product Data:

Audio, label, booklet, text, video and control data or accompanying data sets can all be stored if required. The SONOPRESS strategy, via an internal working group, is to have TOPAC administer all print data. What label data is stored depends on the needs and cooperation of BMG. The PQ accompanying data is all that is needed for production purposes.

### Automated Direct Access:

Storage of all accompanying data sets makes it possible to connect SIPUS to the system. Common data such as the job number, production type and customer number enable the interim memory in Mastering to hold the currently required programme file available according to the priority list.

### High-Speed Transfer:

A number of networks are available. Transfer rates of 48 seconds for 1 hours playing time are realistic.

### Reduction of Archiving Costs:

Changing, maintaining and expanding the data stock is cheap compared to the current system. Running costs are reduced thanks to extremely low space requirements and a maximum staff requirement of just two people. Any future system change, a possibility that technically cannot be excluded, would take a maximum of just 3 days.

### Global Standardisation of Exchange Formats:

Cooperation between the German phonographic industry, the ARD and BMG gives us the chance to exert a major influence. The problems of archiving digital and analogue tape carriers are internationally known and a topic of discussion. Specialised lectures on the subject will be given at the Paris EAS in February 1995 and at the sound engineers' conference in November 1994.

### Data Carrier Compatibility According to Application and Degree of Sophistication:

Differing data carriers can be used in developing the archiving system as the interfaces are known. Preparation for future applications is a major part of the design and specification. Networking archiving systems would be a first stage in development. Involvement of the label as owner of all rights in the programme data and as an aid to updating the system is an essential prerequisite. The latest development for 1994 is ISDN networking. The Musicam data algorithm giving a compression rate of 1:4 is envisaged for transferring music data.

## Mass Storage Requirements

### Automated Access to All Data:

A menu system permits access to all the data stored.

### Data Monitoring Systems:

The system uses three systems to permanently monitor all data files:

Automated Data Consistency Analysis.
Detection of Read and Write Errors.
Automated Data Backup in Case of Errors.

If adjustable correction parameters are exceeded, an automatic backup is made.

### Automated Administration of BackupCopies:

A complete backup system is not envisaged for the first development stage. The backup is created in the memory and stored there. A fully independent backup system is envisaged for the second expansion stage, with spatial separation from the main storage.

| | Sony DIR-1000 | Storagetek "Redwood" | Grau NTP | IBM NTP |
|---|---|---|---|---|
| **Data Rates** | 256 MBit/s | 96 MBit/s | 72MBit/s | 72 MBit/s |
| **Cartridge Size** | 96 GByte | 25 GByte | 10 GByte | 1- GByte |
| **Total Store Size** | 30 TByte | 145 TByte expandable | 57 TByte expandable to over 200 TByte | Up to 200 TByte |
| **Controller** | UNIX | ESCON | | ESCON |
| **Availability of System** | Now | UNIX controller available early 1995 | Early 1995 | |
| **Cost** | For 30 TBytes - 1500000 DM | For 145 TByte - 1500000 DM | Unknown | Unknown |

**Table 1: Storage Systems Available in 1994**

## Other Requirements:

- Standardised Interfaces to Make Connection to Differing Mass Storages Possible.
- Reading and Writing Media Content in Less than a Minute (700 MB)
- Data Transfer with Definable Band Width
- Low Space Requirement (12 m2)
- Scaleable Drive Configuration
- External Data Carrier Storage in Passive Archives

## Advantages of Optical Mastering

### High Speed Mastering of All CD Products:

Transfer of data is currently possible in a sixth of the time (one hour's music in 10 minutes)

### No Mastering Process Interruptions Due to Errors:

Copying files from the archive to mastering is automatically monitored and logged. Current dependence on tape drive quality (U-matic) becomes irrelevant.

### Delay-Free Loading of LBRs During Changing of Glass Master:

While the glass master is being changed in the LBR, the data for the next programme is transferred. The configuration is shown in Figure 2.

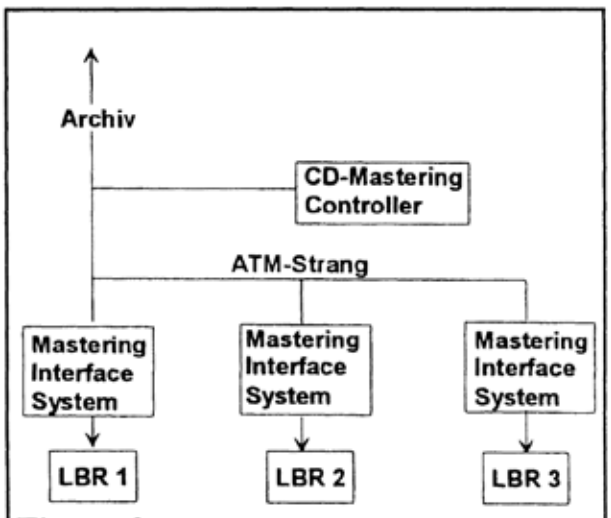



**Figure 2: Diagram of Optical Mastering**

**Quality Control by Fault Analysis of Transfer Routes:**

**Mastering of all CD Products on all LBRs:**

Creation of PQ data from the DDP file, R-W data per standards CD + G, CD + MIDI and ITTS

**Direct Control of LBRs Without Data Carrier Transport:**

| Network | Transfer Rate | Transfer Time | Real Time | Available |
|---|---|---|---|---|
| Ethernet | 10 MB/s | 485 s | No | Yes |
| Token Ring | 16 MB/s | 303 s | No | Yes |
| Fast Ethernet | 100 MB/s | 48 s | No | 1995 |
| FDDI - 1 | 100 MB/s | 48 s | No | Yes |
| FDDI - 2 | 100 MB/s | 48 s | Yes | 1995 |
| ATM - 1 | 155 MB/s | 31 s | Yes | 1995 |
| ATM - 2 | 622 MB/s | 8 s | Yes | 1996? |

**Table 2: Networks**

# Conclusion:

## Advantages of Listed Storage Medias

**High-speed Transfer:**

Example - 10,000 hours of audio in 24 hours.

**Low Space Requirement:**

Example - a computer with a storage of 145 TB (64 TB are equivalent to 10 years continuous music.

**Quick Access Time:**

Typically, less that two minutes to gain access to any sounds.

**Low Staffing Requirements:**

To service the system, only two people are normally required on duty.

**New Forms of Commercial and Non-Commercial Exploitation of Material:**

# A Strategy for the Long-Term Preservation of Data from Space Missions


## Claude Huc

French Space Agency, Toulouse, France


## Summary of Paper


The long-term interest in the enormous amount of digital data produced by scientific missions into space has been well demonstrated: this interest will be illustrated by some examples.

Despite the enormous cost of these missions and the interest in the data generated, little consideration has been given to the preservation of the data and to making it available to a wider audience.

***Data Preservation***

The aim should be to preserve the data with all the supplementary information that could assist with its interpretation (data descriptions, documentation etc.) Taking into account the fast and continuous changes in the computer world and the high cost of data migration, we have defined a data preservation strategy based on three principles:

- Make the data structures and formats as independent of operating systems as possible.
- Solve the problem in several layers and limit the effects of technological change in each layer - physical preservation, information preservation, data access.
- Use the existing international standards in the area of digital data representation, storage,
description etc.

***Data Availability***

The role of the International Directory Network (IDN) will be presented. The IDN permits researchers to find out what information is available in a given field and how to access the information.


*Claud Huc is a physicist and a data processing engineer. He has worked for the French Space Agency in Toulouse since 1973. For 15 years he worked on the design and development of large software systems for the processing of data coming from space missions, mainly in the field of Earth observations, Space Physics and Astronomy.*

*Since 1992, M. Huc has been in charge of the Space Data Management Service within the French Space Agency. He deals with the data archiving, the data description and data access. He is currently working on the organisation of the French Space Physics Data Centre.*

*M. Huc is also the French correspondent of the International Directory Network, an international structure that permits researchers to investigate the available information in a given field.*

# A Strategy for the Long-Term Preservation of Data from Space Missions

## Claude Huc

## Introduction

After explaining why the long-term preservation of data stemming from scientific space experiments is essential, this paper analyses the main difficulties which at present obstruct access to this data. On the basis of this analysis, and taking into account the rapid advances within the technological context, a strategy is proposed to improve methods for ensuring the long-term preservation and availability of this data.

## The Data Concerned

An enormous amount of data stemming from scientific space missions has been accumulated since the beginning of the Space Era. This data covers the study of the universe (the sun, the planets, astronomy, etc...) to the same extent as the observation of our terrestrial environment and its evolution (observation of the Earth, atmospheric study, oceanology, etc...)

The data collected is as highly diverse with respect to the way the information is organised as it is with respect to the nature of the observations themselves. Part of this data is available through directly readable media: graphs on paper, films, microfiches, etc... but most of it has been archived in a digital format. This article concerns itself uniquely with the latter form of organisation.

The quantity of information accumulated is enormous and amounts, on the international level, to millions of magnetic tapes, Compact Discs, cartridges, and other forms of digital storage.

## Reasons for Long-Term Data Preservation

The need to preserve our historical and cultural heritage has long been acknowledged, as this heritage is such an integral part of our societies collective consciousness. On the contrary, a clear understanding of the need for the long-term conservation of data stemming from scientific space experiments is quite recent. During the 1970's, it was still thought that science would progress with each space mission. Thus a new mission, with more effective instruments, could be defined in terms of the previous results and would in turn provide much higher quality

information than its predecessors. Experience has shown that this linear view of scientific progress does not match the reality. Moreover, while numerous physical and chemical experiments are entirely reproducible in a laboratory, this is no longer the case when the experimental objective is to analyse the evolution of our terrestrial and planetary environment over time.

The investigation and analysis of a space mission data can in practice last twenty years or more. Numerous observed phenomena are unique (solar events, comets, etc...). The origin of many phenomena has not yet been elucidated, thus requiring that relevant observations be conserved. Over the past 20 years, many scientific theories have evolved, allowing for the re-examination of phenomena from a fresh point of view. Certain phenomena, in particular those which concern our terrestrial environment, evolve very slowly, and observations spread over several decades are needed to understand them. This is the case for transformations of the global climate, the atmosphere and the ozone layer. Our time is witnessing the appearance of new branches of science, as well as the overlap of disciplines, which leads to the use of data in domains unforeseen at the outset.

In economic terms, space missions are expensive for national communities, and it is much cheaper to preserve the data than to launch a new mission.

## Analysis of Current Difficulties in Data Preservation and Access

The preservation of digital data can be summed-up by three simple requirements:

- The data should be physically intact.
- The necessary hardware and software for reading this data should be available.
- As scientific data is not simple to use, the information allowing for correct interpretation of this data should be available.

The loss of information linked to the deterioration of physical data storage media is today a significant potential risk, as the losses are generally irreversible. Luckily, only slight losses have been recorded up until now. During the 1970's and 1980's, the data was generally stored on digital magnetic tape (Compatible computer Tapes). For example, nearly 100,000 such tapes are being stored by the French Space Agency at the Toulouse Space Centre. As for internationally available information, this data on magnetic tape has been transferred or is in the process of being transferred to other forms of physical media: magnetic cartridges, optical discs, etc...

The main current obstacle to access to old data is of another order: it is most often the case that each space experiment is a unique prototype which is different from all preceding experiments, and thus the nature and organization of the data collected changes with each experiment. Consequently, each experiment requires new software for the reading and analysis of its data. This has lead to the development of an enormous quantity of software tools, and these are far from being totally independent of the systems within which they operate. In consequence, the software used in the 1970's, on computers which are nowadays obsolete, no longer works, and the corresponding data can only be accessed after costly adaptation of the reading software.

Another important difficulty should be highlighted: in order to correctly process the data, it is generally necessary to know how the experiment was constructed and how it operated. Furthermore, it is necessary to know with no ambiguity how the data is organised, what each elementary piece of information signifies, which measurement unit was used, etc... In other words, it is not only a question of preserving the data, but also of preserving all the information required for interpreting and using this data. This information is usually called the metadata. The main difficulty is that this metadata must allow for the re-use of the data in the future, and that by researchers who will not have participated in the initial experiment. For the oldest data, certain parts of this metadata are lacking, making re-use of the data highly difficult, if not impossible.

Aware of these problems, the national and international space agencies have started to organise institutions or departments for salvaging and preserving this data heritage.

It is on the basis of this analysis and this awareness of current access difficulties that a new preservation strategy has been defined.

## The Spectacular Development of Technology

Over the past 20 years, a veritable explosion has occurred in the diversity and, above all, in the capacity of digital data storage media. This storage capacity has been multiplied by more than 1000 for unitary media, and a sizeable additional increase beyond that provided by the organisation of media inside robots.

The information storage capacity of these media is measured most frequently in bytes. A byte allows for the storage of one character, for example a letter or digit. For large capacity media, terms typically used are megabytes ($10^6$ bytes), gigabytes ($10^9$ bytes) and terabytes ($10^{12}$ bytes).

In 1972, the 800 bpi magnetic tape allowed for the storage of 18 megabytes. Then, between 1975 and 1980, this tape's capacity increased first to 36 and then to 120 megabytes.

Since the 1980's, new high-capacity storage media have appeared, for example:

- Optical techniques: the Compact Disc (600 megabytes).
- Magnetic techniques: the DAT (1.3 gigabytes).
- Video techniques: Ampex or Sony cartridges (up to 96 gigabytes).

In 1975, 30,000 magnetic tapes, or 150 cupboards, were necessary for the storage of a terabyte. Today, robot manufacturers boast 3 to 10 terabytes of storage per $m^2$.

It may be estimated that the cost of storage diminishes by no less than a factor of two every two years. Naturally, the progress concerns not only storage capacity, but also media lifetime, reading and writing rates, conformity to acknowledged industry standards, etc...

As far as long-distance access of archived data via information networks is concerned, the techniques required for access at a very high transmission rate have become available. The rate of data transfer in an information network is measured in bits per second. The bit is by definition the most elementary piece of information, and can take only two values: either 0 or 1. A byte constitutes of 8 bits.

- For the local-area or short-distance (100 km) networks, rates of 100 megabits per second are available with Ethernet and FDDI (Fibre Data Distributed Interface) networks.
- For long-distance networks, the X25 protocol currently used by France Telecom registers a rate of 2 megabits per second. Rates from 34 to 155 megabits per second are available with new technology called ATM (Asynchronous Transfer Mode) already in use in certain sectors.

Over the period of a few years, technology has advanced from thousands of bits per second to millions of bits per second. Today, 600 megabits per second is already being envisaged.

***The consequences of this development in network capacity is that the place where the data is archived is no longer necessarily the place where it is exploited.***

These two sites can in fact be a great distance from one another. Similar advances have occurred in computing power. These technological advances present obvious advantages:

- Conservation of digital data with no or negligible deterioration,
- Ease of duplication and transport without deterioration,
- Increased performances and lower costs.

However they also involve serious inconveniences:

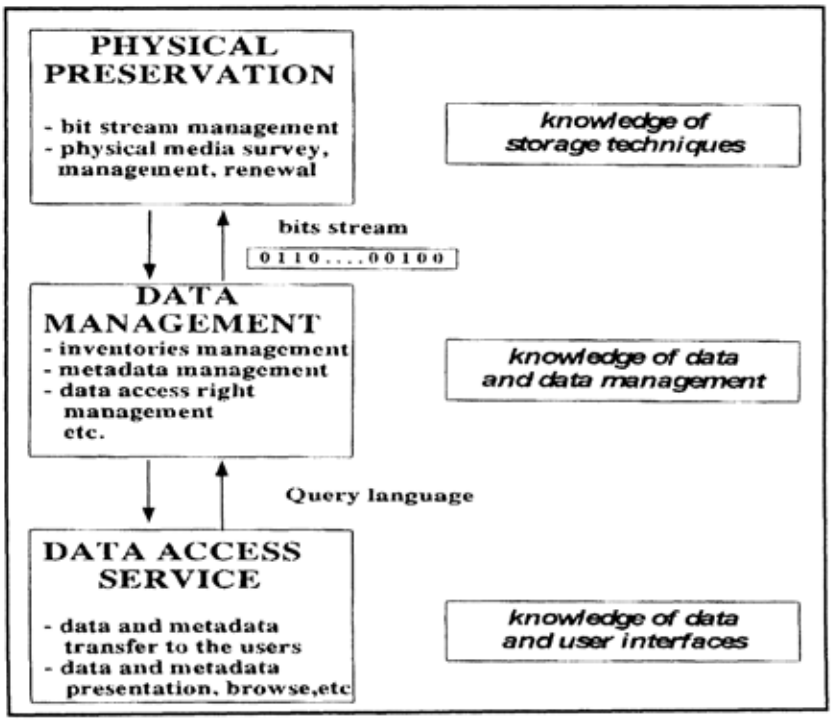
- The technology being used very quickly becomes obsolete.
- Risks of data and information loss are considerable if adequate precautions are not taken.
- The users are completely dependent on the development of a market which obeys its own laws.

