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ABSTRACT

This report is intended to give the preservation community an overview of the most significant preservation science research that has been conducted in the last five years. The primary focus is on developments in Australia, Europe, and North America. The report presents an overview of recent research in the preservation of three information carriers: paper, film and photographic materials, and magnetic tape. Chapter 2: Paper, Chapter 3: Film and Photographic Materials, Chapter 4: Magnetic Tape, and Chapter 5: General (other materials) present an overview of preservation science activities. Under each of these major divisions, the research items in each of the preservation categories--decay, treatment, and storage--are presented in alphabetical order. The data included in this overview present the main aspects of the preservation science activity in question, including the names of the research institutes and scientists involved; the background, goals, and main results of the research performed; and references to crucial publications. Chapter 6, "Trends and Gaps," outlines research trends and knowledge gaps identified in the process of preparing this overview. Appendixes include the names and institutional affiliations of the individuals mentioned in the report and an index of projects undertaken by each institution. (Contains 119 references.) (AEF)

Preservation Science Survey

An Overview of Recent Developments in Research on the Conservation of Selected Analog Library and Archival Materials

by Henk J. Porck and René Teygeler

December 2000

Council on Library and Information Resources
Washington, D.C.

About the Authors

Henk J. Porck studied biochemistry at the Free University (VU) of Amsterdam. His Ph.D. thesis was a biochemical-genetic study at the VU Medical Faculty Department of Anthropogenetics. In 1983 he was appointed conservation scientist at the Koninklijke Bibliotheek (KB), the National Library of the Netherlands in The Hague. His research on paper preservation has included studies on deacidification, artificial aging, ink corrosion, and discoloration. In 1991 he became curator of the KB Paperhistorical Collection. His work in paper history has concentrated on the investigation of historical sources about the quality of nineteenth-century paper and on the classification and identification of handmade decorated papers.

René Teygeler started his academic career with a study in sociology and social psychology at Utrecht University. In 1988 he was appointed teacher in bookbinding and graphic techniques at the Amsterdam School of Printing. He completed his education as a book and paper conservator at the State School for Conservators in 1993, and was appointed conservator at the Koninklijke Bibliotheek in The Hague. He continued his academic training in anthropology at Leiden and Utrecht University, and obtained an honorary degree in 1996. His research projects in preservation concentrated on the tropics in general and non-Western manuscripts in particular. He has studied writing materials from South and Southeast Asia, and was involved in a research project on Indonesian writing materials at Leiden University. In 1997 he started the consultancy firm *Paper in Development* and has since advised many projects in developing countries on preservation, papermaking, and book production.

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Contents

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Preface

Maintaining original physical objects—evidence or artifacts—for scholarly use in the future remains a primary responsibility of research libraries, archives, and museums, even as more and more information is created in digital form. Most of our recent history, the record of the nineteenth and twentieth centuries, is kept on film, magnetic tape, and paper.

Today, great sums of money are being spent to digitize materials for broader access. In many cases, electronic availability has boosted demand for the original. Nevertheless, concern with preserving the original seems to have fallen out of fashion. In the United States in recent years, digitization projects and acquisition of electronic resources have received greater emphasis than has traditional preservation. We are concerned that new interests—both of local institutions and of funding agencies—may jeopardize preservation budgets. It is therefore more important than ever that funds for preservation be spent wisely on measures that are appropriate, effective, safe, and economical.

In commissioning the Koninklijke Bibliotheek to undertake this study, the Council on Library and Information Resources aimed to provide information on recent significant developments in the preservation of analog library and archival materials as well as a summary of informed opinion concerning where there are significant research gaps in preservation science. The review focuses on work being done in North America, Europe, and Australia. It is intended for those who make decisions about preservation as well as the foundations and other organizations that support such work. Recognizing that this survey cannot convey the full scope or detail of the research noted, the authors have provided contact information for the individuals and institutions mentioned in this survey and a list of references.

I am deeply grateful to the authors for their extensive and careful research, and to the Koninklijke Bibliotheek for its cooperation and support for this project.

Deanna Marcum
President

Glossary of abbreviations

AMIA	Association of Moving Image Archivists
ASTM	American Society for Testing and Materials
BPS	Blue Pink Scale
CA	controlled atmospheres
CCI	Canadian Conservation Institute
CGSB	Canadian General Standards Board
CLIR	Council on Library and Information Resources
CMI	critical moisture indicator
CRCDG	Centre de Recherches sur la Conservation des Documents Graphiques
DEZ	diethylzinc
DP	degree of polymerization
DRIFT	diffuse reflectance infrared Fourier transform spectrometry
DSC	differential scanning calorimetry
ECF	elemental chlorine-free
EOL	end-of-life
EtO	ethylene oxide
FICA	Film Institute Conditioning Apparatus
FPL	Forest Products Laboratory
FTIR	Fourier transform infrared spectrometry
GC/MS	gas chromatography coupled to mass spectrometry
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
IPM	integrated pest management
IPI	Image Permanence Institute
ISR	Institute for Standards Research
KB	Koninklijke Bibliotheek, The National Library of the Netherlands
LACLEPA	laser cleaning of paper and parchment
LE	life expectancy
MA	modified atmospheres
NARA	National Archives and Records Administration
NICH	Netherlands Institute for Cultural Heritage
NML	National Media Laboratory
NYPL	New York Public Library
PAT	photographic activity test
RH	relative humidity
SEPIA	Safeguarding European Photographic Images for Access
TGA	gas thermogravimetric analysis
TLC	thin-layer chromatography
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappellijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TWPI	time-weighted preservation index
UPAA	Universal Procedure for Archive Assessment
VELOXY	Very Low Oxygen
VOC	volatile organic compound

CHAPTER 1

Introduction

Summary

This report presents an overview of recent research in the preservation of three information carriers: paper, film and photographic materials, and magnetic tape. It covers significant developments internationally over the last five years and concentrates on emerging technologies that have the potential for large-scale application. For each information carrier and for the materials in general, the research items are listed in three categories: decay, treatment, and storage. The research items are ordered alphabetically within each category. The major limitations of the survey—the availability and accessibility of relevant information—and recommendations for follow-up activities are noted in the introductory sections to the report.

With respect to paper, the preservation science overview emphasizes the following topics: accelerated aging, indoor air pollution, ink corrosion, techniques to monitor the degradation process, methods of disinfection, laser cleaning, and mass deacidification. For film and photographic materials, the report emphasizes stability and risk assessment of nitrate and acetate film, the vinegar syndrome, studies concerning daguerreotypes, and climate control. For magnetic tape, life-expectancy studies and quality standards are emphasized. Topics relating to materials in general include indoor air pollution, disinfection by oxygen reduction, and climate conditions and standards.

The final chapter summarizes current trends and knowledge gaps in preservation science. There is a clear shift in preservation research toward large-scale passive conservation. Research has increasingly become integrated into preservation policy and management, and there is now greater emphasis on interdisciplinary approaches, multilateral cooperation, and preservation funding and education. With regard to the study of paper deterioration, the focus of paper preservation research has shifted from hydrolytic to oxidative degra-

dation processes. Finally, especially in Europe, there has been less research on the preservation of film, photos, and magnetic tape than there has on paper preservation.

The following areas emerged as needing special attention: research into the active conservation of individual artifacts, standardization of accelerated-aging tests, effects of solvents and solvent residues, further development of nondestructive microanalytical tools to monitor degradation, side effects of large-scale scanning of original materials, standards for paper deacidification and the required testing procedures, determination of the life expectancy of magnetic tape, and elucidation of typical non-Western conservation problems. Finally, the importance of an optimal interface between preservation science and conservation practice and policy is stressed.

Objectives

The multitude of preservation research activities being carried out worldwide indicates an international awareness of the need for scientific tools to tackle the problem of degradation of the world's cultural heritage. Many researchers and research institutes are making efforts to supply conservators and restorers of archival and library materials with properly tested means to treat individual artifacts as well as with techniques for mass conservation. Research is providing new insights into why and how objects deteriorate and is informing the development of new active and passive (preventive) conservation procedures.

One drawback to preservation-directed scientific enterprise is the lack of an easily accessible overview of all the activities. In the absence of such an overview, there is a risk that research activities may be duplicated, or that decisions about conservation practice may be uninformed. In addition, a good overview is needed by those who are seeking suitable partners with whom to set up joint research projects. Finally, such a document may serve as a guide for funding organizations that are establishing criteria for project support.

For these reasons, the Council on Library and Information Resources (CLIR, Washington, D.C.) requested the Koninklijke Bibliotheek, The National Library of the Netherlands (KB, The Hague) to prepare a preservation science overview. CLIR formulated the objectives and scope of this project in consultation with the KB.

This report is intended to give the preservation community an overview of the most significant preservation science research that has been conducted in the last five years. The primary focus is developments in Australia, Europe, and North America. The target audience includes policy makers, library directors, archivists, chief librarians for preservation, preservation administrators, curators, preservation specialists, and conservation scientists. The survey focuses on developments in methods for preserving analog materials held by libraries and archives on paper, film, and magnetic tape. The report does not address the preservation of digital data or of optical media. It concentrates on emerging technologies that have the poten-

tial for broad application, rather on those that are relevant to only a subset of library and archival materials. The final section of the report is intended as a critical evaluation of the survey and an attempt to indicate areas in greatest need of further research.

Setup and approach

To facilitate the systematic collection and arrangement of data, the survey authors created a matrix covering the specific materials in question—paper, film and photographic materials, and magnetic tape. A fourth field was included for information on library and archival materials of a more general nature. The preservation science activities for each type of material were divided into three categories: decay (cause and mechanism of degradation); treatment (active conservation); and storage (passive conservation, damage prevention).

In gathering information, the survey investigators relied primarily on collections and databases of specialist literature, on data from the Internet, and on interviews with researchers and staff of research institutes. The amount of material that could be gathered was limited by the fact that the required information was not always readily available, or accessible. Another limitation was the willingness and ability of the researchers and research institute staff to provide the requested information in a usable format and on time. Because of these inherent limitations, the work of individuals and institutes that actively disseminate information and that take part in the international preservation science community dominates this overview.

The survey focuses on research done in Australia, Europe, and North America. The investigators do not wish to imply that significant research is not being done elsewhere. The challenges of gathering comprehensive information in several languages, and from great distances, argue in favor of creating an international database of preservation science research to which scientists everywhere can contribute.