## The Main Guidelines of the Preservation Strategy

In order to meet the necessity for long-term data preservation while remaining in control of technological advances, the preservation strategy should be based on the following principles:

- A system model built of successive layers.
- The application of certain standards.

### A Layered Model



This model defines a system reference architecture allowing data preservation and access.

This model, defined by the French Space Agency, does not pretend to be unique. Nevertheless, it presents two major advantages:

- Each layer communicates with the other layers by means of standardised interfaces. Each layer is thus autonomous as regards its own development. Development linked to technological progress is possible, but the related undesirable effects and chain reactions noted in the previous generations of systems have been minimised. A change in the physical storage medium will thus have no effect on data management. The use of the new data management system will likewise have no impact on the storage media.
- The second advantage resides in the fact that the human skills required for each layer are distinct: the layered structure greatly facilitates the organisation of these skills.

Consider, for example, the physical data preservation layer. Despite the sizeable progress achieved in quality and durability of storage media, an institution in charge of the preservation of a heritage cannot blindly trust the storage media qualities announced by the manufacturer. The body must introduce a technical policy concerning the surveillance and preventive renewal of these media. For this purpose, use must be made of methods, hardware and software to handle this surveillance and these renewals. The specific task in question is independent of the nature of the data to be preserved, be it text, sounds, images, scientific data, etc...

Likewise, data management, in logical terms, is similar to inventory management. This management consists of having at one's disposal a list of available 'data objects', and of knowing the characteristics of each data object without having to be aware of the type of medium on which the data is being stored. This activity is organised on the basis of knowledge and logical understanding of the data, which was not the case for the previous layer.

The last layer corresponds briefly to what the user (generally a laboratory researcher) can see and do from within his work environment. In particular, this layer concerns such functions as data and information presentation, data selection, and data requests.

The French Space Agency is currently testing this model. An archiving service which assures physical data preservation, the STAF (Service d'Archivage et de Transfert de Fichiers), has been created and put into operation. Space data servers for the national and international scientific communities are currently being developed.

## The Use of Standard Formats

It is frequently the case that when data is created with the help of a computer, this latter inserts additional information into the user's data, often called 'control words'. These control words are used by the 'system' which drives the computer in order to administer this data. These control words are invisible to the user, but are nevertheless present in the data. Furthermore, these control words are not standardised and are incompatible from one computer to another; they are the cause behind much of the difficulty in accessing old data. When creating this data, particular precaution should therefore be taken to choose options which do not make use of these control words. Archived data should consist uniquely of usable data. Likewise, the encoding used for the representation of numbers (integers, real numbers) should be standard encoding, and not the specific numerical representations of such and such a manufacturer.

The basic precautions indicated above, which consist of making the data independent of the computers, are however far from being enough. It has already been said that it is illusory to try and maintain in working order all of the specific software used to read and analyse the preserved datasets. The only possible solution would be to create so-called 'generic' software, i.e. software capable of accessing and reading all the data in a given scientific field, regardless of the data's origin. The condition for this solution to be workable is that the data in question must respect a certain number of organisational and structuring rules. In other words, this data must conform to standards that define not only the data organisation and structuring but also the data description.

These standards have emerged little by little: note for example the SFDU (Standard Formatted Data Unit) defined by the Consultative Committee for Space Data Systems, and likewise the FITS (Flexible Image Transport System) acknowledged worldwide in the field of astronomy, or even the HDF (Hierarchical Data Format) used mainly in the terrestrial environmental sciences, etc... Certain of these standards are acknowledged by the international standardisation organisations, while others are de facto standards. These standards do not all have the same functions, and some are competing. Still, their emergence and undeniable success is a major asset when it comes to resolving the difficult question of long-term data preservation.

## Global Availability of Space Data Through the International Directory Network (IDN)

It is impossible to end this article without having mentioned the International Directory Network.

In scientific experiments, users are researchers and laboratories interested in data analysis. Generally, each experiment embarked has been carried out under the supervision of a scientist (the principal investigator) who, along with his team, owns exclusive rights to use the data for several years. After this period, the data becomes available to the national or international scientific community. Taking into account the high cost of space experiments, it is in fact justifiable to market the data produced by these experiments whenever possible. This means making the data widely available, so that the greatest number of researchers can make use of it.

Moreover, taking into account the international character of most scientific missions, it follows that the community of users is worldwide and that these users are almost always found at a great distance from the place where the data is archived.

This is why, in response to the suggestions of the Committee on Earth Observation Satellites (CEOS), the IDN was created as a type of great international catalogue of available scientific data, both spatial and otherwise. The IDN is administered by the CEOS, and access facilities are provided jointly by the American, European and Japanese space agencies. It consists of a data base which itemises the available data sets in the international community. This data base is freely accessible on a permanent basis through digital networks (Internet, etc...). The available information for each set of data consists mainly of its general scientific and technical characteristics (scientific discipline, parameters measured, measurement periods, instruments used, etc...), as well as the name and address of the 'data centre' in whose possession the data can be found. This description of the data set is provided in English according to a standardised format. A specialised consultation system allows each user to consult the IDN in terms of his own criteria of interest.

The IDN therefore plays an essential role in providing access to data to the worldwide scientific community today. Furthermore, it paves the way towards a greater compatibility among current data access systems.

## Conclusion

This article has concentrated on the technical aspects of data preservation and access. It should be emphasised that these technical aspects must be accompanied by the arrangements of human organisations, notably as regards the durability of those bodies in charge of preserving the data and of making it available.

# Computers in Archive Storage


## Michael Alexander


### Introduction


*Michael Alexander works for the Computing and Telecommunications section of the Information Services Department of the British Library. He is based at the Boston Spa premises near York.*


I trust my presence here today will not be considered fraudulent. This is after all a symposium for those working in the field of audio-visual archives and I have no experience of that field and only a layman's knowledge of it. However, for the past eighteen months The British Library has been carrying out a programme to investigate the impact of digitisation and networking on its collections and services. This programme has the title *Initiatives for Access*.

This gathering will, I am sure, be well aware of the work of my colleagues at the National Sound Archive in maintaining their excellent audio collection. The Library also has an extensive photographic collection. But it has to be admitted that the overwhelming bulk of our collection is written or printed text on every conceivable material from tree bark to offset-litho print. It is the digitisation and distribution of this material with which the Initiatives for Access programme is most concerned. Nevertheless I am happy to share with you our general information on digital computer storage and I very much hope that it will be of some value for you.

### Types of Digital Storage Media

For many years past magnetic media, both disk and tape, have been and remain, the fundamental means of mass storage for computers. Magnetic disks still remain the most effective medium for on-line computer storage; that is computer storage that is directly and continuously available for data processing. Off-line storage usually represents the computer centre's own data archive where large volumes of data can be held in the form of magnetic tape. To gain access to this data the tapes will normally be physically retrieved by the operator and loaded onto the computer.

What neither of these two systems account for adequately is the growth of digital image files which are considerably larger than the average character-based data file. Although this may be permanent data it needs to be more readily accessible than off-line material. This has lead to the development of near-line storage where banks of optical disks or magnetic tape are kept in devices known as jukeboxes and which are loaded automatically when data is required

## Magnetic Disks

The most common form of magnetic disk is the Winchester disk drive, which is available in a range of capacities up to 1.2 gigabytes. The average access or read/write time for these devices is 10 milliseconds. No other storage device matches this speed. From the concept of disk mirroring, where data is duplicated on a second disk to provide greater fault tolerance has come the idea of RAID or Redundant Array of Inexpensive Disks. Typically twenty 1.2 gigabyte disks may be placed in a single cabinet with the data configured across all the disks in such a way that it can be reconstituted and processing can continue even if an individual disk fails.

This does require more processing power than for a single disk, but the one thing that can be said with certainty about computers is that processing power will continue to increase. To my mind this makes RAID technology a most practical form of storage for small-scale image display systems and as a magnetic cache store for larger systems. However RAID is still an expensive solution and any system developer will need to weigh carefully the justification for high-speed access against cheaper but slower storage media.

## Magnetic Tape

Traditionally, nine track magnetic tape or IBM-style tape cartridges holding between 160 and 200 megabytes of data have been the main form of archive backup within data processing. More recently cartridges holding between 5 and 25 gigabytes have been introduced and this capacity can be scaled up considerably by mounting racks of cartridges in an autochanger or jukebox device. Tape is still a considerably cheap way of storing large amounts of data. However access times are severely restricted in comparison with disks, both through time taken to load a cartridge and the slowness of locating data on a linear storage medium like tape. As a backup device on small imaging systems DAT (digital audio tape), which hold between 4 and 8 gigabytes of compressed data, has proved itself to be a very effective device.

## Optical Disks

The development of lasers has led to the use of optics in storage media. We are all familiar with the CD as a storage device for digital sound and increasingly common is its counterpart for general digital data, the CD-ROM, which I will touch on later. First I will mention the WORM (write once, read many) optical disk, most commonly seen in 3.5" or 5.25" sizes. There are 12" and 14" variants produced by companies such as Mitsubishi and Kodak but these are proprietary formats whereas the smaller size

conform to ISO standards. With an average access time of 120 milliseconds they are considerably slower than magnetic disks but their advantage is that they can be written to directly and then placed in a jukebox device to facilitate the sort of near-line storage I mentioned earlier. They are an effective medium for building up a digital image bank through a programme of continuous and progressive scanning from which data has to be made available almost as soon as it has been captured.

Re-writable optical disks are also available. The most common is the magneto-optical (MO) disk which combines the use of laser with magnetic field polarity. There is also a wholly optical re- writable based on a development of the WORM technology. Access time for MO disks is about 55 milliseconds, considerably better than WORMs but not close at all to magnetic disk times. The effective development of RAID for magnetic storage must put a question mark over the viability of re-writable optical disks for this form of storage.

The CD-ROM conforms to the Yellow Book CD standard. Its capacity for digital data is 540 megabytes and it has an access times as long as 280 milliseconds; the slowest of all the disk access times. Moreover, until a couple of years ago it could only be produced as an expensive master in one continuous session and then copies pressed, as for an audio CD. It does however have the advantage over other optical storage devices in that CD-ROM players are very cheap and increasingly ubiquitous, especially in the library and information sector.

These factors tend to confirm the role of the CD-ROM as a very effective distribution medium rather than as a means of archival storage. The arrival of the writable multi-session CD-R (Orange Book CD standard) and the ability to package a variety of data forms (i.e. text, graphics, sound) have not substantially altered that view. Recently both Philips and a Japanese consortium have announced plans for a double-density CD-ROM. If this is successful and access times continue to decrease then it could become a competitor to WORMS for near-line archive storage, either in jukeboxes or in small installations.

## Tape Stores

One interesting new development that could become increasingly common in data archives is the optical tape. Based on a product developed by ICI and now built into a storage system by Creo Systems, a Canadian company. Each tape cartridge holds one terabyte (i.e. 1000 gigabytes) of data and is claimed to have a life expectancy of 15-20 years. Its most likely use would be a replacement for the standard 9-track tapes in computer centre archives.

The volume of digital data, whether it is still images, audio or video is both expanding and expansive. For any organisation with a substantial archive which is prepared to digitise all or part of its collection, the kinds of disk media mentioned previously will probably not be adequate. It will need to make an investment in a large automated tape store. Some such systems are already in use. The key to their success lies in an effective robot tape selector, high-speed magnetic disk cache and a fast tape-to-disk data loading capability. This will be the only way to provide large-scale storage with a delivery time which will satisfy the end user.

## The Ravages of Time

Everyone working in archives knows about the ravages of time. How does one continue to access the material? One problem is hardware obsolescence. Audio-visual archivists will be used to this challenge because for you the material has always been mediated by some other technology; a gramophone, a tape player, a projector. For many of my curatorial colleagues in the British Library this has been less of a problem. Provided that the spectre of physical decay can be kept at bay then the human organs of eye and brain can be relied on to interpret the written word or drawn image. Nothing else is required.

In a digital future however not only will the devices for physically playing the material become obsolete so will the software that interprets the file formats in which that data is held. Will it really be necessary to maintain a host of outdated technical equipment and to support endless versions of obsolete software in order to read this digital data? Data held as strings of zeroes and ones may be freer from deterioration in copying than data held as analogue signals, but only if the machinery on which it is stored and the meaning of its coded arrangement is accessible to future generations.

Only by instituting a rigorous programme of copying to new devices and new files before such possibilities are encountered can a digital archive hope to sustain itself effectively into the future. Digitisation will not mean a rest for the archivist only another turn on a long, and perhaps unending road, to full and final preservation.

# Archive Retrieval


## Mike Croll

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## Summary of Paper


All television programmes broadcast by the BBC are stored at some stage in their Television and Film Archive. In some cases the recording is only maintained for posterity and may never be viewed again after it has been broadcast. Many programmes, however, are repeated and provide inserts or are packaged to make new programmes. In this way, historic recordings are presented in a modern style within the context of a modern programme. They may be included as historic footage providing the viewer with an on-the-spot record of major events or they may be used to establish the context of a drama or documentary.

Most other broadcasters around the world operate a similar system and have, like the BBC, recognised that there are a number of possible outlets for programme recordings. The BBC release pro-recorded tapes for sale to the public and provide programme input to new satellite and cable channels. In the future, the number of outlets and the range of uses of archival material may expand to the extent where the resources of the archive might become available to a wide range of potential users.

This paper describes processes which are being developed to enable old recordings to appear in a modern context and to be used by new distribution and broadcasting systems to provide the highest possible technical quality. This work recognises the important changes taking place and the significant differences between the requirements for new analogue and digital distribution systems.



*Mike Croll graduated from Imperial College of Science and Technology in London in 1966 with an Honours degree in Physics. Since then he has worked at the BBC's Research and Development Department becoming involved in a wide range of projects associated with digital audio, Teletext, video animation and video recording.*

*He became a Research Manager in 1981 and has recently led projects developing the D1 and D3 video recorders, recording facilities for HDTV and fibre optic networking developments. He has also led projects to devise methods for improving the technical quality of programmes which have been archived. He has contributed to the development of PALplus and participates in a number of European collaborative projects in the field of television networking and recording.*

# Archive Retrieval

## Mike Croll

*Philippe Poncin:*

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## Introduction

Work in the BBC has sought to maximise the value of its archivally stored material through a major concentration of effort and a significant allocation of resources. Efforts are still being made to maintain access to as much historic recording in its original format as possible while also converting material to record it on modern formats which benefit from the convenience of cassette based operation and the reliability of digitally stored methods.

To date, this work has largely concentrated on the elements of conservation although processing to remove film artefacts (grain and dirt) and some adjustment of colorimetry, etc. has sought to achieve the highest quality whenever the signal is transferred from one format to another.

Most processes which have been available historically have been manually intensive and have, therefore, only been applied when a particular programme or programme excerpt is perceived to have a high value by a producer who wishes to incorporate it in a new programme or to rebroadcast it as part of a series. Manually intensive methods, as well as being expensive, are difficult to reproduce and may lead to complications in subsequent reprocessing of the same material.

Systems which can be automated have now been researched for some years. It is now possible to survey a number of possible processes with a view to defining those which may be incorporated into archival processing equipment. In some cases, the processes may be incorporated as pre-processing operations into new coding systems where it is necessary to remove or substantially attenuate picture impairments which would unduly complicate the coding process and lead to poorer reproduction at the eventual domestic decoder. Such processes are already being applied where picture sequences are coded to low data rates as in the distribution of some films on disks. Such processes are expected to become more widespread in the broadcast environment if they can be automated since the expense of some manual pre-processing operations would prevent them being adopted by the broadcaster.

This paper surveys a range of methods of processing archive pictures. It commences with those specifically applicable to film.

## Film Dirt Removal

It is now some 10 years since the BBC first devised a system for electronic detection and concealment of film dirt[1].

The methods described were implemented within hardware which has been applied within the BBC television services to a very large number of films that they have scanned and broadcast. The system has a number of drawbacks and defects in that it does not detect all noise and grain and occasionally makes mistakes which cause elements of a picture to be misrepresented and, in some cases, removed.

New methods have been developed using the benefits of motion prediction to distinguish between real objects and true dirt. This has enabled the sensitivity thresholds to be lowered and a greater overall improvement achieved.

A demonstration will be given showing an original noisy picture, the effect of the existing noise reduction system and the improvement achievable with new techniques.

Like the original dirt reduction system, the proposed new system can be entirely automatic in operation and can be applied to all broadcast film.

## Unsteadiness Correction

Modern film scanning systems achieve a high standard of steadiness within the scanned image. However, old film has poor stability and the images do not have the same mechanical close relationship with the reference points of the medium[2].