Outline and outlook

Chapters 2-5 of this report present an overview of preservation science activities. Paper is the first material discussed; it is followed by film and photographic materials, magnetic tape, and general (other materials). Under each of these major divisions, the research items in each of the preservation science categories—decay, treatment, and storage—are presented in alphabetical order. The data included in the overview present the main aspects of the preservation science activity in question, including the names of the research institutes and scientists involved; the background, goals, and main results of the research performed; and references to crucial publications. Chapter 6 outlines research trends and knowledge gaps identified in the process of preparing this overview. The appendixes include the names and institutional affiliations of the individuals mentioned in the report, and an index of projects undertaken by each institution.

This survey offers only a snapshot of what is going on in the complex field of preservation science. Expanding this overview and converting it into a lasting and up-to-date instrument for research and policy would require that it be continued on a more structured basis. The best means to do so would be through the creation of an electronic database. The idea of such a database has not been broadly discussed, and its construction and maintenance would be a tremendous effort. Its viability would depend on the response from the field and prospective participants' willingness to cooperate in such a venture.

CHAPTER 2

Paper

Decay

Accelerated aging and rate of degradation

Accelerated aging speeds the natural aging process of paper by subjecting it to extreme conditions in a climate chamber. Accelerated-aging tests are often used to determine the permanence (i.e., the rate of the degradation) of paper and to predict the long-term effects of a particular conservation treatment; however, there are many questions about the actual predictive value of these tests. Recently, Henk Porck reviewed the various methodologies for accelerated aging and current discussions in the preservation science community regarding this subject (Porck 1999). Several issues are worth mentioning.

There is a fundamental problem in the use of accelerated aging. While the Arrhenius principles apply to the kinetics of chemical transformations, the complex properties of paper that are often registered in accelerated aging (e.g., folding endurance, tear resistance, and paper discoloration) cannot be simply and unambiguously related to its chemical composition. Nonetheless, studies such as those at the Canadian Conservation Institute (CCI), in Ottawa, have indicated that, under certain conditions, the rate of the changes of such paper characteristics does relate to the chemical processes that take place during accelerated aging. On this basis, it is assumed that the principles of chemical reaction-kinetics do apply in the practice of accelerated-aging analysis (Zou 1996). Andrzej Baranski and others from the Jagiellonian University (Cracow, Poland) have reported on recent progress in the methodology of kinetic studies of cellulose degradation (Baranski et al 2000).

A complicating factor is the way in which the paper is exposed to the aging conditions. Confirming earlier studies from the Library

of Congress (LC, Washington, D.C.) and the Netherlands Institute for Cultural Heritage (NICH, Amsterdam), investigations at the National Library of Australia (Canberra), the Slovak National Archives (Bratislava), and the Koninklijke Bibliotheek (The Hague) have shown that paper in stacks (i.e., books) ages differently than do single, loose sheets (Brandis and Lyall 1997; Hanus et al 1996; Pauk and Porck 1996). Some of these studies have shown that under both accelerated and natural aging conditions, the center of a stack of paper undergoes greater deterioration than do the regions located near the outside.

An interesting line of research in this context is the comparison of identical copies of books that, as part of separate library collections, have been stored under different conditions and show different stages of deterioration. Besides offering insight into the effects of environment on the rate of the natural aging of paper, the results of these studies may also indicate which environmental factors are responsible for the observed differences in aging, and thus in the rate of decay. Such comparative investigations can be of indirect value in developing reliable accelerated-aging methods. A good example is the study of pairs of books from the collections of the New York Public Library (NYPL) and the Koninklijke Bibliotheek, performed by the Koninklijke Bibliotheek in collaboration with the TNO Institute of Industrial Research (Delft, the Netherlands). This investigation concluded that the faster deterioration of the paper in books in the NYPL was caused by a higher concentration of the air pollutant sulfur dioxide, in combination with low or fluctuating high and low relative humidity (RH) in the NYPL storage rooms (Havermans 1997; Pauk and Porck 1996).

Accelerated aging of paper has commonly been done under a variety of temperatures and RHs. Because chemical paper degradation reactions vary according to these conditions, the validity of extrapolating results of accelerated aging to natural aging has severe limitations. A promising approach to the comparison between natural and accelerated aging is found in the ongoing research of David Erhardt and others at the Smithsonian Institution, Smithsonian Center for Materials Research and Education (Suitland, Maryland, USA). Their studies are based on the premise that the results of accelerated aging can serve as a basis for reliable predictions about natural aging only if the applied accelerated-aging method speeds the deterioration of paper without fundamentally changing the process. This means that every individual reaction involved in the decay ought to be accelerated by the same factor, and that the relationships among the reaction velocities must be kept constant. The investigations involved extended comparisons of the effects of different accelerated-aging methods and monitoring of the various degradation reactions by means of sensitive measuring equipment. It is expected that the results of these studies will form a basis for the formulation of more uniform and relevant accelerated-aging protocols (Erhardt et al 1999).

A research program at the Institute for Standards Research (ISR) of the American Society for Testing and Materials (ASTM) is focusing

on the development of accelerated-aging tests (Arnold 1996). Its purpose is to develop testing techniques that will make it possible to develop standards for permanent paper that are based on performance rather than on composition. This program is committed to the development of tests in three areas: the aging of paper, the effect of light on paper, and the effect of environmental pollutants on paper. A wide range of acid and alkaline papers was prepared for the series of collaborative projects.

The ASTM has also set up a natural-aging project. For the next 100 years, 10 North American institutions in different climates will store volumes of 50 test-paper types and submit monthly and yearly storage condition reports. Throughout this time, specimen pages will be extracted from each site and tested for optical and physical durability (McCrady 1999).

As part of the ISR project, the LC has developed an accelerated-aging test for paper that it believes offers several advantages over currently available tests. Instead of relying on expensive aging chambers that often lack the desired precision in maintaining preset RH levels at high temperatures, the LC investigators retain control of moisture concentration around paper at elevated temperatures by sealing paper samples inside airtight glass tubes. These tubes have the added advantage of retaining degradation products, as LC researchers believe books do as they age naturally under ambient storage conditions. They have compared the chemistry underlying the aging of paper in loose sheets, book-like stacks, and within airtight glass tubes with the natural aging process by chemical analysis of the degradation products that result in each case. The data demonstrate that aging paper within airtight glass tubes simulates natural aging better than does aging of paper in loose sheets or in stacks. Paper aged inside airtight glass tubes at 100°C ages to about the same extent in five days as it does when single sheets are aged at 90°C and 50 percent RH in a humid oven for 30 days. This test method is being evaluated at the CCI (Shahani 2000).

The CCI is also engaged in a parallel collaborative study of accelerated aging of paper under the ISR/ASTM framework for development of accelerated-aging tests for potential use in the development of performance-based standards for permanent paper. Elzbieta Kaminska, Paul Bégin, David Grattan, Donna Woods, and Anna Bülow from the CCI are examining the thermal-accelerated aging of paper in sheets and in stacks for some of the ISR papers (Kaminska et al 1999).

A review of historical sources can also provide a basis for insights into the natural aging rate of paper. Recent studies have drawn on historical sources from the mid-nineteenth century that document the inferior quality of Dutch paper at that time. These records can be compared with the findings of present-day examinations of the same material, traced in archival collections. Such comparisons should yield useful indications on the rate of paper decay (Grijn et al, in press; Grijn et al 1996; Porck et al 1996).

Air pollution and deacidification

Expert insight into the effects of air pollutants on paper-based collections is essential for the development of an adequate preservation policy. Although the problem of air pollutants is generally acknowledged, the mechanism of deposition and threshold concentrations—in particular, the impact of air pollutants on deacidified paper—is not well understood.

Useful information can be expected to emerge from a current research project of the Dutch General State Archives (The Hague, the Netherlands). In this study, conducted in cooperation with the TNO Institute of Industrial Research, identical archive and library materials and other test papers are being stored at two locations, one of which is equipped to filter air pollutants. Continuous monitoring of environmental conditions such as temperature, humidity, and concentrations of air pollutants, as well as frequent analysis of the quality of the stored material in both storage rooms, will yield useful data over time. Besides offering more insight into the long-term effects of air filtering, these data will give a realistic indication of the rate at which various papers deteriorate under different degrees of air pollution (Feber et al 1998).

Anna Johansson devoted her doctoral thesis research at the Göteborg University (Sweden) to the synergistic effects of air pollutants (sulfur dioxide, nitrogen dioxide, and ozone) and climate on the stability of paper. The effect of trace amounts of these pollutants on the degradation of paper was investigated by means of in situ DRIFT (diffuse reflectance infrared Fourier transform spectrometry) and reaction product characterization techniques. Different mass-deacidification processes were evaluated with respect to their ability to provide protection against further acidification of papers. They included the DEZ (diethylzinc), Battelle (magnesium titanium ethoxide), Bookkeeper (magnesium oxide), Wei T'o (methoxy magnesium methyl carbonate), and Sablé (carbonated magnesium methoxide and ethoxide) systems.

The investigators concluded that RH plays an important role in the uptake of the air pollutants. Clear synergistic effects were demonstrated in the deposition rate. Deacidification treatments did protect paper against the attack of acid air pollutants, although there were some quantitative differences. Deacidification did not provide adequate protection from oxidative degradation of the paper (Johansson 2000).

Dr. Johansson's thesis was based on work carried out within the framework of an extensive research project, "Effects of Air Pollutants on the Accelerated Aging of Cellulose-based Materials." The research was funded by the European Union (STEP program) and coordinated by John Havermans of the TNO Institute of Industrial Research (Havermans et al 1994; Havermans 1995). The effect of air pollution on deacidified paper remains a subject of interest, and it is being addressed in one of the development projects of the Helsinki University Library (Finland).

Formation of acids

While it is well known that papers become more acid with age, it is generally assumed that this declining pH does not significantly contribute to the degradation of paper. It is often presumed that only the acids introduced in the manufacture of paper and those absorbed from the environment are responsible for the deterioration of paper. In this context, the term "acid-free," which in effect equates neutral and alkaline papers, is often used to imply permanence. However, the spontaneous formation of acids in cellulose during aging cannot be overlooked as a cause of paper degradation.

The LC investigated the role of acid formation in the process of paper aging. The researchers used capillary electrophoresis to establish the spontaneous generation of formic, acetic, lactic, oxalic, and several other weak aliphatic acids in acid, neutral, and alkaline papers at room temperature at a rate that is fast enough for detectable concentrations of these acids to form in a few months. Thus, neutral papers cannot remain acid-free for long. Weak acids formed in the degradation of cellulose and hemicelluloses have generally been considered not to pose as significant a threat as do stronger acids introduced from acidic alum-rosin size or those formed by absorption of oxides of nitrogen and sulfur from the environment. However, the present findings suggest that these weak acids accumulate at a sufficiently high rate to contribute significantly to the increasing acidity in paper as it ages. Alkaline papers showed appreciably higher rates of accumulation than did other papers, since the acids formed are immediately neutralized and cannot enter into other reactions or dissipate. It was also shown that these weak acids attach themselves strongly enough to paper, probably by hydrogen bonding, that they are not easily dislodged from the paper matrix, even upon airing. Because of this tenacity and because they catalyze their own formation, these acids present a constantly escalating source of damage that can be dealt with only through deacidification (Shahani 2000).

Foxing stains

Local yellow or brown discolorations of paper, often referred to as "foxing stains," have been the subject of investigation; however, preservation science research has not yet reached a consensus on the cause of this phenomenon. Several factors presumably are involved in this form of paper damage.

In a joint project of the Université de la Rochelle, the Université de Technologie de Compiègne, and the Musée du Louvre (Paris), two noninvasive techniques—fluorescence and FTIR (Fourier transform infrared spectrometry)—were used to identify chemicals in 154 samples of foxed papers from the seventeenth to the twentieth centuries. The study aimed to define objective criteria for a taxonomy of the foxing stains.

Although fluorescence appeared to produce little chemical information, these researchers maintained that the quantitative measure-

ment of fluorescence would be of significant interest if fluorogenic compounds were the precursors of the brown stains. FTIR provided more insight into the chemical characteristics of the foxing stains than did fluorescence. The use of FTIR spectra as a tool for categorizing foxing stains is discussed in detail by Choicy et al (1997).

Indoor air pollutants

One cause of paper degradation is indoor organic pollutants that are generated from certain storage and exhibit materials. Anne-Laurence Dupont and Jean Tétreault from the CCI are assessing the potential impact of acid-emissive materials on cellulose-containing materials. They use cold extraction pH measurements and determination of the degree of polymerization (DP) of cellulose to assess the effects of acetic acid vapor on various test papers (Dupont and Tétreault, submitted).

Coatings are often used as a means of passive conservation; however, direct contact with unsuitable coatings or the emission of harmful volatile compounds from coatings can damage artifacts. Tétreault has reviewed and updated the knowledge of the various coatings used in museums and other institutions. Different spot tests are included in his final report (Tétreault 1999).

Rapid aging of poor-quality paper materials, such as acidic mat boards, lignin-containing papers, and file covers are known to affect the aging of higher-quality unbuffered paper that is in contact with or in close proximity to them. John Bogaard and Paul Whitmore from the Carnegie Mellon Research Institute (Pittsburgh, Pennsylvania, USA) are studying the migration of degradation products from poor-quality materials into higher-quality papers by determining chemical properties, such as DP, carbonyl and carboxyl groups, and pH.

Ink corrosion

Two ingredients in iron-gall inks are known to cause degradation of paper artifacts: sulfuric acid, which catalyzes the hydrolysis of cellulose; and iron (II) sulfate, which catalyzes the process of cellulose oxidation. Because both sulfuric acid and iron (II) sulfate are water-soluble, these ingredients are able to migrate and could spread ink corrosion throughout the paper. However, this migration process is not understood.

Using scanning electron microscopy and X-ray fluorescence analysis techniques, Hans Neevel (Netherlands Institute for Cultural Heritage) and Cornelis Mensch (Shell Research and Technology Centre, Amsterdam, the Netherlands) studied the presence of iron and sulfuric acid outside the inked areas in test samples onto which iron-gall ink lines had been applied. The paper was subjected to accelerated thermal aging at fluctuating RH conditions to simulate the ink-corrosion process. The distributions of iron and sulfur across the paper were then determined, and the results were compared with the levels and distribution of iron and sulfur found in a sixteenth-century manuscript. The researchers discovered that in the artificial-

ly aged samples, sulfur (sulfuric acid) had moved out of the inked areas, whereas iron had not. Iron migration could likewise not be observed in the naturally aged samples, while contradictory results were found with respect to the migration of sulfur (Neevel and Mensch 1999).

Before we can fully understand the ink-corrosion mechanism, we must answer a question concerning the release of contaminants from the paper material during the aging process. Researchers from the TNO Institute of Industrial Research and the Shell Research and Technology Centre studied the effects of iron-gall inks on the emission of volatile organic compounds (VOCs) from paper artifacts. The VOC emission of test papers onto which lines of an iron-gall ink preparation were plotted was determined during accelerated aging by means of gas chromatography coupled to mass spectrometry (GC/MS).

The findings showed that the presence of iron-gall ink increases the rate of formation of formic acid, acetic acid, and furan derivatives as main volatile compounds. The research findings indicate that the presence of iron in the ink appears to stimulate certain paper-degradation processes, namely acid-catalyzed hydrolysis and dehydration. The harmful effects of some of the released VOCs have been discussed in relation to the conservation of ink-corroded paper (Havermans et al 1999a).

Charlotte Ahlgren (National Museum, Department of Paper Conservation, Stockholm, Sweden) is investigating the role of oxygen in the ink-corrosion process. An iron-gall ink preparation is applied to handmade rag and newsprint papers that are housed in encapsulations at 30 percent or 65 percent RH, with or without oxygen absorbers. The effect of oxygen will be determined by means of Raman spectrometry and/or by accelerated aging and measurement of the bursting strength of the paper samples. The aim is to determine whether an oxygen-free microclimate could retard the ink-corrosion process, which involves oxidation.

Monitoring of paper degradation

Monitoring the degradation of paper is essential for improving our understanding of how paper ages. At the CCI, Elzbieta Kaminska is determining, by means of statistical analysis, which methods are most useful for describing the chemical and physical changes that occur as paper ages. More than 20 different tests were conducted on various kinds of new and naturally aged papers after different treatments or accelerated aging or both.

The preservation community needs a suitable instrument for diagnosing the state of paper deterioration. Existing standardized testing methods often cannot be applied because of the large number of test specimens required. A research project by J. Luiz Pedersoli, initiated at the NICH, aims to develop microanalytical methods for characterizing the condition of paper. Investigators will evaluate a number of chromatographic, spectroscopic, thermal, and microscopic

techniques to determine whether they are able to assess several paper properties using smaller samples than those that are currently required. The properties to be assessed include acidity, DP, transition metals content, and oxidative stability, as well as the nature and amount of degradation products. The evaluation of the microanalytical methods will be based on accelerated aging of representative standard reference papers and on comparisons of the results obtained with those of related standardized testing methods (Pedersoli 1999).

Chemiluminescence was put forward as a means of monitoring the aging of paper at an International Council of Museums, Conservation Committee Working Group meeting in Ludwigsburg in 1998 (Pedersoli and Hofenk de Graaff 1998). NICH began to work on chemiluminescence as part of Pedersoli's research. NICH's work on chemiluminescence will be continued within the framework of an international project that was recently accepted by the European Union and coordinated by Matija Strlic, of the University of Ljubljana, Faculty of Chemistry and Chemical Technology, in Slovenia (Kolar 2000).

To help better understand the complex chemical processes of paper deterioration, Matija Strlic, Boris Pihlar, Jana Kolar, and coworkers from the University of Ljubljana's Faculty of Chemistry and Chemical Technology, and the National and University Library's Conservation Department are trying to develop new analytical approaches to the elucidation of cellulose degradation. The studies concentrate on the following methodologies:

- quantification of the presence of oxidized functional groups in cellulose
- determination of molecular weight and its distribution and evaluation of errors
- development of models for testing antioxidant formulations
- determination of early oxidative degradation pathways
- studies on lignin models
- determination of low-molecular-weight degradation products (Levart et al 1999; Rychl et al, in press; Strlic and Pihlar 1997; Strlic et al 1998; Strlic et al 1999; Strlic et al, in press).

Oxidative degradation

Oxidative paper-degradation processes have become the subject of increased attention in preservation science research. This new focus on oxidation is not only confined to specific problems such as ink corrosion and photodeterioration, but also concerns the study of paper decay in general. Jana Kolar and Matija Strlic are studying oxidative processes in paper. The main factors leading to the deterioration of deacidified paper made from bleached pulp were identified and their importance in the degradation of paper considered. These studies also clearly demonstrate the protective effect of antioxidants (Kolar 1997; Kolar et al 1998; Kolar and Strlic 1999; Strlic and Kolar 1999).

Paper permanence

To secure the preservation of the written and printed cultural heritage, Canada is preparing a Canadian Permanent Paper Standard. This enterprise is offering new insight into several factors responsible for the degradation of paper. Paul Bégin, David Grattan, and Joe Iraci from the CCI are participating in the preparation of a draft permanent paper standard for adoption as the Canadian General Standards Board (CGSB) standard. The Canadian Co-operative Permanent Paper Research Project provided valuable information about the impact of lignin and air pollutants on the stability of paper. After undergoing several revisions, the draft standard is in its final stage. An important conclusion is that the fiber composition of paper is of minimal importance to its permanence, as long as the paper is buffered with at least 2 percent calcium carbonate (Bégin et al 1998, 1999; Zou et al 1998).

Photodeterioration

Although papers in archives and libraries are generally well protected from light, the effects of light on paper should not be underestimated. In a review article, John Havermans and Javier Dufour (Complutense University of Madrid, Spain) identify the serious risk that, during consultation of archival documents and books, certain compounds, called *initiators*, may be formed that cause further deterioration of the paper (Havermans and Dufour 1997). The extent of this risk was unknown until now, and in recent years only a few research attempts have been made on the topic. These include studies on the role of oxygen and on the effectiveness of certain inhibitors (Destiné et al 1996; Wang et al 1996). To improve our understanding, and in connection with the fact that alkaline compounds may promote photo oxidation, research into the effects on the oxidative/alkaline deterioration process, especially with respect to naturally aged papers that have been deacidified, is recommended.

Wet/dry interface

The wet/dry interface phenomenon concerns a specific form of paper discoloration (generally resulting in a brown line) that takes place at the border between (formerly) wet and dry regions in a sheet of paper. The phenomenon has been known since the mid-1930s and has drawn recent attention because it might be part of the cause of several types of local paper discoloration.

At the NICH, Anne-Laurence Dupont used a variety of solvents to study the formation of brown lines on filter paper at the wet/dry interface. She also investigated the effects on aging and conservation treatments of washing and bleaching with sodium borohydride (Dupont 1996a). In additional studies on the nature of the brown-colored oxidation compounds formed at the wet/dry interface, the use of

analytical tools, including TLC (thin-layer chromatography), FTIR, and GC/MS, has been evaluated (Dupont 1996b). Frank Ligterink and J. Luiz Pedersoli of the NICH plan to continue this research.