A further complication arises when the only recording available is taken from a film scanned with old equipment and where the original film is no longer available.

Detailed investigation in the latter case has revealed that some old telecine systems introduced impairments as a result of a twin lens system which was used to enable each frame of the film to be scanned twice to originate the two fields required for television. Here the brightness, position, height, and orientation of the alternate images may differ significantly. The process of removing unsteadiness involves identifying large parts of the picture which are intended to be stationary or to have easily predicted motion and to remove from these those elements of image perturbation which have been added as a result of mechanical and scanning deficiencies.

Such processes are easier to apply in some scenes than others and can lead to distractions where the process is ineffective. Such deficiencies may for instance enable a scene setting shot to appear well reproduced whereas the close-up of a person speaking, where the background is out of focus, may not be able to be improved by automatic processes.

In the demonstration, some sequences are presented where a motion compensated system seems to work well and where the major impairments have been removed. These sequences, however, show that, because the image orientation and brightness changes between two consecutive fields are not corrected, the image still has a fragile appearance.

Television PAL Decoding PAL decoding methods have been under development almost as long as the PAL system has been used to deliver colour pictures.[3,4,5]

Techniques more advanced than the conventional delay line decoder achieve advantages in terms of reducing false colour created when picture detail is misinterpreted. They can also substantially attenuate small dots which appear in coloured areas which are interpreted by the colour part of the decoder as the coloured elements of the picture. In some cases, loss of resolution occurs where elements of the picture are improperly distinguished.

More advanced recent decoding methods have highlighted the limitations which apply because some elements of a picture intended as detail may perfectly synthesise a plain coloured area or where the colour information carried by the minute dot patterns are confused with texture because the movements of objects within a picture is perfectly replicating the rate at which the dot patterns normally move. These limitations apply such that there will always be picture sequences which will fool PAL decoders into misinterpreting the information available. The trick is to define advanced decoders which work well and avoid attenuating picture detail or blurring edges of coloured objects.

New systems attempt to distinguish different objects within a picture and it is clear that some benefit can be achieved by applying these new techniques. However, the cost-effectiveness of developing ever more advanced PAL decoders is now causing many people to suggest that we stick with what we have. Further tests and studies of the type of decoder that can be implemented economically within currently available hardware will continue to generate different types of decoders, some of which are better suited than others to particular applications.

When the decoded signal forms an input to a digital broadcasting system, it becomes more important to attenuate dot patterns introduced by the colour elements of the composite PAL signal.

This requirement is also shared where the decoded signal may be re-coded to PAL and residual dots from the first coding may then interfere with dots introduced during the second coding when the picture is finally decoded. Therefore, this is an area where there is considerable knowledge and a number of techniques have been established as adequate.

## Image Enhancement

The original scanning of images involves installing in the electronic signal characteristics which make assumptions about their display. Aperture correction is always adjusted "to taste" rather than to correct the spot aperture of the scanning tube installed in the camera. As a result, the edges of defined objects within a picture may have been adjusted for a particular size and type of display which was used at the time the picture was formed.

New display devices may have a finer resolution and be a larger size than those used at the time an old programme was made. The scanning device may also have been installed with filters to prevent picture detail synthesising colours as discussed above. It has been common practice to curtail the frequency band in cameras, etc., at about 4 MHz to avoid introducing spurious PAL artefacts and to minimise the effects of CCD alias in modern cameras.

When a picture which has visible edge ringing is displayed up-converted to a higher line rate on a larger display, these artefacts become very distracting. They also cause significant unnecessary load on digital coding methods since the high frequency picture content has been amplified beyond the point where it contributes to the picture.

Methods of removing edge effects in pictures have been researched using both linear and non-linear methods.

## Linear Edge Correction

It has been found possible to analyse the spectral content of pictures and to deduce from this systematic spectral shaping introduced by aperture correctors and other similar devices. While applying the inverse of such processes can reduce large unnecessary peaks, this cannot be used to amplify spectral energy which was attenuated at source without incurring substantial noise penalty. The application of linear edge correction is, therefore, limited to the picture improvements that can be made by attenuating some of the spectral content.

## Non-Linear Edge Enhancement

Several non-linear methods have been researched and found to perform in general better than linear methods because they can be set to operate at the position of edges in such a way that background noise and textures are unaffected

Under some limited circumstances it has been found that non-linear edge enhancement can achieve the subjective impression of a greater bandwidth. These methods are limited in the way they can be applied since pictures quickly take on an artificial appearance. Our work suggests that about a 20% bandwidth extension may be possible by these means.

## Noise Reduction

The reduction of electronic noise in video signals has been achieved in various video processing systems and was originally researched by the BBC more than 10 years ago[6].

Noise reduction involves installing a filter whose operation on the picture detail is insignificant whereas its operation on the noise causes this to be attenuated visibly. Early work was based on the use of simple temporal recursive filters with motion detection to avoid the filter being applied to picture areas where there is substantial movement. New methods use motion measurement[7] so that the filters which are applied can be motion compensated and, therefore, track moving objects.

Systems incorporating motion measurement and motion compensation have been simulated and found to achieve substantial reductions in the subjective appearance of background noise.

## Reversal of Outdated Simple Standards Conversion

In days when the cost of video recording tape was perceived to be greater than the value of a programme, the BBC reused most of its tapes. In some cases, programmes had been sold for use in other countries and the broadcast organisations in these countries have retained copies of standards converted versions of the programmes.

Early standards converters worked in very simple ways and installed visible picture impairments such that if the signals are reconverted back to 625/50 they are unusable, even using the most advanced motion compensation standards converters.

A detailed analysis of the operation of early standards converters shows that in some cases six fields were generated from the 5 input fields by reproducing 3 of the 5 fields directly and

interpolating 3 fields from the next 2 input 50Hz fields. Reversing the standards conversion operation can, therefore, be achieved by simple analytical arithmetic given "3 equations and 2 unknowns".

This standards conversion reversal has been applied successfully to a range of recordings and highlights the need to study the detail of processes which may have been applied to television signals before blindly cascading further processing elements.

## The Effect of Pre-Processing on MPEG Coding Efficiency

| Condition | Normalised Bit Rate |
|---|---|
| No artefacts | 1 |
| Unsteadiness only | 1.3 |
| Grain only | 2.8 |
| Grain and unsteadiness | 3 |

Table 1

A limited series of tests have been conducted where a number of artefacts were introduced via MPEG2 coding and comparing this with the coding efficiency where there are no artefacts. The figures in Table 1 give the overall bit rate to achieve the same signal to noise ratio after MPEG2 coding and decoding.

The table shows that film artefacts could cause the overall bit rate required for coding films to achieve a satisfactory performance to be increased by up to 3 times what is required to transmit a good quality film. Clearly, pre-processing will be necessary to enable archival films to be broadcast with the same efficiency as those which have a higher technical quality.

## Conclusions

A large number of methods for improving the technical presentation of film and television originated archival material have been reviewed.

These and other methods will need to be developed and applied to enable satisfactory exploitation of our archival recordings and to maintain their value in the context of new delivery methods and new opportunities for their exploitation.


## Acknowledgement

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# Digital Mass Storage in a Radio Sound Archive: The Customer's Requirements

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## Summary of Paper

Many large public broadcasting companies have large sound archives that have collections of sound carriers dating back 50 or more years. These collections form a valuable resource for modern programme makers and the demand for access to the archive material is increasing. The problem facing the archives is to find a solution that answers this increased demand without increasing the danger to the carriers.

This paper examines the options starting from the current situation in a typical radio archive like that of Südwestfunk. The considerations that led to the idea that the sound archive, as a integral part of the stations operations, cannot be omitted from the use of modern digital techniques are explained. An operational plan for a pilot project, based on the future needs of the German radio companies, is described. This pilot project will be run at Südwestfunk for one year starting in early 1995. The intention of the project is to demonstrate the benefits of a large digital mass storage system in a radio stations archive.

*Albrecht Häfner studied Electrotechniques at the Technical University in Munich. He worked as a sales engineer in the A-V industry for ten years before joining Südwestfunk in 1980 Since 1984, he has held a senior position within the radio archive and has spent the last two years working on the introduction of a digital mass storage system into the archive operation.*

# Digital Mass Storage in a Radio Sound Archive: The Customer's Requirements

## Albrecht Häfner

Let me begin by emphasising that the subject of my paper is a special kind of sound archive - a radio sound archive. A radio sound archive holds the programme assets of a broadcasting company. This can mean a stock of more than 700000 tapes and discs, a yearly growth rate of about five percent, about one thousand sound carriers per day needed and used for transmission, production or listening. It is that special type of sound archive - in particular, the archive at Südwestfunk in Baden-Baden - that is the concern of my paper. The situation may be different in other archives.

## The Current Problem

In order to understand why a mass storage system is needed, let me first reflect upon the basic functions of a radio sound archive and how they are arranged at present. There are four basic functions that a radio sound archive has to fulfil:

- The acquisition of:
- The documentation of:
- The making available/giving access to:
- The preservation of:

sound documents.

Acquisition of sound documents relates to the radio station's own recordings, purchased records and commercial record samples. Documentation means the registration, indexing and cataloguing of them. Making accessible means that we have to provide suitable boxes which will protect the sound documents; mark the box with a catalogue number and a short description; provide the proper storage facilities and storage conditions; and quickly provide a tape or a disc when the user wants it. Finally, preservation means not only the general maintenance of the archive equipment, but focuses especially on the quality control and on the safeguarding by ensuring the continuing existance of the sound documents, including, when necessary, the making of preservation copies.

At present, we do not face any particular difficulties with acquisition and documentation. Providing the material is, however, getting more complicated. The more our radio programmes use only the latest pop hits the less necessary it makes large radio sound archives.

Another delicate area is preservation, especially the quality control and the safeguarding of our stocks. Because the public broadcasting companies could afford the best material and equipment as well as the optimal storage conditions in the past, regular quality control and copying systems hardly existed. To make up for that omission today means a gigantic expenditure: more than half a million of tapes would have to be examined for their mechanical, electromagnetic and chemical condition - a task which is not feasible for us now. In addition, the struggle to achieve the ideal aim - that every sound document should be accessible in the best quality to everybody at any time - creates more problems and conflicts:

- Tapes and discs required for transmission are not accessible for other purposes for three days.
- Tapes and discs issued on loan are not accessible for at least one week.
- Lost tapes and discs are not accessible at all (this sounds ridiculous but, in practice, creates many problems).
- Tapes and discs are worn out, sometimes even damaged.
- Parallel/simultaneous use is not possible.
- Copies can only be made in real time.
- Maintenance and quality control are very costly.
- Copying is costly and possible only in real time
- Supplying the tapes and discs needed for transmission, production or loan purposes requires costly staff.
- Tapes and discs need proper casing/housing and labelling.
- Tapes and discs need appropriate storage conditions (air conditioning).
- Limited duty hours (05:00 am - 12:00 midnight).

The result of a short analysis is that there are three areas of conflict which can be summarized as:

1. Availability problems
2. Quality control and safeguarding problems
3. Operational/organizational problems

As a consequence, we have to look for an equipment which is able:

1. To considerably improve the speed of availability bringing it down to a few minutes only.
2. To implement automatic quality control and automatic making of preservation copies thus ending our slavish reliance on the survival of all the sound carriers used so far and on the obsolescence of recording and playing machines.
3. To lower the running expenses.

## The Solution

The only solution that can be envisaged for these problems requires the introduction of a digital mass storage system. The reasons are:

- Data files are permanently available for any purpose; they cannot get lost.
- No wear or damage by the users.
- Parallel use possible.
- Copies made faster than real time possible.
- Automatic quality control, automatic preservation copying.
- No supply or loan service necessary.
- Compared with existing stores, much less storage space is needed.
- No boxes/housings, no labelling needed.
- Comparatively, lower air conditioning requirements.
- Unlimited duty hours.

In other words, applying the 1993 recommendation of an ARD working group examining and specifying a strategy for the safeguarding of radio sound documents:

- A short term strategy suggests the use of marketable digital systems like DAT or CD-R according to rules which ensure a future automatic copying into a computer based mass store.
- The middle/long term strategy recommends the introduction of a computer based digital mass store in the radio sound archive of each ARD company.

In order to escape the famous "Adidas Interface" (Figure 1), which devours a lot of our resources, three storage hierarchies will be required (Figure 2):

- A hard disc store in each transmission studio with an access time in the range of milli-seconds and a storage capacity of about 24 hours.
- A shared working buffer with an access time in the range of one second and a storage capacity of about four weeks; the reason for this working buffer will be explained later.
- A shared central mass store with extremely large storage capacity (some years) and an access time within the range of one to two minutes.