Treatment

Aqueous treatments

Aqueous treatments have always been important in paper conservation, and there is an extensive literature on their benefits, especially with respect to the improved appearance of the treated papers. Although it is acknowledged that treating paper with water also brings about profound, and often permanent, structural and mechanical changes, less attention has been paid to the characterization and quantification of these influences, particularly with a view to optimizing conservation procedures.

In 1997, Anthony W. Smith reported on a long-term preservation science project entitled "Paper Substrates and Graphic Media" that was undertaken at the Camberwell College of Arts and funded by The London Institute. The purpose of the project was to investigate the effects of aqueous conservation treatments on the mechanical properties of paper. A preliminary study on the effects of "washing" showed several main changes, including a reduction in the elastic modulus and an increase in the extensibility, compared with untreated paper. No significant differences were observed between tensile strength before and after washing. These findings provide a better understanding of the "improvement" that is generally observed by conservators as a consequence of the washing of paper; that is, the changes detected have less to do with an increase in the strength of a sheet than with an increase in its flexibility. The report gives special attention to the need for careful specimen preparation and control of test conditions. It also describes future research plans, including studies into the effects of repeated washing and of washing brittle paper, and the influence of drying methods (Smith 1997).

Disinfection with ethylene oxide

The vacuum fumigation system, using the gaseous sterilizing agent ethylene oxide (EtO), is considered the most effective means of protecting documents from the harmful effects of microbiological damage. Although EtO is a significant health hazard, many institutions still use this system to sterilize archival and library materials. In such sites, strict regulations are established to govern the permissible level of exposure.

To make a comprehensive comparison of the techniques of EtO sterilization and methods of determining the residual EtO in the material treated, an international project has been set up among the Centre de Recherches sur la Conservation des Documents Graphiques (CRCDG, Paris, France), the Slovak National Archives, the State Central Archives (Prague, Czech Republic), and the Chemi-

cal-Technological University (Prague, Czech Republic). The results of the different sterilization equipment and procedures employed in Paris, Bratislava, and Prague were compared using different sorts of test samples, including Whatman, Xerox, handmade, and notebook papers. Independent determinations of residual EtO were carried out by GC (gas chromatography) in two laboratories (Paris and Prague) using different GC systems.

Calculations of the content of residual EtO indicated that the samples tested by the method used in Paris contained two to nine times higher levels of EtO than did those tested by the method used in Prague. Such discrepancies could be explained by differences in technical procedures and time shifts among the various tests. Nonetheless, the differences underscore the need for a detailed comparison of different techniques and methods and indicate that a standardized method for measuring residual EtO in sterilized materials would be very useful (Hanus et al 1999).

Disinfection with beta radiation and microwaves

The treatment of microbiological damage is seriously hampered by the fact that the use of ethylene oxide gas is restricted, and in many countries forbidden, because of its high risk of harmful health effects. Consequently, research is under way to develop suitable and safe alternative fungicides.

Malalanirina Rakotonirainy and other researchers at the CRCDG investigated the disinfecting capacity of beta radiation and microwaves. The test material consisted of different sorts of paper that were artificially contaminated with various fungi from the "mycothèque" of the Natural History Museum in Paris. In addition to the fungicidal effect, the influence of radiation on the physicochemical characteristics of the paper samples was determined using accelerated-aging tests.

Although beta radiation, in a sufficiently high dose, was found to be effective in attacking the fungi, a strong dose-dependent depolymerization of the cellulose molecules was observed in all cases. Consequently, beta radiation, like gamma radiation, which previous studies of the CRCDG and others had found to produce similar adverse effects, cannot be recommended. A fungicidal effect of the microwaves was also demonstrated; however, the microwave treatment did not show significant negative side effects on the paper itself. Though the practical limitations of the microwave equipment used do not yet allow the possibility of large-scale treatment, the study has clearly indicated the applicability of microwave treatment (Rakotonirainy et al 1999).

Freeze-drying

Paper that has been heavily damaged by water (e.g., by a flood or other disaster) can be treated in different ways. A popular method,

which is often used in commercial settings, is to freeze-dry the damaged documents. Possible negative influences of this drying procedure have not yet received full attention.

Søren Carlsen and colleagues from the Royal Library, Department of Preservation (Copenhagen, Denmark) investigated the effects of freeze-drying on the mechanical strength and aging stability of paper. The authors used three types of paper: groundwood, cotton, and coated. All were freeze-dried, air-dried, and exposed to accelerated aging. They found that freeze-drying primarily influences characteristics such as moisture content, folding endurance, and tear strength. Freeze-drying particularly affected the mechanical strength of paper with low initial strength; its effect on paper with high mechanical strength was relatively small. In general, freeze-drying influenced paper more than did air drying (Carlsen 1999).

Ink-corrosion treatment

The treatment of ink-corroded paper artifacts remains a concern in the field of paper conservation. The effectiveness of treatments and their possible negative long-term side effects are often a reason for particular anxiety.

Iron-gall ink corrosion has become an important research priority at the NICH. The NICH Ink-Corrosion Project includes four components:

1. investigations into the causes and mechanisms of ink corrosion
2. the development of early-warning and condition-rating methods
3. the development of suitable methods to accelerate and measure the corrosion process
4. the testing and optimization of the treatment of ink corrosion by means of phytates (Neevel and Reissland 1998).

The NICH's work on nonaqueous treatment of ink corrosion will be continued within the framework of an international project recently accepted by the European Union and coordinated by Jana Kolar (National and University Library, Conservation Department, Ljubljana, Slovenia). The State Central Archives in Prague (Czech Republic) are also contributing to this project (Durovic 2000; Kolar 2000).

Birgit Reissland and Suzanne de Groot from the NICH studied the effectiveness of nine commonly used aqueous treatments for iron-gall ink corrosion. Standard reference papers with an applied corrosive iron-gall ink preparation and four original seventeenth- and nineteenth-century iron-gall ink written manuscripts were immersed in different treatment solutions. The effect on the degradation process was determined by measuring the bursting strength of the paper samples after accelerated aging. Side effects, such as mechanical damage, color changes of paper and ink, and ink bleeding, were determined by visual examination. Results of this study indicated that a combined calcium phytate/calcium bicarbonate treatment, as well as a single treatment with calcium bicarbonate, could effectively delay ink corrosion and showed minor side effects (Reissland and Groot 1999).

At the LC, Heather Wanser and others have studied the effect of several aqueous and non-aqueous deacidification treatments on manuscripts written in iron gall inks. The effect of treatments on inks was evaluated by X-ray microanalysis to monitor changes in metal content and by colorimetry to measure changes in color. A potassium peak frequently found in the untreated samples was invariably lost after aqueous deacidification treatments. The presence of the potassium peak in the untreated ink samples has been tentatively ascribed to the presence of potassium salts in gum arabic, one of the essential ingredients of iron gall inks. The loss of potassium salts resulting from aqueous deacidification was not related to the appearance of the inks. Magnesium bicarbonate solutions prepared in 70 percent alcohol retained the potassium peak, as did the Bookkeeper and Wei T'o-like methyl magnesium carbonate treatments. These treatments had no noticeable effect on the color of any of the inks; aqueous treatments, by contrast, changed the appearance of most of the inks with dark-brown tints changing to light or even orange-brown. The appearance of the inks was also judged by visual examination by a panel of paper conservators.

Laser cleaning

Laser cleaning is a relatively new technique in the field of conservation. More and more museum artifacts are now being cleaned with laser techniques; however, the possible harmful effects of this process are not yet known.

Carole Dignard, Paul Heinrichs, Tom Stone, and Gregory Young from the CCI have undertaken an in-depth study of the photothermal, physical, and chemical effects of laser radiation on the surfaces of natural organic materials. The goal is to contribute to the establishment of guidelines for the appropriate use of lasers on museum artifacts (Dignard et al 1997a, 1997b).

Nd-YAG laser cleaning has been practiced since the early 1990s. Its effects on the materials are still not well understood. Little information is available on the assessment of Nd-YAG laser-cleaned organic materials, in particular. Carole Dignard, Paul Heinrichs, Tom Stone, and Gregory Young from the CCI are developing expertise and experience with analytical methods to assess the results of laser cleaning. They have performed tests on a variety of soot-covered organic materials. Fluence (energy density) and repetition rate (frequency) were varied incrementally (Dignard et al 1997a, 1997b, 1997c).

Cleaning of paper is necessary not only for aesthetic reasons but also for conservation purposes. Given that conventional mechanical and wet cleaning methods have proved insufficient in numerous cases, contactless cleaning by means of the laser technique could offer an appropriate solution.

In 1997 the European Union announced the Eureka/Eurocare LACLEPA (LAser CLEaning of PAper and PArchment) project (EU 1681). The participating countries (Austria, Germany, Slovenia, and Vatican City) are developing a prototype laser-cleaning system par-

ticularly fit for flexible paper and parchment. The method will be based on the use of ultraviolet (UV) pulse lasers, which will ensure preservation of the delicate artifacts by minimizing the absorption volume, the heat-affected zone, and mechanical shock. To complement the laser system, a catalog of working parameters for typical artifact types will be defined.

Institutes in each of the participating countries contribute their own expertise:

Austria (project coordinator): Institut für Papierrestaurierung (paper restoration), Österreichisches Museum für Angewandte Kunst (paper restoration), Österreichisches Staatsarchiv (paper restoration) (Müller-Hess et al 1999);

Germany: BAM, Laboratorium für Dünnschichttechnologien (dry-laser cleaning by means of UV pulse lasers), Freie Universität Berlin, Kunsthistorisches Institut (historical and ethical context of antique paper artifacts), Staatsbibliothek zu Berlin-Preussischer Kulturbesitz (paper restoration), Bayerische Staatsbibliothek (paper restoration) (Kautek et al 1998; Rudolph et al 1998);

Slovenia: National and University Library, Conservation Department (testing of new conservation treatments); University of Ljubljana, Chemistry and Chemical Technology Faculty (evaluation of possible damage to cellulose); Fotona dd., Ljubljana (manufacturer of laser systems) (Kolar and Strlic 1998, 2000; Kolar et al 2000; Kolar et al, in press);

Vatican City: Biblioteca Apostolica Vaticana (paper restoration).

The first goal of the joint research project was to assess the immediate effects of lasers running at three different wavelengths (308 nm, 532 nm, and 1064 nm) on paper and to determine the long-term impact that the treatments may exert on the stability of cellulose. The paper samples were purified cotton linters cellulose (Whatman filter paper), elemental chlorine-free (ECF)-bleached sulfate pulp, gelatin-sized handmade paper from rags (from 1600), Fabriano Roma paper, coated paper, and modern book paper from bleached chemical pulp. One side of each sample was treated either with excimer pulse laser (running at 308 nm) or with Nd-YAG pulsed laser (running at 532 nm or 1064 nm). After microscopic examination, accelerated-aging tests were performed at 90°C and 65 percent RH for up to six days. The paper parameters tested included the DP and brightness.

On the basis of the Eureka/Eurocare LACLEPA project, a two-year follow-up study was initiated in Slovenia in 2000. In cooperation with the Slovenian manufacturer of laser systems Fotona dd. (Ljubljana), Jana Kolar and Matija Strlic are attempting to define optimum parameters for cleaning cellulose-based substrates using Nd-YAG laser. The immediate as well as the long-term effects of Nd-YAG laser irradiation on paper have been studied. Analysis by FTIR indicates that laser treatment induces the cross-linking of cellulose, resulting in an increased DP. Changes in content of acidic or carbonyl groups were below threshold sensitivity of the method (Kolar et al 2000).

Mass deacidification

Mass deacidification has become an integral part of mass conservation and preservation strategy in the United States and several European countries. Recognition of the benefits of deacidification has been accompanied by a diminished interest in research in this field. Since the joint publication of the European Commission on Preservation and Access and the Commission on Preservation and Access on the possibilities and limitations of the current mass-deacidification techniques (Porck 1996), deacidification has received relatively little attention in preservation research. Nonetheless, several developments are worth mentioning.

Lynn Kidder, Terry Boone, and Susan Russick (LC) have studied treatment of paper artifacts with Bookkeeper spray deacidification. They found that humidifying the objects after the spray treatment improved the effectiveness of the deacidification process (Kidder, Boone, and Russick 1998).

Since the end of the 1980s, the Bibliothèque nationale de France (Paris) has used a mass-deacidification system adapted from the Canadian Wei T'o process. Research into the effectiveness of this system has produced satisfactory results; however, questions remain about both the amount and the distribution of the alkaline reserve in the paper after treatment. The CRCDG investigated the different stages in the deacidification procedure to find ways to increase the final alkaline reserve in the deacidified paper and to improve the homogeneity of its distribution (Daniel et al 1999a).

Thi-Phuong Nguyen (Centre Technique de Bussy-Saint-Georges, France) described a new approach to mass deacidification that is being developed under the auspices of the Bibliothèque nationale de France. The procedure involves microencapsulation of the deacidification agents and the use of supercritical carbon dioxide as a carrier gas. Part of the work will focus on the possibility of combining deacidification with reinforcement of the paper. Detailed information on the progress of the studies is not yet available.

A Wei T'o mass-deacidification system has been used in Canada for many years. It was implemented by the Conservation Division of the National Archives, and, since October 1997, has been run by the National Library of Canada (Ottawa). One of the major challenges has been the replacement of the original chlorofluorocarbon (CFC) solvents, consequent to a ban on CFCs that became effective January 1, 1996, under the Montreal Protocol. Initially, CFCs were replaced by hydrochlorofluorocarbons (HCFCs). Although the use of the HCFCs could be continued until the year 2000, when the state of Ontario planned to ban its use, it was decided in 1997 to test a new chemical formula using hydrofluorocarbons (HFCs). The results of these tests have been fruitful. Inks that had been affected by the previous solvents remained stable in the new solution, which was named the "Good News Formula." Work is in progress to improve the recovery of the solvent after treatment (Couture 1999).

At the 15th Annual Preservation Conference of the National Archives and Records Administration (NARA, Washington, D.C.,

USA), held in March 2000 under the title "Deacidification Reconsidered," conservation scientists, preservation professionals, and conservators discussed technical issues related to deacidification. The following recent research results were reported:

- John Bogaard (Carnegie Mellon Research Institute, Pittsburgh, Pennsylvania, USA) presented the results of chemical studies of the beneficial effects of calcium-enriched wash water applied in the course of the conservation treatment of paper objects. The compounds used were calcium hydroxide, calcium bicarbonate, and calcium chloride. Chemical properties such as DP, pH, and carbonyl and carboxyl groups were followed to monitor the behavior during accelerated thermal aging and exposure of the treated papers to UV light.
- Chandru Shahani (LC) discussed new insights into the effects of deacidification on the life expectancy of paper-based collections. Recent research suggests that acidic paper ages considerably faster than has been indicated by currently accepted aging tests.
- Elissa O'Loughlin and Anne Witty (NARA Document Conservation Laboratory, Washington, D.C., USA) addressed the possible impact of previous deacidification on the conservation treatment and care of paper artifacts.

Natural insecticides

Insects can cause extensive, and often irreversible, damage to paper and other cellulose-containing materials. Although the use of insecticides is often successful, it has several drawbacks. These compounds are not only generally harmful to humans but also can produce damaging reactions with paper artifacts.

Attention has recently focused on the applicability of a natural insecticide extracted from seeds of the neem tree (*Azadirachta indica*), a tropical evergreen. Robert O. Larson of Vikwood Botanicals (Sheboygan, Wisconsin, USA) has developed the pesticide Margosan-O, a neem extract in ethanol. The unique qualities of the neem product have been investigated intensively and have yielded encouraging results. In particular, insecticides containing significant amounts of neem oil do not appear to be harmful to human health.

John Dean from Cornell University, Department of Preservation and Conservation (Ithaca, New York, USA) has designed a research project to study the effects of neem products on treated materials. Specifically, the project aims to

1. determine the effectiveness of neem products as repellents when applied directly to paper
2. test the effects of neem products on paper appearance and longevity
3. evaluate the effects of the product on inks, dyes, and pigments
4. identify the most appropriate methods of application.

The project is currently seeking funding.

Non-photographic copies

Long before the invention of photocopying, other methods were used to duplicate documents. Knowledge of these early techniques is rapidly vanishing. Because of the need to preserve these materials, there is renewed interest in these non-photographic methods.

Sebastian Dobrusskin started a project at the Conservation Program of the Berner Fachhochschule (Bern, Switzerland) to study the history, technology, identification, and conservation of early, non-photographic copying and duplicating techniques. In addition, this project examines the effects of mass deacidification on such early copies. The goal is to develop recommendations for the preservation of collections of non-photographic copies.

The individual techniques have been systematically ordered. The technology of the direct dye-transfer copying techniques has been described in depth with all its variations, coloring agents, and support materials. The study showed that several of the coloring agents used for these techniques are sensitive to pH, humidity, organic solvents, and light. In the next stage of the project, additional copying and duplicating techniques will be studied. The materials will be tested to understand their response to conservation treatment (Dobrusskin 1999).

Paper splitting

Reinforcing deteriorated paper objects on a large scale has proved to be problematic, although many attempts have been made to combine mass deacidification with paper strengthening. The mechanization of conservation procedures using paper splitting has made much progress recently and offers good prospects.

The Zentrum für Bucherhaltung (Leipzig, Germany) is exploiting a mass-conservation system for loose sheets of paper. The system uses several consecutive processes, including aqueous washing and deacidification, leaf casting and mechanized paper splitting, and insertion of a thin layer of paper that forms the new core of the original sheets (Wächter et al 1996). Results of independent research into the effectiveness and possible negative side effects of this technique are not yet available; nonetheless, there is a growing worldwide interest in the paper-splitting system. The Bibliothèque nationale de France supported a study on mechanical reinforcement methods for paper that compared thermal gluing with splitting. The investigation, carried out on different types of printed paper, demonstrated that splitting resulted in a greater improvement of the mechanical properties of papers, combined with an unaltered readability of the text, than did gluing. On the basis of the results, the reversibility of the splitting process was also considered satisfactory (Vilmont et al 1996).

Plasma treatment

Plasma, defined as "almost completely ionized gas, containing equal numbers of free electrons and positive ions . . . formed by heating low-pressure gases until the atoms have sufficient energy to ionize each other," has been used in the restoration of metal objects.

Little has been published on attempts to use plasma treatment in the conservation of paper. What has been published includes initial results of efforts to remove mold spores and other stains on paper, suggestions to use plasma in paper deacidification and strengthening, and indications that a low-temperature plasma treatment by glow discharge of hydrogen can improve the strength of aged papers (Anders et al 1996; Vohrer et al 1996). In 1995, John Havermans organized an expert meeting to discuss the potential of plasma treatment for strengthening brittle paper and to establish a joint research program (Havermans 1996). Definite plans for this program have not yet been worked out.

Suction devices

In the development of devices that exploit the benefits of suction and airflow in the conservation treatment of paper artifacts, attention is being focused on designing suction tables with a safe, built-in light source. There is also growing interest in using small suction devices in the treatment of paper and other materials for local conservation treatments, including the removal of non-aqueous solvents.

Paul Heinrichs and Stefan Michalski from the CCI are attempting to make several of the desired improvements. With respect to the addition of a light source, the prototypes have proved the utility of the concept and shown that a commercial fiberoptic delivery system is most effective. With respect to the selection and testing of solvent-capture devices that can be inserted between the vacuum table and the vacuum source, work is still in progress.

Storage

MicroChamber

Archival storage materials have received much attention lately, particularly the product MicroChamber; however, independent research into this archival paper product is scarce. First marketed in 1992, MicroChamber is a lignin-free, sulfur-free, alkaline-pulped, alkaline-reserve paperboard with an additional element—molecular traps or sieves. At the CRCDG, Floréal Daniel, Vassiliki Hatzigeorgiou, Serge Copy, and Françoise Flieder compared the protective quality of MicroChamber with that of other archival papers. These researchers concentrated on two of the most widely used MicroChamber products: MicroWrap 155 g/m^2 and End Leaf 130 g/m^2. The papers contained 10 to 15 percent mineral absorbents (zeolites, calcium carbonate).

Interestingly, the verso and the recto sides of each of the MicroChamber products showed different results. The MicroChamber papers absorbed much more sulfur dioxide than did the permanent papers. This difference appeared to be connected to the weight and sizing of the papers, rather than to the presence of absorbents. In general, MicroWrap performed much better than did End Leaf (Daniel et al 1999c).

Nitrogen dioxide pollution

The air-pollutant nitrogen dioxide is considered a growing threat for repositories of records of cultural heritage. One way of dealing with this problem is to protect archival materials by storing them in boxes. C. M. Guttman and W. R. Blair from NARA studied the effect of nitrogen dioxide on archival boxboards and model papers. They focused on determining the absorption coefficients of nitrogen dioxide in low-lignin and acid-free buffered boxboards that are used for storage containers. An earlier report indicated that few data existed on these coefficients for sulfur dioxide and nitrogen dioxide (Guttman and Blair 1996).