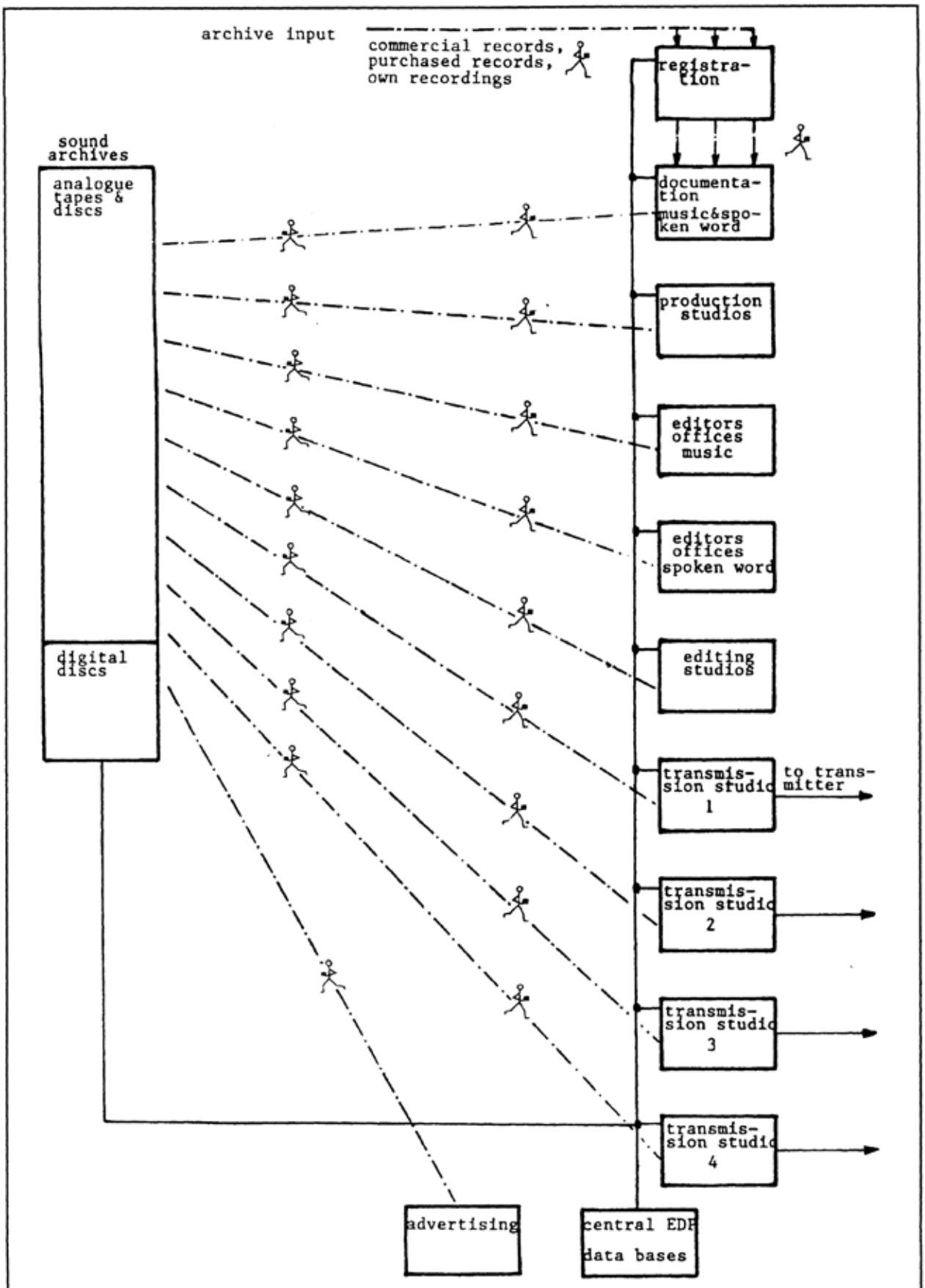



**Figure 1: Radio Broadcasting "Local Area Network" using "Adidas Interfaces"**

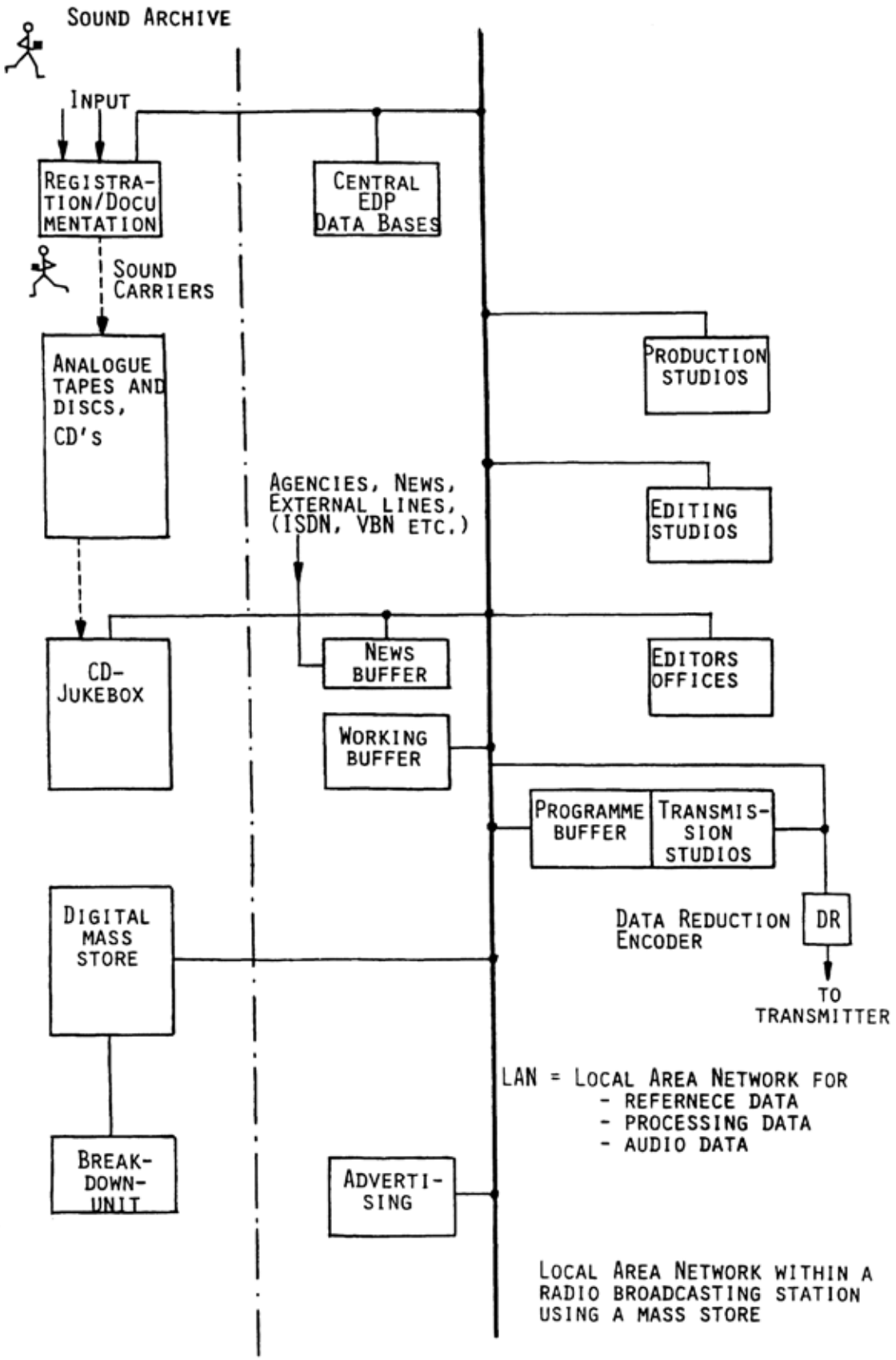



**Figure 2: Local Area Network within a Radio Broadcasting Station using a Digital Mass Store**

## Equipment Availability

Digital mass storage systems are today offered by several manufacturers. They perform all the requirements listed previously. Some more fundamental requirements can be added to cope with future needs:

- Very large data rate (bits per second), i.e. transfer of files many times faster than in real time. This is a very important requirement - the more users, the higher the data rate required for an efficient service.
- Automatic quality control of tape and drives, automatic preservation copying - this is a mandatory requirement.
- Access time within the range of 1 to 2 minutes (as available systems are based on magnetic tape cassettes) - the shorter the better.
- Extremely large storage capacity - the larger the better.
- Low error rate, error correction.
- Standardized recording without being fixed to a specific format, i.e. audio files as well as text or still image files - a must as a digital mass store will not hold the CD or LP booklets and covers we use for detailed information.

## Other Considerations

Because of the very large investment costs for a complete digital mass storage system, including the necessary computer environment, I believe that, for the time being, only intensively used, large collections can justify the acquisition of such a system and make its operation efficient.

In my optimism, I must not forget to mention that the introduction of a mass store is inseparably connected with decisions about selection. Should all of the analogue audio documents be transferred into the mass store or only a selected group of them. This question unavoidably arises when calculating the costs of the transfer and necessarily leads to discussions about the possible automation of the transfer, bearing in mind that the transfer is to be performed only once (the latter point is of utmost importance).

## Action to be Taken

After three years of market observation and of debating the right way to the future sound archive, we felt that we could risk a jump into cold water. It was decided that a first practical step should be taken in order to test modern digital mass storage equipment in our radio sound archive. We thought that, as first step, a pilot project should be set up in co-operation with a qualified

manufacturer to run for a period of one year, in order to gain experience of how to deal with a digital mass storage system. We have nearly finished the necessary administrative formalities and the pilot project will probably start in April this year.

As the pilot project will be run in parallel with the regular archive activities, it is restricted to a functional mini-model of what is likely to be the future final installation. Moreover, priority will be given to those functions needed in the sound archive. For this reason, users like our production or editing studios and the editors will not take part in the pilot project. It is, of course, not a matter of an isolated action, but will be performed with the aim of achieving an integration of the sound archive into the digital development of our radio station.

## The Hardware and Software Requirements

The hardware for the pilot project will consist of the following components (Figure 3):

- A digital mass store with 2 TeraByte storage capacity (about 3.000 hours of audio)
- A working buffer based on hard discs with 10 GigaByte storage capacity
- Two import/export stations for data input and output
- Two retrieval stations
- A local area network, which is to connect to a existing FDDI network
- Use of the reference data in the existing data base

The mass store, including the system administration module, is the core of the digital archive system. The administration module controls all controlling processes which are required for the communication of the single components including access to the different stores and buffers, access to the data base and the file transfers between the stores and buffers. It initiates plausibility controls and safeguarding functions such as preservation copying and performs retrieval functions. The mass store itself consists of a cartridge magazine, a tape access robot and two drives. It is connected to the system via a controller which is responsible for internal activities. Data security is guaranteed by a "read after write" mode including error correction, a tape quality control and a drive control.

As long as a mass store system, for economic reasons, is based on magnetic tape as the storage medium, which affects the access time adversely, we cannot use it for immediate transmission purposes. For that we use the 'working buffers', a hard disc based system, with a medium storage capacity and an access time within the range of a second. The working buffer holds all the

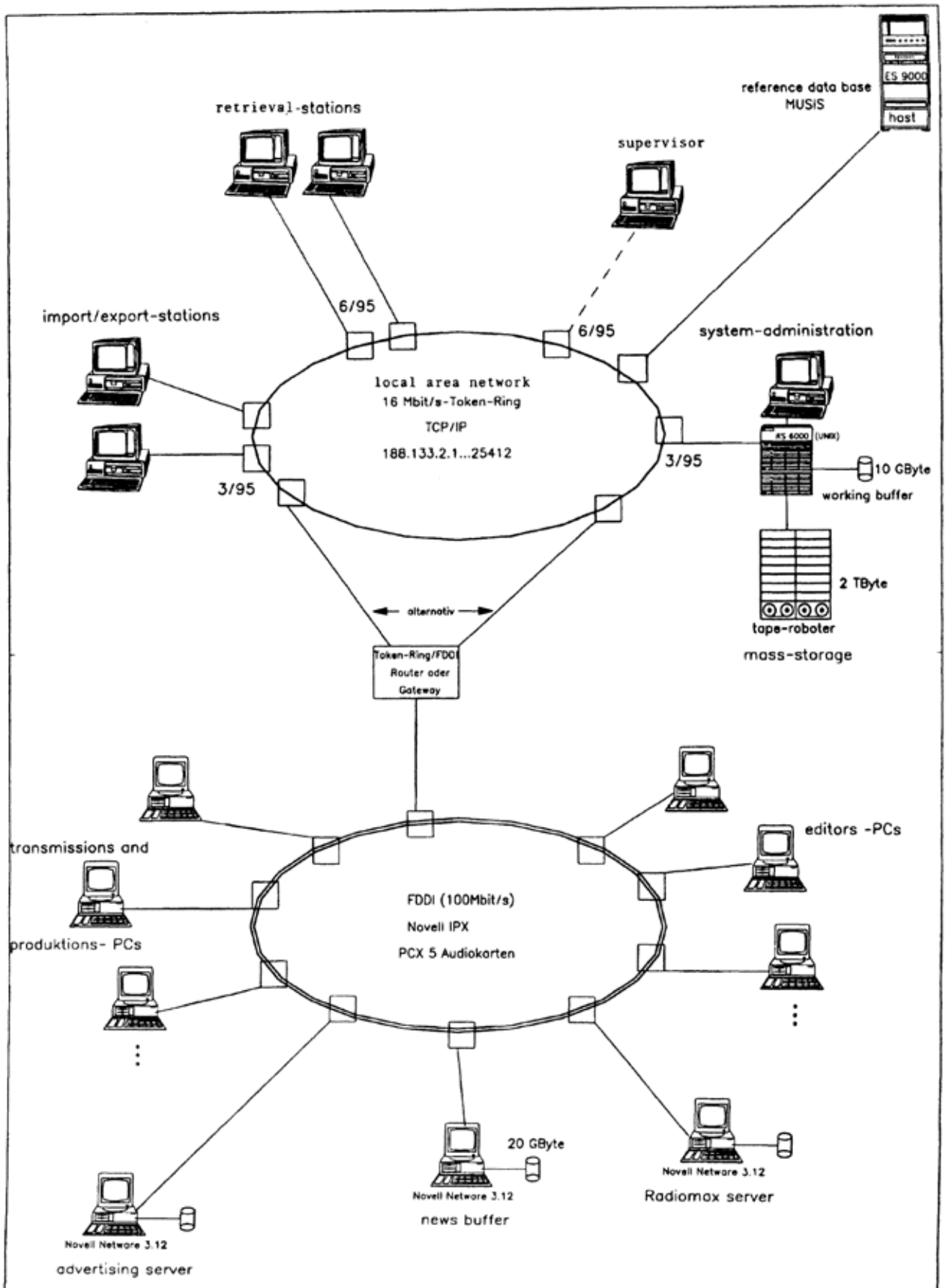



**Figure 3: Schematic of the Pilot Project**

current pop music hits, which are used more or less frequently, and cares permanently for an up-to-date status. Each user inquiry arrives at the working buffer. At the beginning of the pilot project, the working buffer will have a rather small storage capacity of 10 GigaBytes, which can be expanded.

Two input/output stations allow the input of analogue as well as digital audio signals into the mass store and also the export of data from the mass store for listening or dubbing purposes. Every audio input is converted into AES/EBU format with 48 kHz sampling frequency and 16 bit linear quantization - the standard used by the German broadcasting companies. Further input modes have yet to be designed within the framework of the pilot project, especially one for a faster than real time CD or hard disc input. The audio files are stored in WAVE-format according to the RIFF standard. The input stations are provided with a simple editing facility for hard cuts and with fader start. Two input methods will be supplied:

- The input of a single audio file for immediate online availability/accessibility;
- The input of several audio files *en bloc* in times of low activity, eg. overnight.

The retrieval stations will allow the export, i.e. the downloading of an audio file onto a local harddisc and offer the possibility of modifying the reference data. With a graphic interface, the user can access functions such as 'play back', 'monitoring volume', 'stop', 'variable fast forward with/without monitoring', 'variable fast rewind with/without monitoring' and 'skip to top/bottom of file'. Audio files can be marked for later revision or final documentation within given periods.

At thestart of the pilot project, the local area network will be a token ring with TCP/IP (Transmission Control Protocol/Internet Protocol) and a data rate of 16 Megabit/s, which should be sufficient for the first tests.

The existing data base will be used to supply the reference data needed. That will require an interface between the administration server and our host computer.

A connection to an existing network is intended. At present, a digital news buffer for the editing of external audio signals eg. from agencies or correspondents is going to be installed for a three month suitability test. It will run in an existing FDDI local area network. An appropriate gateway will connect both networks. Thus, it will be possible to transfer all those audio files, which are marked in the news buffer as ready for transmission, to the mass store and to carry out the proper documentation at a later date.

***Ian Gilmour:***
*How do production and operational staff get the material that they wish to work with into the working buffer? Do they have to request material in advance of their requirement?*

***Albrecht Häfner:***
*All requests are made first of all to the working buffer. If the requested material is not held there, a search is made of the main store and the required material is down-loaded into the working buffer. From there, the material is made available to the production team.*

Although we prefer linear audio signals as the audio data format within the studios, we cannot avoid the input of data reduced signals from outside. Hence, the system must, from the first, be able to create a MUSICAM reduced audio file from a linear PCM signal and to process each of them. When a user requires an audio file for mere listening, then he will get the reduced file. For editing purposes, the linear audio file will be supplied.

## Conclusions

We do not believe, that to wait further for a better technology is of substantial benefit for US. The future of broadcasting will definitely be digital - radio as well as TV - and being aware of the backlog of work for quality control and safeguarding, we do not think it wise to hesitate. On the contrary, we are sure that it is high time to make a modest entry into the digital future. We expect much of our pilot project and we hope that more questions will be answered than it creates.

# Multimedia Mass Data File Server


## Horst Niederehe

Sony Broadcast and Professional Deutschland, Köln, Germany


## Summary of Paper


Recent advances in Digital Signal Processing and Storage Technology have brought the vision of Interactive Multimedia Information Systems closer to reality. "On-Demand" Services, Digital Radio and Television Broadcasting, Electronic Newspapers and the like will soon be accessible from the Personal Computer at home or from Wireless Personal Communicators through the newly fashioned Data Highways. Only a small fraction of the communicated information will be produced on-line in the form of E-Mail or Video Conferencing. The major part of the information will be obtained from archives and libraries of various types. Although the term "Archive" is retained, it is already clear that the archive of the future will look very different to the traditional document repository:

The backbone of future archives will be Digital Mass Storage Systems. Their open architecture will allow all kinds of information to be stored - Still and Moving Images, Audio and Texts. Access to the information carriers will be via robotic stores. The access will be achieved via communications networks.

The logic behind such a concept is precise. A Multimedia Information System cannot exist without a sizeable automated archive.

The paper outlines the structure of a Multimedia Mass Data File Server System currently under development and its implications on archives and archivists.


*Horst Niederehe was born in 1944 in Germany. He studied as an Engineer at the Rheinische Akadermie in Köln and Graduated in 1969. He joined Sony Deutschland in 1976 as an Instructor in Video Technology in the Technical Training Department. In 1978, he was assigned to develop the new Digital Audio Department and in 1992 was appointed Manager of the Instrumentation and Data Recording Department.*

# Multimedia Mass Data File Server

## Horst Niederehe

Recent advances in digital signal processing, storage technology and network development have brought the vision of *Interactive Multimedia Information Systems* closer to reality. Formerly unrelated businesses e.g. the graphic industry, radio & television, book libraries, publishing houses, medical and science, to name only a few, are on common ground in their intention to make use of networked computer systems in order to communicate the information which they acquire, process, offer and disseminate. Digital radio and television broadcast, "On-Demand" services, electronic newspaper and the like will soon be accessible from the personal computer at home or via "Wireless Personal Communicators" anywhere in the world through the newly fashioned "Data Highways".

Only a small fraction of the communicated information will be produced on-line in the form of E-Mail or video conference etc. The major part of information will be obtained from archives and libraries of various types. Although the term archive is retained, it is already clear, that the archive of the future will look very different to the traditional document repository:

- The backbone of future archives will be digital mass data storage systems.
- Their open architecture will allow all kinds of information to be stored - still and moving images, audio, texts or any other data.
- Access to the information carriers will be via robotic systems.
- Access to the information itself will be achieved via communication networks.

The logic of such a concept is precise. Multimedia information systems cannot exist without a sizable automated *digital* archive. With ever increasing speed, production of information (print-media, audio & video) is going digital. Present analogue material will have to be digitized.

- This is the indispensable prerequisite to perpetuate and preserve the recorded information.

The prime advantage of a digital archive is that, under normal conditions, the copy of a digital recording will be identifiably and reliably an exact replica or "clone" of the original.