Polyester film encapsulation

Polyester film encapsulation is used to protect paper from harmful environmental factors such as air pollutants, dust, and microorganisms. The benefit of this preventive measure has often been discussed, and contradicting experimental results have been reported.

The system Archipress 1000 of the Dutch firm Multipak (Putten, the Netherlands) offers a technique by which an object can be encapsulated under low pressure. The CRCDG has studied the effects of this kind of storage, taking into account both the external and internal factors that can contribute to deterioration.

After analyzing the effects of several accelerated-aging tests on the DP of different kinds of paper, the authors concluded that encapsulation enhances the deterioration of acid paper. The rate of degradation of nonacid paper appeared to increase significantly only when such paper aged together with acid paper, especially when the mixed stack had been encapsulated. Additional experiments have shown that interleavage with alkaline or MicroChamber paper could partly circumvent this influence. Depending on the situation, this kind of interleavage should be weighed against a deacidification treatment before encapsulation (Daniel et al 1998, 1999b).

Relative humidity

The choice of a range of relative humidity and temperature for storage depends on a number of factors. Relative humidity affects the preservation of objects in many ways. It influences the physical, chemical, and structural properties of the materials. It is a factor in many chemical reactions and determines whether biological attacks

might occur. Changes in RH can produce dimensional changes that can result in strains, stresses, deformation, or fracture. Because each material is affected differently, research into the effects and optimum value or range of RH leads to overlapping, or even conflicting, recommendations.

The Smithsonian Institution's Center for Materials Research and Education has investigated suitable conditions of RH in a general museum environment, with an emphasis on hygroscopic organic materials.

Measurements of the elastic modulus (stiffness), strain-to-yield (deformation required to cause permanent distortion), and strain-to-failure (deformation required to cause fracture or breakage) of cellulose-containing materials contradict the general assumption that these materials are necessarily brittle or stiff at all low RH values. In fact, if very low RH (less than 30 percent) is avoided, important physical properties, as well as chemical reactivity (rate of hydrolysis and cross-linking reactions) are relatively insensitive to RH over a wide range. Similar results have been found with aged paper, indicating that while paper may become weaker as it ages, its stiffness and response to RH do not change significantly (Erhardt and Mecklenburg 1995; Erhardt et al 1997).

By means of stress-strain studies, it could be shown in cellulose and other hygroscopic materials that changes caused by environmental fluctuations are generally reversible (non-damaging) within a relatively wide (10 to 15 percent) range in the moderate RH region (30 to 60 percent). This represents a much wider range than is generally supposed (Erhardt et al 1996, 1997).

An approach similar to that used in determining the mechanical and physical effects of RH has been used to evaluate the effects of temperature (Mecklenburg and Tumosa 1996).

CHAPTER 3

Film and Photographic Materials

Decay

Gelatin and air pollution

Pollutant gases are known to be very damaging to both the silver image and the gelatin binding of photographs. The mechanisms of photographic gelatin deterioration have received less attention than have those of silver imaging deterioration.

At the CRCDG, Thi-Phuong Nguyen, Bertrand Lavédrine, and Françoise Flieder investigated the degradation of photographic gelatin caused by nitrogen dioxide and sulfur dioxide. The behavior of photographic gelatin was studied by measuring the degree to which it swells and by conducting high-performance steric chromatography.

The investigation, performed on one unhardened gelatin and two hardened (and more water-resistant) gelatins, showed that all three are sensitive to pollutants. Two major effects were noted: the first was an increased swelling of the gelatin films in demineralized water; the second was a change in the steric exclusion chromatographic profile. Both phenomena indicate that air pollutants induce the hydrolysis of the gelatin macromolecules. Nevertheless, for the same exposure, the hardened gelatins showed less degradation than did the unhardened gelatin. Thus, even if hardening does not protect the photographic gelatin totally from attack by air pollution, it does slow the deterioration process (Nguyen et al 1997).

Monitoring of polyester film degradation

Early methods to characterize degradation of film yielded useful information, but they were time-consuming and destructive. To overcome these problems, color indicators were developed. Unfortunately, few tests exist for polyester film. Michele Edge from the

Manchester Metropolitan University, Department of Chemistry and Materials (UK), is studying new techniques for monitoring the breakdown of polyester film that is used as a support material for both moving images and sound. The investigations focus on the causes of polymer deterioration and on the features of the degradation process that can be quantified. New spectroscopic and optical methods to assess the condition of polyester film are being developed for these purposes (Edge, in press).

Risk assessment of nitrate- and safety-based film collections

Important for the long-term preservation of collections is risk assessment of the constituent materials. On the basis of the results of such an analysis, preservation priorities can be set.

Risk audits were developed for the nitrate- and triacetate (safety)-based motion picture film and for magnetic tape collections. Studies of these two types of materials were carried out by the Image Permanence Institute (IPI, Rochester, New York, USA) and by the now defunct National Media Laboratory (NML, St. Paul, Minnesota, USA), respectively. Their purpose was to assess the present condition of the LC's film and magnetic tape holdings, evaluate the suitability of existing storage conditions, develop reliable data for planning future storage needs, and specify necessary requirements.

The IPI report reaffirmed choices about film storage that the LC had made in the 1970s; namely, that a cold, dry environment will significantly extend the life of the materials. Film and similar materials stored under ambient conditions would begin to show deterioration after about 40 years, whereas materials stored in the Library's cold-storage vaults would show such effects after more than 900 years. Stored for most of its life under ambient conditions, black-and-white film in the Library's holdings showed little image fading, while 40 percent of the color film exhibited moderate-to-severe color shifts. IPI concluded that placing all the film materials in cold storage would slow the deterioration enough to limit the acute threat, so that appropriate preservation and recovery efforts could subsequently be undertaken (Baker et al 1998; Reilly et al 1998).

Stability of nitrate and acetate film

Many photographic collections house numerous images on nitrate and acetate film, both of which are very unstable. Much research has been conducted into the causes of decay of these polymers.

Alain Louvet and Martine Gillet, from the CRCDG, studied film materials from the Harcourt Collection, which contains almost four million negatives, to find out more about these polymers and their stability. Nitrate films in different stages of decay were examined by means of GC, MS, and FTIR. Two plasticizers were identified: camphor and triphenylphosphate. A lack of camphor caused the polymer to become brittle. Triphenylphosphate reacted heavily with nitrogen

dioxide, an air pollutant that is known to have an adverse effect on film. An alteration in the molecular structure of aged nitrate polymer was also demonstrated. Acetate films also contained triphenylphosphate as a plasticizer. The degradation of this softener seemed to occur at the same time as did that of the polymer itself. The release of acetic acid appeared to catalyze the decay of the triphenylphosphate (Louvet and Gillet 1999).

Surface tarnishing of daguerreotypes

In the past 15 years, conservators and scientists have studied the complex modes of deterioration of daguerreotypes. One important aspect is the surface tarnishing of the plate; however, because the layers of the tarnish are extremely thin, they are difficult to examine.

Three U.S. researchers, Lee Ann Daffner (Metropolitan Museum of Art, New York), Dan Kushel (Buffalo State College, Buffalo, Art Conservation Department), and John M. Messinger II (University at Buffalo, State University of New York, School of Dental Medicine) investigated the surface tarnish on daguerreotypes by means of short-wave UV illumination. The scope of the investigation included preliminary analysis, characterization of the tarnish, and a study of its rate of occurrence in 110 daguerreotype plates.

About half of plates showed some degree of fluorescence. The presence of this fluorescing tarnish may provide evidence of specific past treatments applied to the daguerreotype plates. The fluorescing tarnish can serve as a guide for monitoring the state of deterioration in daguerreotypes (Daffner et al 1996).

Vinegar syndrome

"Vinegar syndrome" is the process whereby acetic acid is released as a result of decay of acetate film. It is useful to monitor the progression of acid formation so that the condition of a film collection can be assessed more knowledgeably.

The acid-detection technologies of the IPI and of Dancan International Sales (Copenhagen, Denmark) were tested by Ed Zwaneveld and Jean Imbeau from the National Film Board of Canada (St. Laurent) and Ken Weissman from the Library of Congress. The results were presented at the 1999 conference of the Association of Moving Image Archivists (AMIA) in Quebec, Canada.

Zwaneveld and co-workers tested detection strips from Dancan International Sales (Danchek 2-hour acidity tester strip and Danchek monitor window button inserts) and from IPI (24-hour A-D strips). At an earlier stage, the National Film Board of Canada had already tested more than 10,000 film containers using IPI strips. The IPI strips gave more reliable results after 72 hours than they did after the recommended 24 hours. The Danchek strips and buttons also worked best after 72 hours, although the results showed a poor reproducibility as compared with the IPI strips. In general, IPI Film

Condition Ratings and Recommended Actions were found to be most satisfactory (Zwaneveld and Imbeau 1999).

Ken Weissman did real-life comparisons of "litmus"-type acid-level detection strips from Dancan International Sales (Danchek 2-hour acidity tester strip), IPI (24 hour A-D strips), and J. T. Baker (Dual-Tint pH special indicator papers). IPI A-D and Danchek strips generally worked as advertised. Dual-Tint also worked well, but the results were subject to interpretation because there was no direct correlation to film deterioration levels (Weissman 1999).

Treatment

Cyanotypes

In 1842, Sir John Herschel invented photographic contact printing, which he named *cyanotype.* The restyled *ferroprussiate process,* the leading method for photocopying until the mid-1950s, endowed the English language with a new word: the blueprint. The conservation of cyanotypes is a recent subject of preservation research.

Mike Ware, consultant to the National Museum of Photography, Film, and Television (UK) made a comprehensive study of cyanotypes, including their history, chemistry, and conservation. Using Herschel's experimental notes, Ware elucidated the cyanotype process and established, through investigation of facsimile material, the damage brought about by three pathways of vulnerability:

1. They were faded by visible light, but this reaction was substantially reversible if the cyanotype was moved to dark storage. Cyanotypes may be safely exhibited at up to 50 lux illumination.
2. Prussian blue was rapidly and irreversibly hydrolyzed to ferrocyanide and hydrated ferric oxide (sensitivity to bleaching by alkali can be greatly diminished by treatment with nickel (II) salts).
3. Significant amounts of image substance were irreversibly lost from cyanotypes in aqueous washing (Ware 1999a, 1999b).