Another advantage, equally important for archives, is that the degree of reliability of both the data carrier and the reproduced data can be objectively assessed, which is impossible in analogue

recording. And there is yet another advantage worth mentioning: Encryption of digital data assures that only an authorized party can retrieve the original data thus providing a high degree of protection against unauthorized access, misuse and tampering.

It is obvious that these advantages are particular assets of digital storage only.

In the long term, there will only be digital storage. This statement is undisputable! However, the recording or storage medium to be used for archiving comes into question. What are the options? Is it possible to define candidates for long term archival storage today? Or should onewait for other, new technologies?

Radically new media (holographic recording, recording crystals, bio memories etc.) have been discussed for years. In practice they have not left the imagination or the laboratory and, it is fair to say, that they do not exist. And even if we had access to these technologies today, we could imagine even more sophisticated, future technologies beyond.

Do not wait for the ideal storage system, we shall never ever see it. From a practical point of view, two technologies are available now: the Optical (including Magneto-Optical) and the Magnetic Technologies. Although both technologies are available as discs or tapes, optical technology is mainly utilised in discs and magnetic technology in tapes. Both technologies are being continously improved, but there are certain limitations, which mean that they cannot be improved significantly because of physical constraints. For tape this is access time and for optical disc it is data transfer rate.

One cannot deny that optical discs are very attractive and serve a growing number of applications but their only advantage over tape is access time. In all other parameters the magnetic tape outperforms optical discs.

Is media life an essential parameter? Yes and no! All other parameters being equal (although they are not), 100 years of media life is better than 30 years. In both 30 and 100 years though, it is fairly certain, that no existing recording format will still be supported by hardware. Even if the documentation for the hardware was still available and complete, reconstruction of a particular piece of equipment would probably not be economically feasible.

In other words: system life is a natural limit to media life (another limit will be the economics in media cost, size, maintenance etc.) Thus, long term archival cannot be conceived without accepting the risk and planning for the probability of repeated transfer from one carrier to the next. There is, by the way, a biological analogy: Mother Nature does not make originals stable for a thousand years but copies many times with good error correction.

What needs to be preserved in reproducible condition by an archive is the data representing the archived information rather than the data carriers. It is far more efficient, to invest money in an intelligent system preserving data, than in physically stable but unmonitored media.

An ideal archive should not be based on a theoretical data carrier so good as to avoid recopy-ing but should, instead, efficiently address the neccessity of recopying. This can be achieved by occasionally monitoring the recorded data's error rate and recopying if a certain threshold has been reached. It should also be able to perform automated format transfer of parts or of the totality of the archive and should perform this faster than real-time without requiring many machines operating in parallel. Finally it should provide negligible error rates and full data security.

Technology, structure and organisation of archives may change considerably in future but there is no reason to assume that the mission of the archive will change:

- Preservation (and Restoration)
- Dissemination
- Administration (with special emphasis on Documentation)

In order to select an appropriate storage medium for archival we should have a look at the data rates in question:

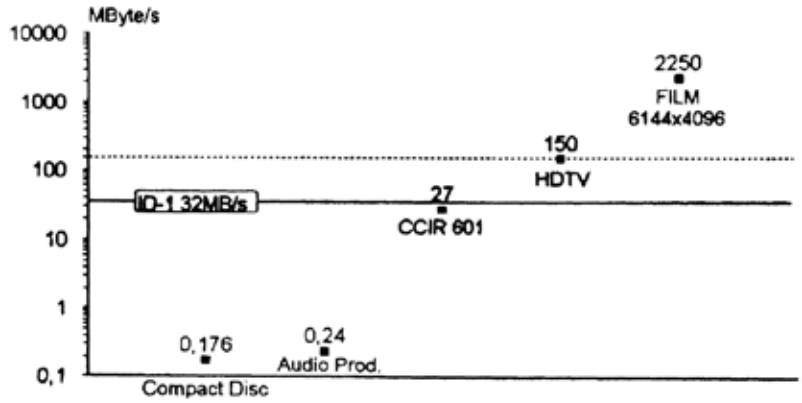



**Figure 1: Typical Data Rates of Different Types of Information**

Figure 1 shows the data rates representing various types of information, starting from Compact Disc at 176kByte/s up to digitized film with a high resolution of, for example, 6144x4096 picture elements x 10bit resolution x 3 colours producing more than 2GByte/s. There is no digital recording system available today that could handle this huge amount of data in real time. The dotted line in this chart shows that a datarate of about 150 MByte/s is about what can be achieved today with commercially available products - the High Definition Video Tape Recorder. The solid line at 32MByte/s hints at a storage device which will be covered later.

There is a consensus that (irreversible) data compression and data reduction is not viable in archiving and there are good reasons for this. We can, therefore, take from this chart the fact

that the electronic industry has, as yet, no technology to offer to accomodate the data rates required for preservation of data produced in high resolution film digitization.

The archives mission is not, however, limited to preservation and restoration of information and their carriers. The situation is quite different if we turn to the aspect of dissemination.

Figure 2 shows that the data rates specified for new services like DAB - (Digital Audio Broadcast) or DTVB - (Digital Television Broadcast) will only convey a fraction of about 10% or even less of the originally produced data rate from the transmitter to the receiver. The standards are decided upon and this is not the place to initiate a discussion about the pros and cons of data reduction.

The fact is that the subscriber will only receive a data-reduced signal from the supplier whether it be from a terrestrial transmitter, a satellite or a network. If we only had to consider dissemination in archiving, the mission could be achieved with only 10% or less of the total storage capacity.

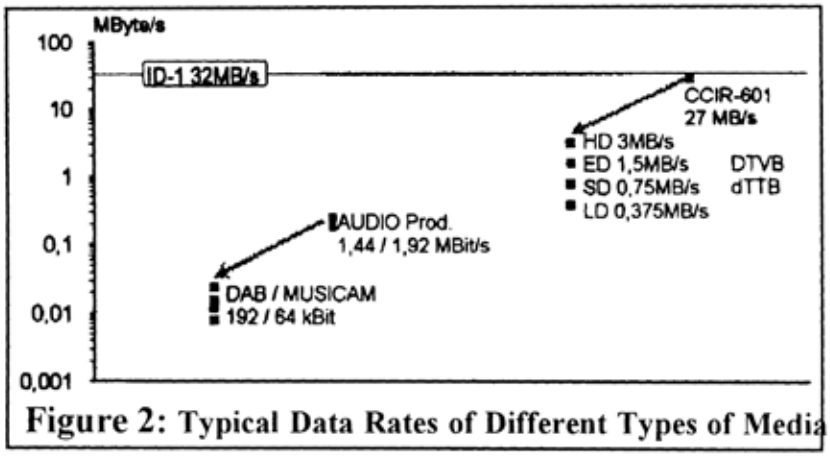



**Figure 2: Typical Data Rates of Different Types of Media**

Figure 3 will make the situation more transparent. Although it shows an example related to video, the conclusions are much the same for audio. Today, archives still contain the edited master tapes or discs as "originals" in a format dependent quality level. ("B" or "C" Format, Betacam, D1, D2 etc. etc.) If the material is still analogue, it needs to be converted into digital for subsequent data reduction. If the material is digital already, it can be fed directly to the encoder input. (CCIR-601 is just for example).

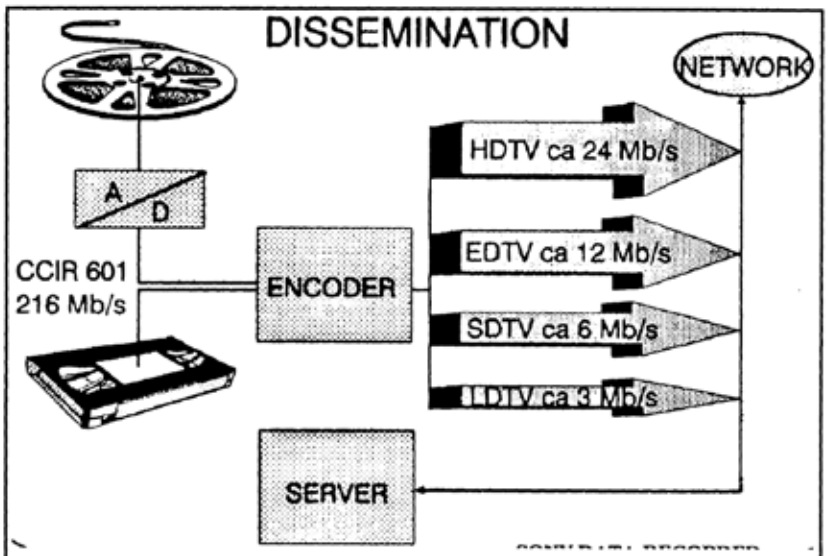



**Figure 3: Data Rates for the Dissemination of Different Video Formats**

The encoder will literally throw away 90% or more of the data depending on the specified quality level for transmission. The encoding is a real time process and the subsequent transmission of the signal will therefore also happen in real time. If the encoded information was stored in a storage

system associated with a server, this server could download the information at much higher speed in a fraction of real time.

What is implicitly suggested here is a differentiation between the Preservation and the Dissemination of information owing to different requirements. This is not entirely new in archiving: the negative film will be preserved in a specially air conditioned environment and positive copies will be made for distribution. Copying from film to any videoformat, a common practice today, effectively means "data-reduction" as the original quality can neither be transferred to the copy nor to the TV screen of the subscriber.

The above gives only a broad outline of the situation. There are many more details worth discussing - but time will not allow it.

## ID-1 Format

Let us turn now to a storage medium which may be deemed to be a suitable candidate to cover a wide range of applications in high volume, long term archival storage.

The product line up conforms to an ANSI (American National Standards Institute) Standard; Figure 4 outlines the specifications.



- ANSI X3B.6 ID-1 FORMAT
- D-1 DATA CASSETTE
- High Density Recording up to 100GByte / Cassette
- High Speed REC. / PLAYB. up to 32MByte/sec (64MB. optional)

**Figure 4: The DIR-1000 Digital High Speed Data Recorder**

The DIR-1000 is a High Speed Data Recorder whose design is, to a large extent, similar to a Video Tape Recorder, as rotary heads are employed for recording and playback. A number of datarates are selectable ranging from 1MByte/s to up to 32MByte/s or, as an option, up to 64MByte/s.

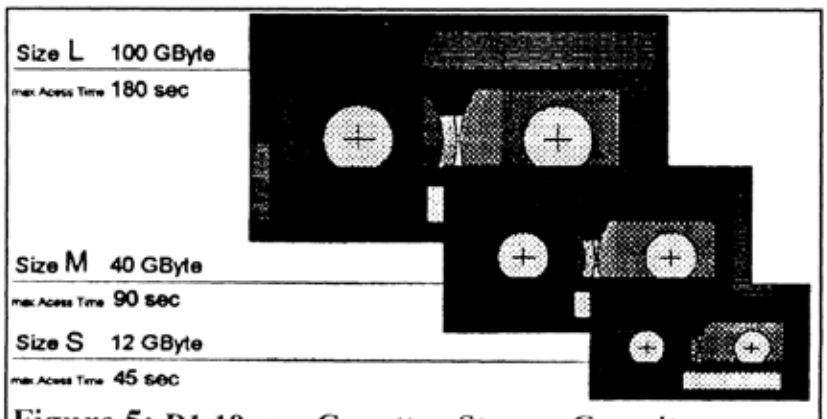



**Figure 5: D1 19 mm Cassette - Storage Capacity**

The Storage Medium is a highly durable and reliable cobalt doped ferrite oxide tape, packed in a D1 Cassette. Although standard D1 Videocassettes may be used, the dedicated data cassette is recommended because it has improved performance in several areas important for archival usage.

Figure 6 gives an idea of the storage capacity of the tapes in comparison to the storage capacity of the Audio Compact Disc.

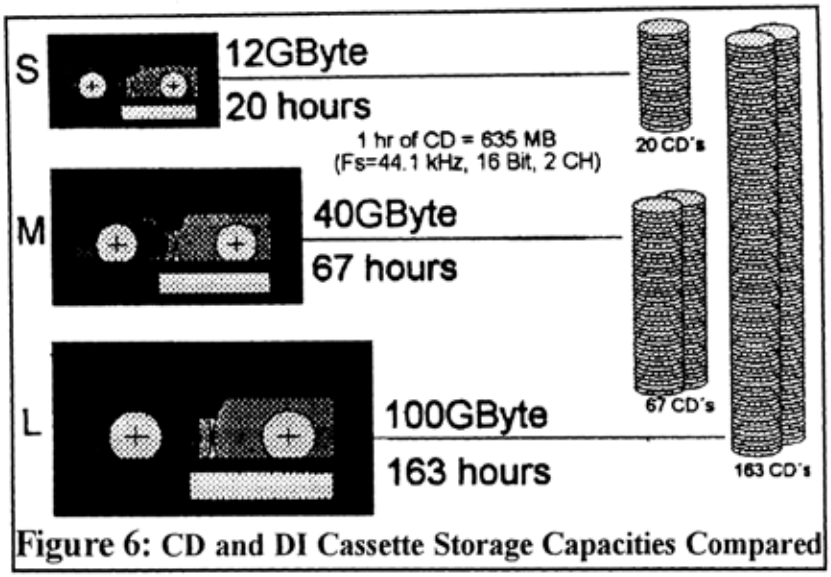



**Figure 6: CD and DI Cassette Storage Capacities Compared**

A data capacity of 100GByte will allow storage of the equivalent of more than 160 hours of Compact Disc quality music without compression. At a data rate of 32MByte/s, 100GByte of Data can be copied or transmitted in only 50 minutes. This means, that a track of music of 1 hour duration will only take 20 seconds to playout.

## Cassette Changers

Combined with cassette changers or juke boxes, ID-1 recorders make High Density Mass Data Storage Systems expandable to virtually limitless capacities. The floor space requirements are drastically reduced as compared with existing storage solutions. A system capable of storing 30 TBytes of date has a footprint of only 3.4m² or 36.3 square feet and is only slightly over 2 meters, or 6 feet high. 30TBytes, again in terms of hours of Compact Disc, represent a volume of almost 6 years of audio information. Copying of 30 TBytes can be achieved, however, in less than one week.

A Mass Data Storage System of that size and performance is quite attractive for a number of applications, as explained in my introduction. It represents however a nucleus only, albeit an indispensable one, for the entire system -

***the Multimedia Mass Data File Server.***

# Multimedia Mass Data File Server

A number of German companies have recently formed a development group named EGIMAS, which stands for Expert Group Integrated Multimedia Information Systems. The objective of thisassociation is the development of custom designed systems based on the specific know how of the contributing companies.

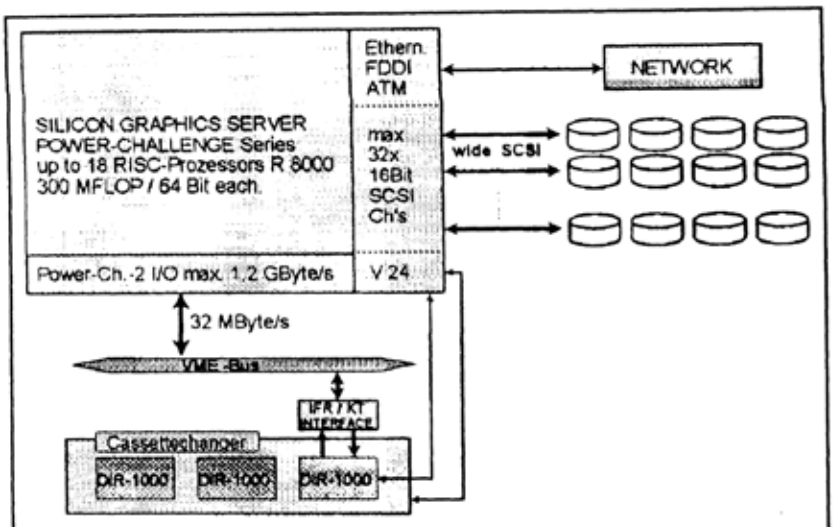



**Figure 7: Schematic of the EGIMAS Mass Data File Server Concept**

The following explanations refer to the EGIMAS concept.

The Mass Data Storage System is a combination of three DIR-1000 recorders and a cassette changer connected to a Silicon Graphics Power Challenge Series Computer. Custom designed high speed interfaces connect each individual recorder via a VME Bus to the Power Channel-2 I/O which is capable of handling data rates of up to 1.2GByte/s.

In this configuration, all three recorders can produce their maximum data rate of 32MByte/s simultaneously, resulting in a peak data rate of 96MByte/s to the computer. The Power Challenge makes up to 32 SCSI-Wide Channels available, which allow control of up to several TByte of Hard Disc capacity for on-line processing and data buffering. Network interfaces provide access to several channels of Ethernet, FDDI or ATM. The performance of the server as an integrated computer and storage system is widely scalable and can, therefore, be easily adapted to the application.