Disinfection

Infestation by fungi can affect film in many ways. Fungi are difficult to identify, and currently available fungicides do not eliminate fungal contamination. At the CRCDG, Malalanirina Rakotonirainy, Fabien Fohrer, and Bertrand Lavédrine identified the main species responsible for degradation of the various films in the collection of the Archives du Film in Paris and developed an effective treatment.

To do so, they tested 15 products individually or in combination. The results of the initial *in vitro* experiments could be reproduced *in situ.* The findings demonstrated the effectiveness of formaldehyde and Aquasan, a commercial solution containing a quaternary ammonium chloride salt (Rakotonirainy et al, in press).

Laser cleaning of daguerreotypes

Removal of tarnish from daguerreotypes is a long-standing problem. In the past, many daguerreotypes were severely damaged, often to the complete destruction of the silver image, as a consequence of inappropriate cleaning. At present, electrocleaning is the only known method of cleaning gilded daguerreotypes safely; however, it is not suitable for the treatment of ungilded and colored types.

Three Israeli researchers, Igor Turovets (Intel Electronics Ltd.), Michael Maggen (Israel Museum, Jerusalem), and Aaron Lewis (Hebrew University, Jerusalem), studied the old methods of cleaning daguerreotypes and developed a new technique that uses an excimer laser. Their goal was to develop a cleaning method that does not alter the optical properties of these early photographs—e.g., that does not etch or pit the polished silver layer substrate and does not alter or damage the image particles. Their laser-cleaning method permits the cleaning of gilded and ungilded plates, local tarnish removal, and removal of tarnish without immersion in solvents and chemicals (Turovets et al 1998).

Storage

Climate-controlled macro- and microenvironments

The preservation of moving images on photographic film is a prime concern today. The serious problems of decay of cellulose triacetate films are well known to film archivists. The development of an adequate conservation approach remains a challenge.

Jean-Louis Bigourdan and James M. Reilly from the IPI worked on a preservation strategy for acetate film based on an environmental assessment and condition survey. They investigated the effectiveness of both the climate-controlled macroenvironment and the microenvironment. At room temperature, they found that tight enclosures had a detrimental effect on film stability. However, open enclosures did not significantly reduce the acid content of the acetate base film. Microenvironments created by absorbents or low preconditioned RH were found to extend the longevity by a factor of three to four. Macroenvironments using low temperatures showed greater potential to improve film stability than did microclimates. The studies demonstrated the utility of the TWPI (Time-Weighted Preservation Index) in evaluating the efficiency of a storage area (Bigourdan and Reilly 1999).

Climate standards

Recommendations for proper storage temperatures and relative humidities are the subject of continued attention in preservation research. The development of climate standards for photographic materials is of special interest, given that safe conditions for these materials generally differ from those for other artifacts.

For the Smithsonian Institution, Mark McCormick-Goodhart studied the allowable temperature and RH ranges for the safe use and storage of photographic materials. The findings indicated that to maintain a constant level of moisture, the RH of a storage environment must be reduced by 3 percent to 4 percent for every 10°C drop in temperature. The author concluded that it is extremely important to avoid environmental conditions that cause photographic gelatin to cross its glass transition temperature and revert to a gel state. The acceptable range for storage temperatures was -25°C to 25°C (McCormick-Goodhart 1996).

Cold storage

In recent years, we have gained a new understanding of the effects of temperature and humidity on photographic materials. Cold storage is now considered the highest standard of care, but it requires the moisture content to be maintained within a safe range.

For the Smithsonian Institution, Mark McCormick-Goodhart from Old Town Editions Inc. (Alexandria, Virginia, USA), evaluated three methods of cold storage that are economical for historical societies and individuals:

1. Custom dehumidified cold-storage vaults. McCormick-Goodhart is working with Wilhelm Imaging Research, Inc., to investigate housing methods for photographs and motion picture films stored at -20°C in moderately priced, commercially available non-humidity-controlled freezer units.
2. Specific packaging techniques. The Smithsonian Institution developed a critical moisture indicator (CMI) package that, unlike the high-moisture-barrier package, is a reusable design. As such, it is preferred over the Film Institute Conditioning Apparatus (FICA) system developed at the Swedish Film Institute.
3. Sealed-gasket cabinets. Models have been developed for the use of sealed-gasket cabinets for passive climate control (McCormick-Goodhart 1999).

Environment and enclosures

The effects of temperature and relative humidity on photographic film are well established. To protect these materials against negative influences of the environment, they are often put in some kind of enclosure.

James M. Reilly, Douglas W. Nishimura, Peter Z. Adelstein, Jean-Louis Bigourdan, and Catherine Erbland, at the IPI, participated in a project entitled "Environment and Enclosures in Film Preservation." This project completed a cycle of research into the ways in which the storage environment, together with storage enclosures (sleeves, boxes, cans, and cabinets), can be used to extend the useful life of cinema, still, and micrographic films.

The project has yielded several findings:

- With the exception of completely permeable enclosures such as cardboard boxes, most enclosures had the desirable effect of slowing the rate at which the moisture content of the film inside approaches the equilibrium RH outside the enclosure. However, the thermal equilibration rate was relatively unaffected by enclosures.
- Enclosures could moderate daily cycling of relative humidity and even seasonal drift, depending on their moisture-buffering capacity.
- Data on moisture conditioning and thermal equilibration rates of photographic film provided background information on the use of microenvironments.
- The capacity of buffered paper to neutralize exposure to acetic acid was not directly correlated to its initial alkaline reserve. A significant amount of absorbed acetic acid can coexist with residual alkaline reserve in the paper structure (Bigourdan et al 1996).
- Buffered and nonbuffered paper enclosures placed in contact with degrading acetate films acted as acid-receptors. As a result of the presence of alkali reserve, buffered paper reduced the acidity; however, the practical impact on the film was limited.
- The extrapolation to room temperature of results obtained at 50°C in a sealed bag remained problematic.
- Investigations at room temperature showed that the use of a paper envelope was a secondary contributor to the vinegar syndrome. This risk was not eliminated by the use of buffered paper.
- Although segregation of degrading objects, rehousing, and efficient ventilation are important for collection management, control of temperature and relative humidity remains the most effective preservation strategy for acetate film collections.
- Studies of moisture-equilibrium rates at low temperatures provided more comprehensive data than had been previously available. These investigations indicated that low-temperature equilibration is slow, but appreciable.
- On the basis of these findings, the use of moisture-proof packing is recommended for storage in frost-free freezers or in cold storage vaults where the RH exceeds 40 percent.
- Analysis of gelatin-degradation studies at conditions both above and below the glass transition temperature showed that linear Arrhenius relationships may be obtained, although contradicting results have been reported.

Light conditions

Many photographs and graphic documents quickly deteriorate as a result of exposure to light. Reliable measurement of the light conditions is therefore necessary for effective preservation management. The Blue Wool Standard, a light dosimeter, is often used; however, this scale is not sensitive enough for exhibition of very fragile artifacts such as early or color photographs, which should not be exposed to more than 12,000 lux hours.

Bertrand Lavédrine from the CRCDG studied a new light dosimeter for the exhibition of photographs and sensitive artifacts: the Blue

Pink Scale (BPS). The BPS enables a precise and sensitive quantification of light exposure. It can monitor low light energy, (i.e., between 5000 and 100,000 lux hours) and allows a visual judgment of the amount of radiation. When exposed to light, the BPS, a card support with a bluish polymer, turns from bluish-purple, to pink, and finally to gray (Lavédrine 1999).

MicroChamber

The zeolite molecular traps of MicroChamber's archival-quality paperboard (see pp. 22-23) make it possible to deal with both airborne pollutant gases and the byproducts of media deterioration. MicroChamber has been widely used in the passive conservation of photographic and film materials.

Brenda Keneghan and Elizabeth Martin from the Photographic Studio of the Victoria and Albert Museum (London, UK) have investigated the use of molecular sieves for extending the life of cellulose acetate photographic negatives. The efficiency of Type 4A molecular sieve as a scavenger for acetic acid was measured using GC/MS. Initial results show a significant reduction of the concentration of acetic acid when the sieve was used over a three-month period. The active lifetime of the scavenger, along with the possible changes in the physical properties of the negatives, is under investigation (Keneghan and Martin 1998; Rempel 1996).

Polystyrene products

There has been debate over whether polystyrene products are safe for storing museum objects. Graphic boards made from polystyrene are often used in storage cabinets to mount slides and other photographic materials. The use of "food-grade" polystyrene, which is safe for food products, has been suggested, but there are conflicting recommendations about whether to use it in conservation.

Scott Williams from the CCI is investigating the suitability of polystyrene products for archival storage. Naturally aged samples will be analyzed for additives and decomposition products; accelerated-aging tests will also be conducted. Williams has already analyzed several products containing polystyrene foams and reported them as safe for conservation applications.

CHAPTER 4

Magnetic Tape

Decay

In the early days, carriers of magnetic tape were made of nitrate or acetate film; today, they are made of polyester film. Recent research developments on these materials are described in the chapter entitled "Film and Photographic Materials."

Aging phenomena

Audiovisual data carriers play an increasingly important role in cultural heritage documentation, but they are prone to degradation. From 1993 to 2000, the European Union subsidized the Eurocare AVIDA project (EU 892). Its aims are to clarify the degradation mechanisms of magnetic tape (audio and video) and to identify appropriate conservation measures. The project will create a catalog of conservation and rejuvenation measures. It will be in the public domain and independent of the polymer industry and its trade secrets.

The following institutions are participating in the project:
Austria: Phonogrammarchiv der Österreichische Akademie der Wissenschaften (life-expectancy studies), Österreichisches Kunststoffinstitut Arsenal (life-expectancy studies);
Germany: Bundesarchiv (investigation into research needs, evaluation of ongoing research programs).

Constituent materials and standards

To understand the process of magnetic tape deterioration, it is essential to know something about the constituent materials. Given that most of the crucial information is an industrial secret, this is not an easy task.

Ian Gilmour and a team of engineers from the Engineering and Research Group of ScreenSound Australia (Canberra) are testing magnetic media, particularly in relation to the development of standards. Their goal is to answer such questions as how to measure tape characteristics and performance, how magnetic tapes fail, how to study the aging process, and how to define end of life (EOL) and life expectancy (LE) of tape.

The present research concentrates on magnetic tape constituents, such as metal particles, on different coatings. Among other methods, the research team uses the abrasion testing facility, which was developed by the ScreenSound engineers. The research team also attempted to formulate a workable definition of LE using pigment binder degradation as an indicator (Gilmour, in press).