## Digital Tape Format

The recording of data on the tape conforms to the specifications of the *19mm Sony Digital Tape Format* (DTF), an extension of the ID-1 Format, which provides the neccessary logical structure for the recording of data files.

The design goals of the DTF were as follows:

### 1. Quick Access to a Desired Data File

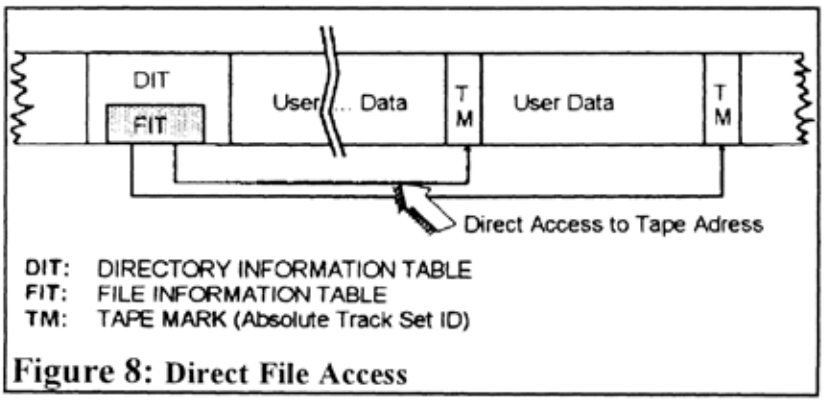



**Figure 8: Direct File Access**

Streamer tapes will normally access to a desired data file by counting the file marks from the beginning of the tape - a time consuming method if the data capacity is high. The DTF specifies an area at the beginning of the tape to record additional information neccessary for data administration.

This data area contains the so called DIT, the Directory Information Table and FIT, the File Information Table. The FIT, a subset of the DIT contains the *Track Set ID's*, of the Tape Marks which were recorded. The Track Set ID is an absolute tape address, comparable to the SMPTE Time Code. After reading the FIT, the desired portion on the tape is accessed at fast winding speed within a very short period of time.

## 2. High Reliability

The high reliability is based on four elements:

- As mentioned earlier, a special data cassette with improved performance was designed.
- The DIT and FIT etc., being very important information, are recorded several times as data blocks. (between three and seven times).
- If neccessary, Read Retry and Write Retry procedures will be applied.
- The *Bad Spot Table* (Figure 9) is another subset of information stored in the DIT. It is a special feature of ID-1 and the DTF that blank tapes need no preformatting. During recording, the recorded information is read from the tape by the playback heads (read after write) and error rates are measured. Should the error rate reach a threshold critical for data security, the tape area is marked as being unusable for storage. The start and end address of the bad spot are stored in the Bad Spot Table.

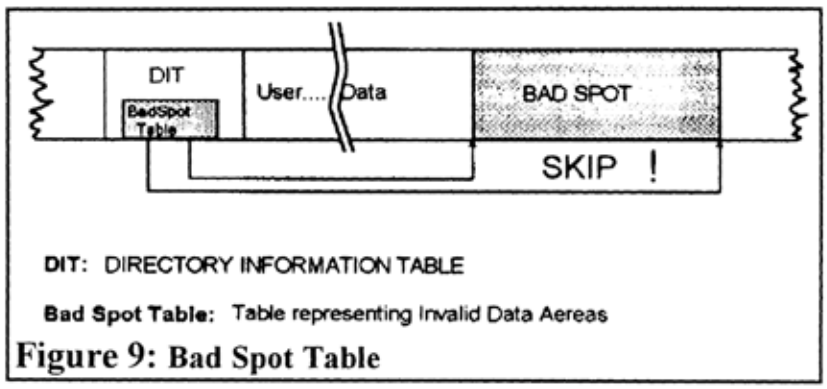



**Figure 9: Bad Spot Table**

## 3. Efficient Exploitation of the Storage Capacity

The Digital Tape Format (DTF) allows the definition of multiple logical volumes on one tape. Each volume can be individually rerecorded without affecting the remaining volumes. It is also possible to attribute a huge logical volume to more than one tape or physical volume.

So far a brief overview on the tape format. The documentation is, as you can imagine, more comprehensive.

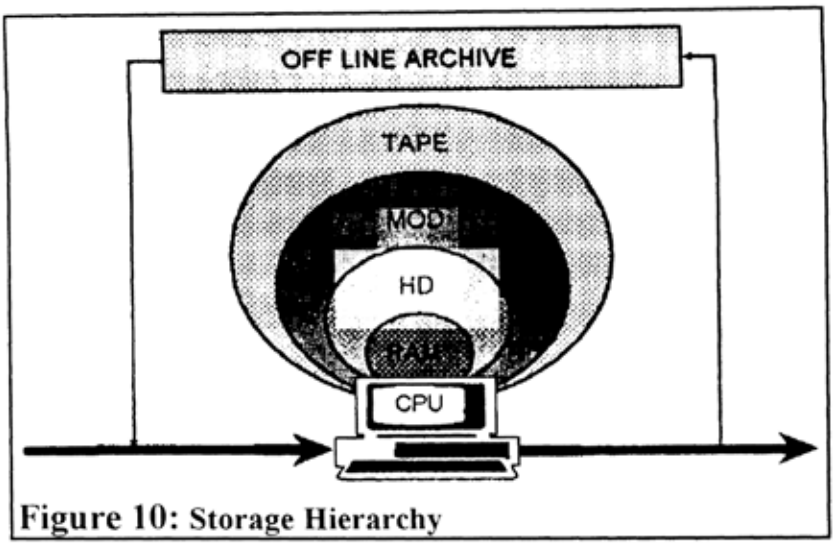



**Figure 10: Storage Hierarchy**

## Hierarchical Storage Management

From outside, the Mass Data File Server appears as a huge virtual hard disk, although the access time is comparitively long. One can ensure, however, that access to a particular data file will not take longer than 3 minutes.

In order to ensure optimum accessability and availability of the stored information, both hardware and software need to be complemented by a so called HSM, a *Hierarchical Storage Management.* The HSM is a software product, designed to monitor and influence the movement of information in the entire system according to statistical criteria.

Figure 10 shows several different storage technologies in hierarchical order. With increasing distance from the CPU (Central Processing Unit) of the computer, storage capacities increase while access time becomes longer.

The HSM will ensure that information accessed more frequently can be retrieved faster compared to that which is hardly ever required. Depending on the system design and the capacity of the various storage media, but also controllable by the system administrator, the information will be moved between hierarchy levels. The more the information is required, the higher in the hierarchy it is stored. Further functions of the HSM are related to data security (Mirroring/Backup) error monitoring (Tape sniffing) and restoration. Repacking of fragmented carriers and migration onto new media are also HSM tasks.

The user can be assured that he will be able to access and retrieve the recorded information under the originally defined file name even after decades. He may not be sure, however, if the information is still obtained from the original storage medium.

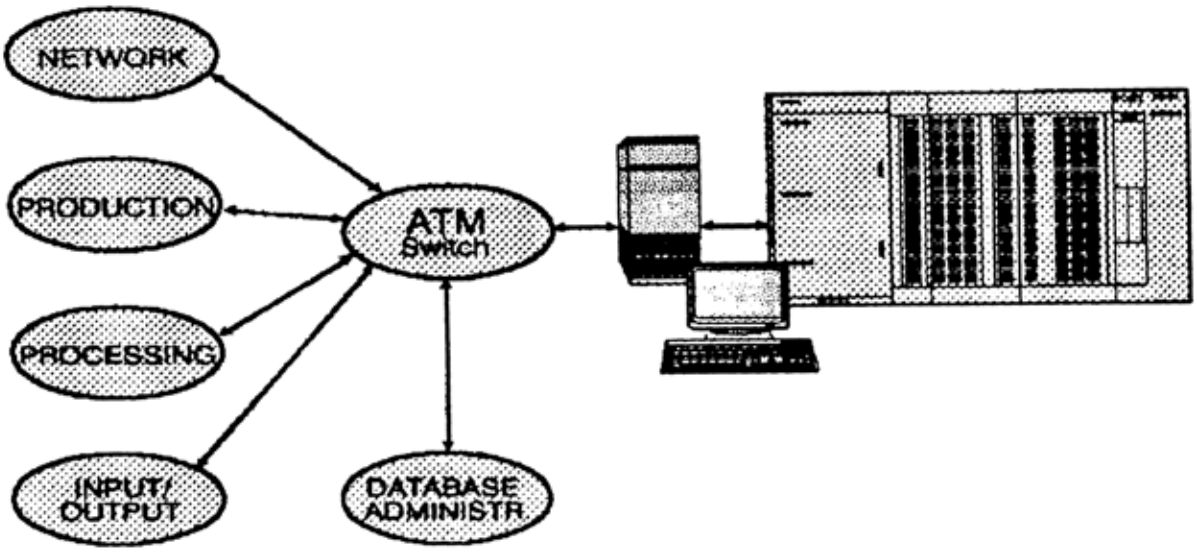



**Figure 11: Mass Storage Archiving System**

# Conclusion

The intention of this paper was to acquaint you with some design considerations and challenges facing future archival policy. The File Server was described as being essentially a warehouse for all kinds of data. The "warehouse" will be nothing but an ample burial ground for data, however, unless it is complemented by the neccessary logistics to administer the flow of data. Figure 11 suggests that the topic is much broader. Every item on the chart is a topic worth developing in its own right.

The technology is here today and affordable. Hence, it is no longer a big challenge. The true challenge for archives is not the new technology but the implicit changes in the organizational structures and the professional environment.

# Computer Assisted Management System for the Commercialisation of the Television Archives at INA

**Denis Frambourt*** and **Jean-Luc Morizur****

*Institut National de l'Audiovisuel, Bry-sur-Marne, France
**Société Générale de Téléinformatique, France

## Summary of Paper Presented by Denis Frambourt and Jean-Luc Morizur

The purpose of this application is to offer a modern computerised management of the process of delivering short archives sequences for reuse in new broadcast programmes.

The Presentation will be in two parts:

- The presentation of the INA Application
- The presentation of the Digital Video Server made by the Société Générale de Téléinformatique, (SGT)

*Denis Frambourt is the Deputy Director of the Technical Direction of INA. He is in charge of the operation of the technical facilities for the television archive. This includes the preservation and restoration of the historic collection as well as the recording and post-production work associated with new programmes.*

*Jean-Luc Morizur was one of the founders of SGT and is the Principal Engineer and Associate Director of the company. He currently oversees the Research and Development Department and is responsible for most SGT products and systems architecture involving software, hardware and DSP technologies. M. Morizur has worked on a number of projects for broadcasters including pay per view systems. Other projects have included NVOD experiments in cable networks and systems for automatic commercial breaks using both terrestrial and satellite technologies.*

# Computer Assisted Management System for the Commercialisation of the Television Archives at INA

Denis Frambourt and Jean-Luc Morizur

## Introduction

Everyday, many producers and researchers come to view television archive programmes at the Institut National de l'Audiovisuel. The reason for these viewings is to select short extracts from the archives which will be used as inserts in new broadcast programmes such as regular live programmes (news, talk shows, entertainment), or historical, sociological and cultural documentaries. At this stage, the clients or the operators note down the start and end timecode or location on the tape of the desired extracts so that a copy can easily be made after viewing. Before copying, the staff of INA check the legal and commercial conditions that apply to the selected programmes. When all the conditions are fulfilled, the pieces of programmes are transferred onto the recording formats required by the clients.

Many different people from the various departments of the Institute are involved in the processing chain. In addition, agreement from authors or from rights owners is required. This means that it can take a long time between request and delivery for some programmes. Every step of the process is described in separate documents making the task of the sales manager, who wants to know how the transaction is progressing, difficult.

In order to improve the service, it has been decided to use computer techniques to handle the different data, not only the information about the processing, but also the documentary data and pictures and sound from selected pieces of archive programmes. Every person involved in the process will be able to handle data by means of a multimedia type PC terminal:

- Technical, copyright and commercial information.
- Documentary information about the audio-visual archives obtained from the TV Archives data base.
- Digital pictures and sound from the archives, converted using bit rate reduction.

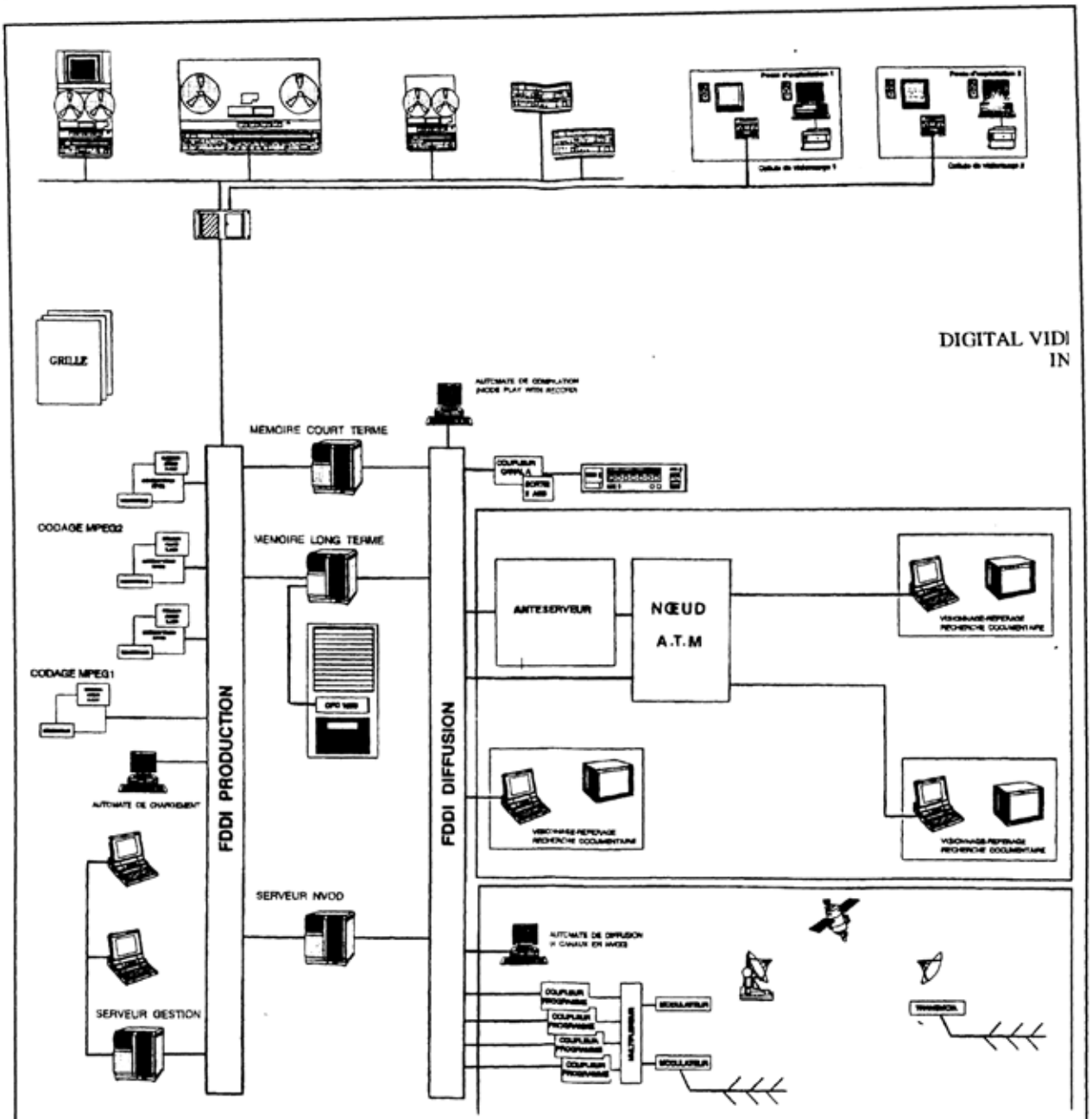



**Figure 1: Schematic of the Digital Video Server at INA**

## Principles of the System

The application is based on the use of two connected sets of equipment

- A digital video server for encoding and storage of television archives.
- A computerised system for data and technical processing management called "Management Server".

The data and technical processing management system with multimedia PC network is connected to the digital video server through a high data rate network.

### Digital Video Server

The digital video server can hold about 50 hours of television programmes with bit rate reduction at 4 Mbits per second. The codec will use the MPEG II standard with bit rate from 1 to 10 Mbits per second. Bit rate reduction has to be decided and in the near future some quality tests will be held to do this.

## Data and Technical Processing Management System

### Viewing Station

From each station it will be possible to:

- Display data about TV programmes to be viewed. Data about archive programmes can be downloaded into the local data base directly from the general archive data base.
- Control video tape players. It is possible to digitise and store programme material in the video server while simultaneously viewing it.
- Input descriptive data about the chosen extract into the local data base.
- Use a scratchpad facility for notes.
- Save information about duration of viewing and formats used for invoicing purposes.

Initially, INA will set up viewing stations close to the archives handling facilities and will offer the users the possibility of viewing pictures before or after encoding with a high level of quality.

### Multimedia PC Terminal

PC Multimedia Terminals connected to the management server will be used by the different departments of INA. They permit the following work:

- Plan viewing sessions and describe required equipment for each session.
- Write letters to obtain agreement from the rights owners.
- Order copies to be made and arrange delivery in the final step of the process.
- Provide statistics and invoices.

Multimedia terminals allow the user to view:

- Low resolution pictures and sound from the digital video server.
- Documentary data from the local server
  - Schedule of the viewing sessions
  - Data concerning the state of process achievement.

## Future Developments

The immediate aim of the new computerised system is to improve efficiency and to increase the productivity of the service devoted to the professionals from broadcasting area. Other services connected to the digital video server will be developed in the near future.

### Online Video Server

This will hold a large number of short archive extracts. Archive extracts selected by users during viewings will be stored in a digital form using bit rate reduction. Extracts will be described In the local data base. It will be possible to search some extracts and to view them on a PC Multimedia terminal connected to the digital video server through the high data rate network.

### Digital Storage of News Programmes for Long Term Archiving

As with many other TV archives, INA will soon have to face the problem of preserving a huge number of old recordings on obsolete formats. This is already the case with two inch video tapes. The problem will soon arise with news programmes recorded on U-Matic 3/4 inch video cassettes. For these programmes, taking into account the technical quality of the recordings, it is possible to consider the use of a digital format with bit rate reduction as a new format for preservation. However, before deciding to use bit rate reduction for long term preservation, it is necessary to assess the compatibility of the present techniques with the quality level required for future broadcasting use.

As MPEG II is now an International standard, an assessment of this coding technique will be carried out in 1995 with the encoding station used for the new digital video server. For this, bit rate reduction will be used at different levels between 2 and 8 Mbits. The aim is to highlight the specific problems which may be encountered with audio-visual archives (noisy pictures, scratches, ageing degradations ... ). At the same time, INA will study the possibility, in the medium term, of using a "permanent", format-independent, digital television archives management system.

# Guest Speakers and Restoration Lectures

# Memory of the World Programme

## Joie Springer

*George Boston:*

*It is my pleasure to introduce our first Guest Speaker - Joie Springer of UNESCO. Joie Springer is the Programme Officer for the UNESCO General Information Programme. This is a very wide ranging programme that covers the activities of archives and libraries of all types. She is representing the Director-General of UNESCO, Federico Mayor, at the JTS.*

*Ms. Springer will be talking about the major new Programme that UNESCO has started to improve the preservation of and access to the documentary heritage of the world - the* Memory of the World Programme.

UNESCO's basic missions is to maintain, increase and disseminate knowledge by assuring its protection and availability for future generations. Library collections and archive holdings are information treasure-houses containing the wealth and diversity of cultures and peoples. They are the memory of the past, the paths we have travelled to build our future and to shape our cultural identity. However, this memory is transient; its loss means an impoverishment of humanity and it must therefore be recorded, preserved and made accessible for posterity.

Enormous losses have already occurred. Some as a result of natural catastrophes such as floods, hurricanes, earthquakes: the recent catastrophe in Kobe in Japan immediately comes to mind. Accidents too, are frequent and fire is perhaps the most feared as it can consume a collection in a sudden blaze. We all know the of the ravages caused by nitrate fires. Less spectacular perhaps but no less devastating however, are the slow fires in modern archives and libraries which are condemning entire collections today: the acidity of paper, the decay of polymers, in fact the whole spectrum of chemical deterioration affecting all information carriers.

Apart from natural disasters and accidents we must not overlook those deliberate acts to destroy our global heritage: the consequence of wars where often the wilful annihilation of a culture is an extension of genocide; ignorance, attempts to rewrite the past or to cover-up certain events (if it is not recorded then it did not happen) and even more tragically perhaps, the lack of means in some countries where there is no other option but to record over existing information fully aware of the damage that is being done but unable to act otherwise. Faced with a situation where countless valuable and unique collections have disappeared and others are inevitably doomed, in 1992 UNESCO created the *Memory of the World Programme* to preserve the endangered documentary heritage. Designed as a new approach to safeguarding the world's heritage while ensuring an almost universal access to it, the programme seeks to compile image banks of endangered collections for reproduction in various forms such as CD-ROMS, videodiscs, postcards, etc. These will be marketed or otherwise distributed with proceeds being reinvested in the programme.

The scope of the programme is therefore quite vast and will involve a variety of partners ranging from users of information: researchers, academics or scholars and the general public, to providers and producers of information, not omitting manufacturers of end products.

Documentary heritage within the scope of the programme covers information recorded on all media. This includes books, manuscripts, newspapers and other textual information; maps, prints, and non-textual information stored on paper-based materials; audio recordings, moving or fixed images as well as oral traditions.

UNESCO is, therefore, called upon to ensure the safeguard of millions of documents, many of them unique or in some way worthy of preservation for future use. It is practically an impossible task requiring far more resources than are available, and we are forced to concentrate on the most endangered collections trying to safeguard them as best as possible and through sales will hopefully obtain additional funding for the programme's continued existence.

The basic concepts of the programme are preservation and access by the most appropriate means. After consultations with different partners, it seems that digitization offers the best solution for the enormous task ahead. In view of the limited resources available, certain criteria have been defined to determine what collections are "most endangered".

The criteria to be considered include: content (the artistic, cultural, literary or scientific value of a work), its national, regional or international significance, context, physical condition, degree of risk (for example, a war zone, disaster area.) and project feasibility (whether it can be carried out in a reasonable period of time). Priority will be given to activities concerning a region, a number of countries or a national project which is of international importance and to an entire collection rather than just individual items. Special consideration will be given to the problem of reconstituting the memory of a people in the case of dispersed or displaced holdings. Combinations of these criteria will determine the uniqueness of the collection or holding and the consequences of its loss for humanity should it become irreparably damaged.

Some preliminary activities are currently underway to enable us to obtain a better idea of the task to be tackled as well as to assist us in mobilizing support for our work by creating an awareness of the problems with which we are confronted. We are first of all preparing an inventory of library collections and archive holdings which have suffered irreparable damage or have been totally destroyed during this century. Earlier losses will be included at a later date if found to be practical; secondly, a world list of endangered collections and holdings, and finally an inventory of ongoing operations to protect the documentary heritage so that duplication and overlapping activities can be avoided. These three lists will be updated periodically and will constitute the basis for the *Memory of the World Programme.*

In addition, as part of the celebrations of the centenary of film, UNESCO's member states have been asked to submit a list of approximately 15 films which they consider to be among the most important or representative of their national cinematographic heritage. There has been a fairly good response so we will publish this inventory later this year, in collaboration with FIAF, for distribution to archival and other institutions.

A three-tiered structure composed of international, regional and national committees has been established to coordinate the implementation of projects. An International Advisory Committee appointed by the Director-General of UNESCO will guide the planning and implementation of the programme, and will make recommendations concerning fund-raising, funding of projects and attribution of the "Memory of the World" label to projects selected, including those not receiving financial support from the programme. The label is intended to be a guarantee of quality serving to ensure the success and wide distribution of the products manufactured and is granted to projects meeting the criteria fixed by the Committee.

The first meeting of the committee in September 1993 outlined the framework of action for the Programme to prepared a strategy to be followed in its implementation. A second meeting is slated to be held in Paris from the 3rd to 5th of May this year to review progress achieved to date.

The International Committee will be assisted by two sub-committees: one for technical questions and one for marketing and finance. The technical sub- committee has already met twice and I will speak of this a bit later on.

National and regional committees will be responsible for the selection of projects for registration with the International Committee, and then for their implementation. In addition, they should increase the general level of awareness of the programme and help in raising funds. An idea of the interest the *Memory of the World Programme* has generated in UNESCO's Member States can be seen from the fact that national committees have so far been formed in twelve different countries from all regions, with regional meetings organized in or planned for Eastern and Central Europe, Asia and Scandinavia.

A number of pilot projects have been initiated as examples of what we hope to achieve under the programme and will be used for promotion of its activities. I will briefly describe some of these.

A demonstration CD-ROM which is now available to the public has been prepared by the National Library of the Czech Republic. It contains samples of valuable manuscripts and other documents from its collections with notes in Czech, English and French. The Library also intends to record some of its most valuable

items on a set of discs thus making these historic works easily accessible without the need to manipulate the originals.

A prototype CD-ROM is being produced to make the Radziwill Chronicle more accessible. This work which retraces the origins of the peoples of Europe, is a rare example of an illustrated Russian medieval chronicle of drawings and almost 600 miniatures. Known since the seventeenth century, it is of tremendous interest to scholars in particular, and there have already been a number of unsuccessful attempts to publish a facsimile version.

A pilot project to protect the nineteenth century press published in Latin America is underway with the collaboration of seven National Libraries. The preparation of a computerized inventory of some 2,000 newspaper titles has been started with a view to their conservation and transfer to microfilm to facilitate exchanges between national libraries and other organizations.

In Yemen, the collapse of a wall of the Great Mosque of Sana led to the discovery of parchment and paper fragments of manuscripts from approximately one thousand different volumes, the oldest of which dates back to the first century of the Hegira; most are extracts from the Koran. With the participation of Germany, some 12,000 fragments have already been restored and a demonstration disk based on a selection of some of the fragments will shortly be produced

An interactive compact disk is being prepared to obtain a multimedia edition of Bulgarian manuscripts evoking Sofia the patron saint of the capital. The documents selected include primarily the facsimile reproduction of some manuscripts in the form of digital images. They are supplemented by reproductions of illuminations, frontispieces and decorative motifs.

I will now conclude by reviewing the more technical aspects of the programme with its two fundamental principles of preservation and access which are interdependent.

The basic steps in carrying out a project within the *Memory of the World Programme* are: selecting and preparing the documents, ensuring that they are stored in an appropriate environment, photographing them where required, digitizing, describing and annotating them, training the personnel required to perform these duties if necessary, translating bibliographic references as required and ensuring that the products which result are distributed as widely as possible. To facilitate this, it has been decided that bibliographic references and other information should ideally be in English and French along with the original language of the collection as a minimum.

The programme must function in compatibility with national

legislation. Since one of the objectives of the programme is to ensure as wide an access as possible to the information, there will be important implications for the owners of rights in the collections or holdings. An agreement must be reached for the technical exploitation of the information without, however, enforcing an excessive protection which will limit access to the documents and be contrary to the principles of the programme. To counter some of the difficulties, it may be necessary to create an international convention of the *Memory of the World*. A decision on this will be made as the programme evolves.

Projects to be funded will require a detailed budget itemizing costs, duration, training and other needs before they can be accepted under the programme. An international fund has been set up in UNESCO to finance some of the programme's projects with priority being given to those having regional or international dimension.

A technical sub-committee has been created to assess the technologies available in order to recommend or set general guidelines and standards for the projects to follow. Another of its tasks will be to ensure compatibility between the different types of systems selected, to permit the free exchange of information.

The committee held its first meeting in June 1994 to examine the methods and techniques of digital preservation. In its deliberations which included a look at preservation standards, mass storage systems, data retrieval and distribution, it was decided that as a more detailed consideration of standards was necessary. Two working groups were set up to prepare technical guidelines with tables for recommended digitization standards and storage requirements based on carriers. One group would work on sound and moving images, the other on texts and fixed images.

During its second meeting, the draft recommendations concerning access and preservation standards prepared by the two working groups were discussed and will be presented to the next meeting of the International Advisory Committee for adoption.

*The Memory of the World Programme* is as yet in its infancy with the most important still ahead. For UNESCO, its potential benefits are enormous: it will allow researchers and the general public to have easier access to important, historical documents; it will facilitate the task of the guardians of our heritage and in the final analysis, the global community whose memory will be preserved for the future.

# The European Commission Information Technology Programme: Multimedia Systems


## Yves Rene de Cotret

European Commission Directorate General III


Dr de Cotret's Presentation consisted of a series of slides containing information about the Information Technology Programme and how the participants in the JTS may be able to to take part. Funding is available to help European institutions that wish to undertake research into aspects of multimedia. Institutions from outside the European Community may also be assisted if they are in partnership with an institution within the Community. Multimedia is defined as being a digital representation of text, graphics, images, speech, music, video, animations, virtual reality etc. which allows separate information streams to be recombined in real time when used.

Further information can be obtained from the European Commission Directorate General III in Brussels.

*Yves Rene de Cotret was born in Verdun, Canada in 1945. He graduated from the University of Liege in 1970 and was an Assistant Professor in the the Science Faculty at the University working on speech recognition until 1978. He received his Doctorate in 1977.*

*From 1978 until 1989, he worked in industry managing R&D projects in the field of electronic document processing and data over radio links for mobile applications on land, at sea and underground.*

*From 1983 Dr de Cotret participated in and managed several projects within the European Community ESPRIT, RACE and DRIVE Programmes and for the European Space Agency. His last post was as R&D Manager for SAIT Electronics of Brussels.*

*In 1989, he joined the European Commission and has been successively responsible within the ESPRIT Programme for the Workstation Area, the Results and Annual Report Area and the Peripherals Area. He is currently responsible for the Multimedia Area of the Information Technology Programme.*

# Restoration Lectures

As part of the JTS, three restored programmes - two television and one film - were shown at public viewings. Each programme was introduced by a member of the team that had worked on the restoration.

# Steptoe and Son

**Introduced by Steve Bryant**

*Steptoe and Son* was a long running BBC comedy series made over 25 years ago. The programmes centred on the stormy relationship between a father and son who ran a rag and bone yard in West London - they collected scrap material.

Several episodes, including this particular episode, had been wiped by the BBC. The BBC discovered that the writers had non-broadcastable copies on the obsolete Philips A format domestic video tape system. The National Film and Television Archive were asked to help with the restoration of the programmes. However, neither the BBC or the NFTVA had a working A format machine. Brian Jenkinson and his colleagues at the NFTVA constructed a player by cannibalising parts from several machines and, by using modern electronics, were able to produce copies suitable for transmission.

In the absence of Brian Jenkinson due to ill-health, the programme was introduced by Steve Bryant, the Keeper of Television at the National Film and Television Archive.

# Restoring Doctor Who to Colour

## Introduced by Ralph Montagu

The project I became involved with came about because of a very particular, and really very improbable, combination of circumstances. For me this all started, as it did for many other then school boys in the 1960's and 70's, when our interest in a particular television programme became so great that we just had to make our own recordings.

The programme in question, a science fiction serial called Doctor Who, was hardly ever repeated and by making a recording on our greatly cherished audio tape recorders we could re-live the excitement of each episode, relying on our memories for the pictures.

I am not sure if we ever expected to view any of these episodes again, although we occasionally heard of old Doctor Who episodes being screened overseas, proving, or so we thought, that the BBC still had the original tapes or films saved for posterity.

Twenty years later, this former school boy still has his collection of audio tapes, but the BBC does not have all its masters. Until fairly recently, videotape was regarded as too expensive for the permanent archiving of all programmes, and despite the launch of home video recorders in 1973, no one in the corporation anticipated the commercial potential for old programme material through Home Video sales, screenings on satellite and cable, or even terrestrial repeats.

The result was that many master tapes were wiped and re-used, and much worse, a lot of film recordings were simply junked. These included many of the Doctor Who stories made in black and white, and of 128 colour episodes made in Jon Pertwee's era (between 1970 and 1974), only 75 episodes still exist in their original form. The other Pertwee episodes have not been lost completely, but only survive in the format supplied to overseas stations from whom they were returned.29 missing episodes were recovered in the American NTSC format which, being 525 line definition, offers less picture clarity than our 625 line PAL format.

At least those are in colour; another 29 colour episodes have only survived in the form of black and white film recordings made for countries who had not made the switch to colour.

For those of us who can remember watching the story when it was originally broadcast in colour, there is something very dissatisfying about seeing it again in black and white.

Fortunately the efforts of Dr. Who collector Ian Levine have partially saved the day.

Back in 1978, he heard that an American station was broadcasting some of the Pertwee stories in colour. Home video recorders were still quite a new thing, but Ian persuaded a friend to hire one of the new Sony Betamax machines so that some off air recordings' could be made.

Four complete stories were recorded, but enquiries made soon after revealed that the BBC's American distributors, Time Life, had wiped their mastertapes, as had the broadcaster KCET. Consequently, the only surviving colour copies of these stories were on NTSC Betamax cassettes; not broadcast quality, but better than nothing.

So, for no less than 21 episodes, we had:

- broadcast quality black and white film recordings, and
- non-broadcast quality colour tapes

Inevitably, several people began think about the possibilities: could the colour from the American tapes could be combined with the sharper images of the black and white film recordings? In theory, the answer was yes, but until the advent of today's television technology, it would have been very difficult in practice.

But before explaining how we tackled the project, perhaps a brief technical explanation would be helpful for the non-technically minded, of which I am one.

A colour TV picture really consists of two main components: a highly detailed black and white image, known as the luminance, over which is laid a much less detailed colour image. Because the brain responds much more strongly to luminance changes than to colour changes, the detailed luminance image fools you into believing that you are looking at a highly detailed colour picture. Traditionally, TV signals have been recorded, processed and edited as composite signals, in which the luminance and colour signals are combined into a single electronic signal. However, the modern trend in video post-production is towards a component way of working, in which the luminance and colour signals are kept separate, and can therefore be processed separately.

The opportunity arose when my department, Graphic Design, created some post-production suites equipped with 4 Betacam machines, as well as a mixer, effects equipment, and Quantel Paintbox, all of which were needed in one place to carry out a project of this kind.

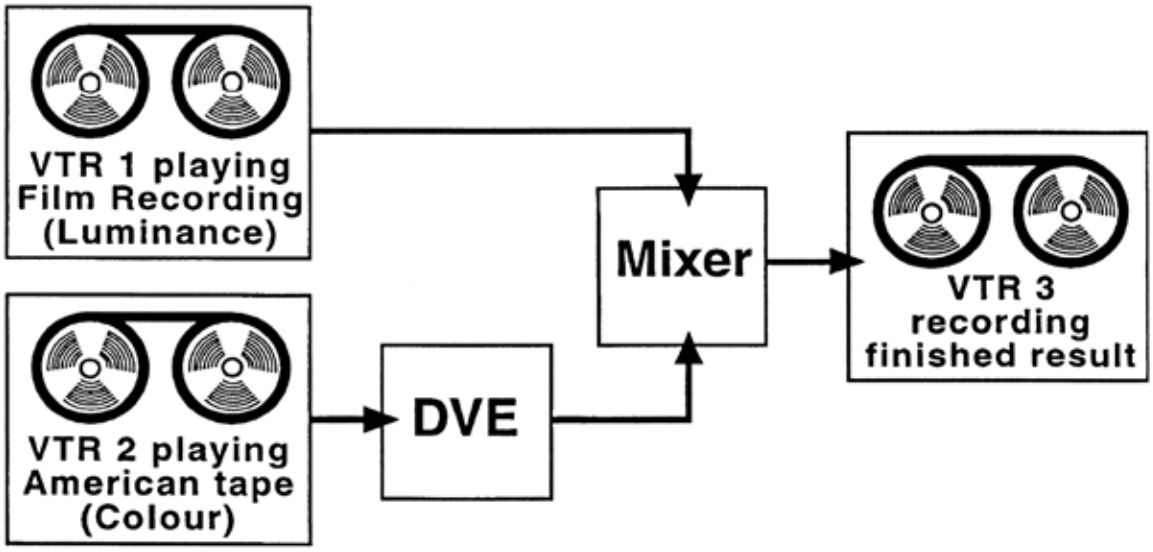



**Figure 1: Combining the Film Recording with the NTSC Colour Tape**

In the ideal world we would have worked in a component digital format, such as D1, but prices dictated Betacam, before the availability of digital Betacam. However the important thing was that we had component equipment which would allow us to combine the separate luminance and chroma signals.

Theoretically it was just a matter of playing a tape of the film recording in one machine, a tape of the colour signal in a second machine, combining these in a mixer and recording the result. In practice however it wasn't that easy; the two images didn't line up.

You might think that the fault lay with the colour tape, which apart from being a domestic off-air recording, had been converted from PAL to NTSC and back again. In fact the problem was due to the characteristics of the film recording.

The film recording process (known as Telerecording in the UK or Kinescopes in North America) was developed in the late 1950's as a way of recording television pictures, which up to that time had to be broadcast live. The process started with a film camera pointed at a television screen, but was developed into a highly sophisticated system whereby each frame of film was synchronised to capture both fields of picture information.

For many years, this was the principal means of archiving programmes, since video tape was considered too expensive not to recycle. Even after the change to colour, black and white film recordings were made of most programmes, almost as if the colour was an added extra which really didn't need to be kept. Colour film recordings were technically possible, but were never widely made at the BBC.

So what are the characteristics of a film recording? The pictures can be very crisp but the process of transferring images from a cathode ray tube to film, and back again via telecine, results in a series of subtle distortions over the picture surface. The edges of the picture are also cropped by about 3%, making the image appear to be slightly zoomed-in when compared with the colour copy. Viewed in isolation it is difficult to detect these changes, but when overlaid with the colour image, it was clear that one was out of register with the other.

To compound the problem, the film recordings for each episode were made on different days, and on different machines, meaning that each episode had a different set of distortions!

The solution was to use a Digital Video Effects Generator, otherwise known as DVE. The use of DVE is now very common in TV for twisting and flying pictures around the screen. Howeve,r we used the system more discreetly to align one picture source with another. The lining-up process was always the problem, and even after an hour of fine adjustment, it was impossible to get an exact match - the distortions were simply too complex. Fortunately, the chroma information is so soft and fuzzy that a certain margin of error was largely undetectable once the two sources were married together.

The quality of these 16mm film recordings varied in other ways: We always tried to work from new prints but whether these were struck from the original negatives is uncertain. In some cases the negatives no longer exist, leaving prints from overseas as the best surviving copies; from these an inter-neg would be made from which new prints can be struck.

Where the episodes included film sequences, it was not uncommon to find the pictures out of phase, so that the first field coming from the in-playing telecine was recorded as the second field on the film recording, and the second field (which, being film, is the same as the first) was recorded on the next frame of the film recording as field one. This doesn't matter on static material but can result in blurring where there is movement - unfortunately, there is nothing that can be done about this.

Another problem was that the resolution on some of the film recordings was so good that it picked up some of the original components of the colour sub- carrier, creating a strobe effect. We successfully eliminated this using a sub-carrier notch filter.

Before showing you some samples, perhaps this diagram will help to explain the numerous generations which this material has gone through (Figure 2).

In those days, any location work was shot on 16mm colour film, from which a print was made after editing. That print was then

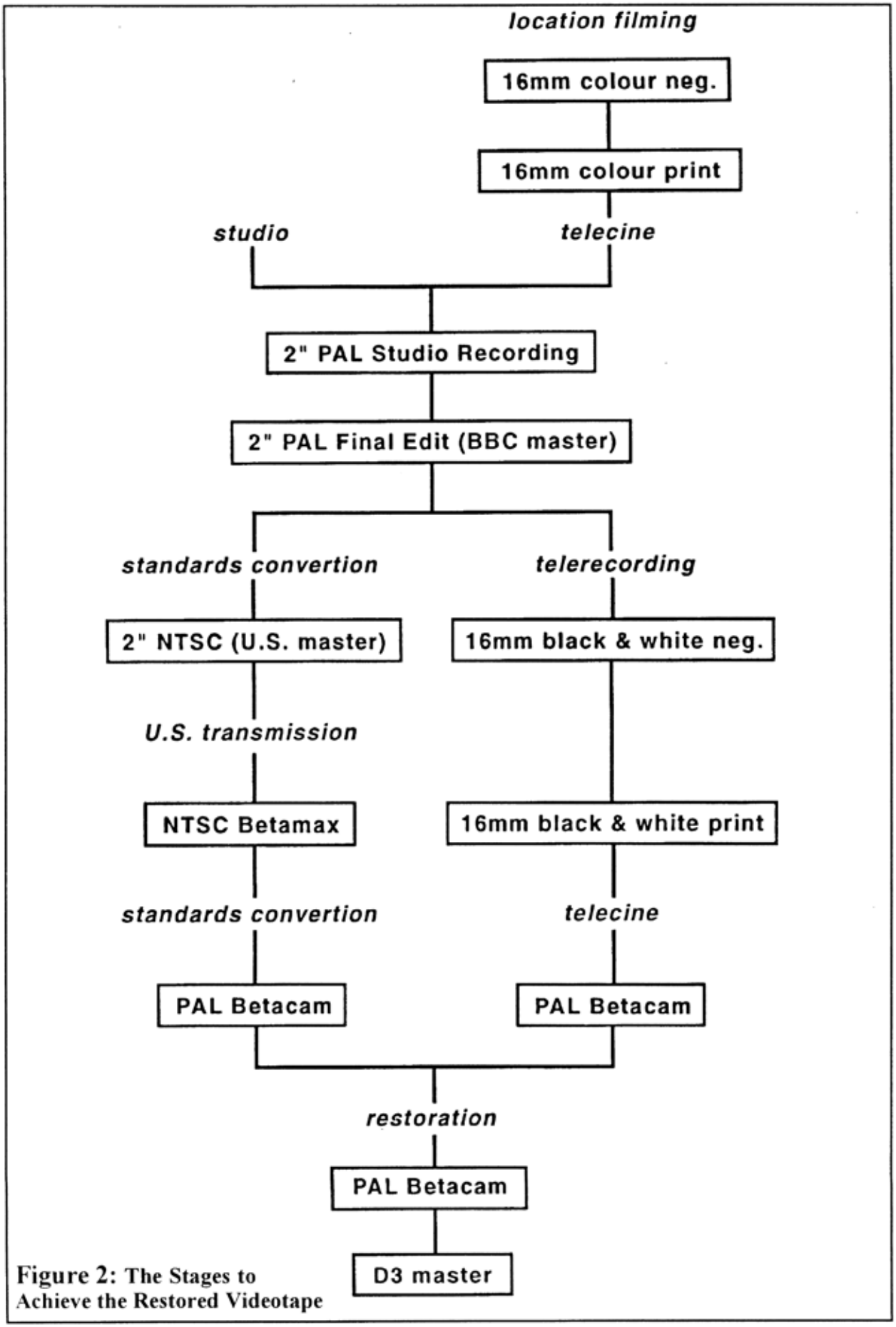



**Figure 2:** The Stages to Achieve the Restored Videotape

run on telecine and played into the studio as an insert. This, together with studio shot material, was then recorded on 2 inch video tape from which an edited master was made.

For overseas sales, copies were either made onto 2" tape (NTSC standard for the American market) or black and white 16mm neg, from which prints were made. Where we recovered copies for colour restoration, these were taken from Betamax off-air recordings which then had to be re-converted to from NTSC to PAL.

Two Betacam video players were run in sync, the first machine containing a tape of the film recording, the second containing the colour tape (now re-converted to PAL). The colour signal then went through the DVE to be aligned with the Film recording, then the colour and luminance were combined in a mixer, and the finished result was recorded on a third machine.

The final stage involved copying the Betacam tape to D3 (which is the BBC's digital standard) and colour grading it at the same time.

The sound usually came from 16mm sep mag, supplied with the film recordings, but in some cases we believe this to have been copied off the optical track, which doesn't produce the best quality. However, it was significantly better than the sound off the NTSC tape, which we only used as a last resort.
The picture quality of the American colour recordings was not consistently good either, and in a number of places we had to stop the recording process to make frame-by-frame repairs. Where this only affected a few frames, we could usually rectify the situation by using the Paintbox, but in one instance (episode 5 of Doctor Who and the Silurians) 90 seconds of colour was affected by interference which made it unusable. After much head scratching and unsuccessful experimentation, we decided to have the offending section Colorised' by American Film Technology, the leading company in the field.

Unlike the colorisation of black and white feature films where the colours are literally invented, the colours added to this sequence were based directly on the original tape. Despite the patterning, it is still possible to tell what the colours should be.

Unfortunately, I can't tell you much about the colorisation technique since the company keeps the details of the process a closely guarded secret. It seems they are able to assign a colour to an area within a defined edge, which is then followed as the object moves around the screen. The major weakness of the system becomes apparent with objects which should alter in tone and colour across their surface. Since they are only able to assign a single colour to each shape, objects like the human face appear rather flat.

There are still 13 other Doctor Who episodes which were made in colour, for which we either have no colour tapes (Planet of the Daleks episode 3, Invasion of the Dinosaurs episode 1, and Mind of Evil all episodes), or in the case of The Ambassadors of Death, colour tapes which are blighted by interference. For the Doctor Who fans amongst you, I can assure you that we haven't given up on the idea of restoring these episodes, but whereas the work done so far has been relatively low budget (about £1000 an episode) the processes involved in any future work will inevitably be much more expensive and labour intensive.

There are, of course, two other good reasons for waiting; first colorisation technology can only improve (and perhaps it will come down in price) and second, there is always the possibility that a genuine colour tape will materialise from somewhere!

Needless to say, many other BBC programmes dating from the 1970's and before were wiped, although some of these were first sold overseas. So, if you come across BBC material on film or 2 inch tape, please contact the BBC's Film & Videotape Archive, it might be missing!

By now, I hope that you will have gathered that the work I've described has very much been the product of a team. I have to declare that as someone with a training in Graphic Design, a lot of what I've described would not have been possible without the technical expertise of colleagues. I would particularly like to thank Steve Roberts who has assisted on many fronts, including the preparation of this paper. Needless to say, we are all Doctor Who fans!

Having demonstrated the improvements which can be obtained with archive material, we are now talking to colleagues in the BBC's Research department about devising a special process for the re-conversion BBC material recovered on 2" NTSC tape. In addition to 29 episodes of Doctor Who there are several other BBC programmes only existing on this format, including Up Pompeii and Moonbase.

Although a normal standards converter can be used, we believe there is scope for improving on this by using a system specifically designed to unscramble NTSC material which started life in PAL. Mike Croll, from the BBC's R&D department will be talking about this tomorrow.

# Snow White and the Seven Dwarfs

## Introduced by Scott Grodner

By special permission of the Disney Corporation, the JTS was allowed to hold a special screening of the newly restored animated film. The film had been digitally restored by the Cinesite Digital Film Centre using the Kodak Cineon process. Mr Grodner of Cinesite gave a short explanation of the work carried to digitally clean and restore the film to its original condition.

# List of Participants

## Arranged by Country

### AUSTRALIA

**Kevin Bradley**
National Library of Australia
**Ian Gilmour**
National Film and Sound Archive
**Mark Nizette**
National Film and Sound Archive

### AUSTRIA

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Österreichischer Rundfunk
**Heinz Kämpfer**
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Austrian Academy of Sciences
**Franz Lechleitner**
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Österreichisches Filmarchiv
**Dietrich Schüller**
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*JTS95 Organising Committee*

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Directorate General III
European Commission
**Christian Dimitriu**
FIAF
**Jean-Pierre Verscheure**
INSAS

### BRAZIL

**João Socrates Oliveira**
Cinematica Brasiliera

### CANADA

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Manitoba Provincial Archives
Moving Images and Sound
**Ernest Dick**
Canadian Broadcasting Corporation
**Roger Easton**
Moving Image, Data & Audio
Conservation Division
National Archives of Canada
**James Hoagland**
Vajradhatu Archives
**William O'Farrell**
Moving Image, Data & Audio
Conservation Division
National Archives of Canada
**Gilles St-Laurent**
National Library of Canada
**Joann Watson**
Public Archives of Nova Scotia

### CROATIA

**Branko Bubenik**
Croatian Radio-Television

### DENMARK

**George Brock-Nannestad**
School of Conservation
**Birte Christensen-Dalsgaard**
Statsbibliotek
**Morten Jacobsen**
Dancan International Sales
**Uffe Lumholt Madsen**
Danish Film Museum
**Birgitte Rathsach**
Danmarks Radio TV Arkiv og
Research Center
**Lise-Lotte Westh**
Danmarks Radio

### EIRE

**Sunniva O'Flynn**
The Irish Film Institute
**Liam Wylie**
The Irish Film Institute

### FINLAND

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Yleisradio Record Library
**Mats G. Lindquist**
Åbo Akademi University
**Timo Muinonen**
Finnish Film Archive
**Jouko Savijärvi**
Yleisradio Oy TV2

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de Toulouse
**Jean-Francois Allouis**
Institut National de l'Audiovisuel
**Philippe Boulanger**
Videothèque de Paris
Centre Audiovisuel de Paris
**Jean-Hugues Chenot**
Institut National de l'Audiovisuel
**Bruno Despas**
Centrimage Laboratories
Neyrac Films
**Jean-Marc Fontaine**
Bibliothèque National de France
*JTS95 Organising Committee*
**Denis Frambourt**
Institut National de l'Audiovisuel
*JTS95 Organising Committee*
**Thierry Gatineau**
CTM
**Laurent Gignoux**
Vectracom
**Gérald Grunberg**
Dépt de la Phonothèque et de
l'Audiovisuel
Bibliothèque Nationale de France
**Claude Huc**
French Space Agency
**Bertrand Lavedrine**
Centre de Recherches sur la
Conservation des Documents
Graphiques
**Jacques Lemaire**
Centre National d'Evaluation de
Photoprotection
**Jean-Luc Morizur**
Societé Générale de
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**Philippe Poncin**
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**Vincent Prost**
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