Life expectancy

LE testing of audio- and videotape is an important and difficult challenge. Experience has often contradicted manufacturers' claims. Standardization of LE testing is advancing slowly, and no serious insight or understanding, based on research by independent laboratories, is available to the public. The chief problem is the lack of knowledge about which tapes will be the first to deteriorate beyond the point where they can be retrieved, which will deteriorate in the midterm, and which will last for another 20 years or more. Such knowledge is a prerequisite for setting up a successful preservation and transfer strategy. For several materials, the LE can be estimated by tests based on the model of Arrhenius; however, this is not possible for magnetic tape because of the temperatures involved in such testing. Alternative minimally invasive or nondestructive methods have to be developed.

As part of the Eurocare AVIDA project, Dietrich Schüller from the Phonogrammarchiv der Österreichische Akademie der Wissenschaften (Vienna, Austria) and Otto Hinterhofer from the Österreichisches Kunststoffinstitut Arsenal (Vienna, Austria) studied various approaches to estimating the LE of magnetic tape. They included mechanical tests to determine the surface hardness of tape against penetration or the resistance of the tape surface against abrasion, as well as chemical methods, such as thermoanalytic tests (e.g., gas thermogravimetric analysis [TGA] and differential scanning calorimetry [DSC]). All these methods are either nondestructive or need only small amounts of sample material. Their reliability and validity, as well as their applicability to the great variety of magnetic tape, have yet to be investigated. A new proposal has been put forward to the European Program of the Institute for Safety Technology (IST) for further research on the life expectancy of magnetic audiovisual data carriers and on other preservation issues of magnetic tape, especially on behalf of the holdings in Eastern Europe (Hinterhofer et al, in press).

Treatment

Disaster recovery

Research on modern records has only just begun; for example, there is still little understanding of how media such as magnetic tape would be affected in a disaster.

Joe Iraci from the Canadian Conservation Institute is performing research on the disaster recovery of modern machine-readable information carriers. The project, which includes the examination of magnetic tapes, is divided into four stages: (1) preliminary testing; (2) soaking experiments; (3) investigation of drying techniques; and (4) investigation of cleaning techniques.

Storage

The basis for magnetic tape is nitrate, acetate, or polyester film, the same base material used for photographic film. Recent developments in the storage of these materials are covered on pages 29–32.

CHAPTER 5
General

Decay

Indoor air pollutants

While temperature, relative humidity, and light have long been major concerns in passive conservation, indoor air pollution has become another recognized factor. The term "carbonyl pollution," as used in this field, refers to indoor air pollutants such as acetic acid, formic acid, and formaldehyde. Many institutes are concerned with carbonyl pollution-induced deterioration and are performing air-sampling and materials-testing experiments. Unfortunately, the results of such studies are rarely published. Without access to the results, it is difficult to determine the current state of carbonyl-pollution research.

A conference entitled "Museum Pollution: Detection and Mitigation of Carbonyls" was held at Strathclyde University in Glasgow in 1998. More than 30 delegates from the United Kingdom, the Netherlands, Denmark, Canada, and the United States attended. The following recommendations were made:

- Construct a database to collate data from past and future sampling experiments on the relationship between carbonyl pollutant concentration and artifact damage.
- Construct a database to collate information on materials that have been judged as safe for short- and long-term use in proximity to susceptible artifacts.
- Develop standard operating protocols for acid and aldehyde vapor testing in museums and other storage areas.
- Form a working group of conservators and scientists, the Indoor Air Pollution Working Group (IAP), to be coordinated by the NICH.

As a follow-up to the 1998 meeting, a second symposium was held at the NICH in August 1999. The symposium, "Indoor Air Pollution: Detection and Prevention," was organized by the IAP Working Group that had been initiated at the 1998 meeting. The primary objectives of the meeting were to exchange information and discuss current research on indoor air-pollution-related problems. The following recommendations were made:

- *Air-sampling techniques.* Laboratories that perform air sampling and analyses should compare their protocols, identify differences, discuss the rationale behind choices, and develop a common protocol.
- *Understanding pollution–artifact interactions.* A consensus must be established with respect to pollution levels and material damage. The Getty Conservation Institute (Los Angeles, California, USA) is willing to fund the construction of a database that could be used to compile sampling data from field and laboratory measurements.
- *Materials testing.* Four types of materials tests are commonly used: (1) qualitative total corrosivity; (2) qualitative specific corrosivity; (3) quantitative total corrosivity; and (4) quantitative specific corrosivity. A format for a materials-testing list is proposed; it should be based on the experience of the National Museum of Scotland.
- *Dissemination of information.* To raise awareness for indoor air-pollution problems in preservation, the discussions in the working group should be disseminated. Several actions have already been undertaken: the postprints of the 1999 meeting have been published in hard copy (Brokerhof and Gibson 2000), electronic versions of the postprints are available from the NICH Web site (http://www.icn.nl/), and Morten Ryhl-Svendsen (School of Conservation, Copenhagen, Denmark) has constructed a Web site that offers additional information on indoor air quality (http://hjem.get2net.dk/ryhl/).

Treatment

Controlled-atmosphere fumigation and thermal treatments

Over the past 10 years, the use of chemical methods for pest control has been replaced to a large extent by the use of nonchemical methods. The emphasis now is on the use of modified atmospheres (MA) and controlled atmospheres (CA).

Tom Strang from the CCI is quantifying the effects of controlled-atmosphere fumigation (carbon dioxide, nitrogen, or argon) and thermal treatments (low-temperature or high-temperature) (Strang 1998).

Disinfection with essential oils

The antimicrobial properties of essential oils have been known since antiquity, but it was not until the nineteenth century that these substances were analyzed.

The study of the antifungal activity of these oils is more recent. Malalanirina Rakotonirainy, Marie-Ange Raisson, and Françoise Flieder from the CRCDG are studying the characteristics of essential oils. They are seeking to develop ways in which to apply them to prevent fungal growth on cultural properties and in storage areas, as well as to treat objects that are already infected.

The fungistatic and fungicidal activity of six essential oils (bay, wormseed, citronella, eucalyptus, super lavender, and sage) was examined on several fungal strains chosen from those most frequently found in libraries, archives, and museums. The effectiveness of the oils was studied in relation to their composition. All six oils revealed antifungal properties, although the results varied. It is unclear, from the preliminary findings, how practical the use of essential oils will be because of the large concentrations required for disinfection (Rakotonirainy et al 1998).

Flexible fumigation enclosures

Fumigation chambers have always been used in conservation practice to treat objects infested with pests; however, these chambers are expensive to construct, and not all institutions can afford them. An English company, Rentokil, has developed a reusable and flexible fumigation enclosure, the Rentokil Bubble. This portable enclosure is designed for use with methyl bromide, phosphine, or carbon dioxide. For the use of nitrogen, the company designed a different line of fumigation enclosures that have a heat-sealable, aluminized barrier film. These bags are not intended for reuse.

Two researchers at the Getty Conservation Institute (Los Angeles, California, USA), Kerstin Elert and Shin Maekawa, tested the enclosures for nitrogen fumigation. The two bubbles, 35 m^2 and 6 m^2, were investigated for both the oxygen-transmission characteristics of the materials and for the gas-tightness of the enclosure. The tests showed varied results but clearly confirmed the suitability of the bubbles for anoxia treatment. Some practical limitations, especially concerning the size of the units, were, however, detected (Elert and Maekawa 1997).

High-temperature treatment

High-temperature treatment has been proved to be effective in exterminating insects in collection materials. Tom Strang from the CCI designed a bag that will allow solar heating of the contents (slightly in excess of 40°C) in such a way that thermal deinfestation of the bag contents will be achieved. A prototype has shown the idea to be feasible, but additional tests need to be carried out.

Oxygen reduction and pest control

It is possible to control insect infestation by reducing oxygen concentration, a form of modified atmosphere. Oxygen reduction is increasingly regarded as a recommendable alternative to insecticides and pesticides, which are harmful to human health, pollute the indoor environment of conservation institutes, and may even produce reactions with the objects in the collection.

In 1998, the European Union financed a project called "SAVE ART." Its purpose is to control pests by reducing the oxygen concentration of the environment through the use of an electromechanical nitrogen generator (the VELOXY [VEry Low OXYgen] system). The idea is simple but effective: the oxygen in the air surrounding the object is removed (replaced by nitrogen) until a residual concentration of 0.1 percent to 0.2 percent is reached, at which level all insects will be killed.

The following parties are involved in the project:

Italy: Resource Group Integrator S.r.l. (coordinate project and produce equipment), MASTER S.r.l. (produce equipment), Istituto Centrale per la Patologia del Libro (test prototype);
United Kingdom: Central Science Laboratory (test effectiveness);
Spain: Consejo Superior de Investigaciones Biologicas (test effectiveness);
Sweden: Swedish Museum of Natural History, PRE-MAL.

Realscale validations of the VELOXY system were performed at the National Marciana Library (Venice, Italy), El Prado Museum and Centro de la Restauracion del Mueble (Madrid, Spain), the Swedish Museum of Natural History (Stockholm, Sweden), and the National Museum of Wales (Cardiff, UK). The real-scale tests showed promising results. Since the project's inception, 12 VELOXY systems have been assembled and are now operative at several museums, libraries, and archives (Conyers, in press; Gialdi 1998).

PRE-MAL is part of the European SAVE ART project. The investigations include testing the effects of pest-control methods on pest insects, artifacts, and humans. The effects of long-term storage in a low-oxygen atmosphere are tested on various materials (Åkerlund 1998; Åkerlund et al 1998; Antonsson and Samuelsson 1996; Bergh et al 1996; Bergh 1998; Björdal 1998; Kolmodin-Hedman and Flato 1998; Petersson 1998).

The following institutions are involved:

Sweden: National Museum of Science and Technology (coordinator), Skokloster Castle (test treatment on pest-infested saddles), Swedish National Testing and Research Institute (test freezing method), Karolinska Institute, Department of Occupational Health (test health personnel), Swedish University of Agricultural Sciences, Department of Environmental Assessment (test health personnel);
Denmark: Technical University of Denmark, Department of Biotechnology (test effectiveness of treatments).

Oxygen-scavenging cell

A modern way to slow the deterioration of organic objects is to minimize the oxygen content of the environment. Mark Gilberg from the National Center for Preservation Technology and Training (Natchitoches, Louisiana, USA) and David W. Grattan from the CCI investigated a prototype of an electrochemical cell and its ability to reduce the oxygen concentration in a small chamber that is similar to a museum display case.

The oxygen-scavenging cell is capable of removing oxygen from enclosed spaces, even in the presence of high leak rates; however, the reduction rate is slow. The most significant drawback is the high relative humidity that develops in the chamber. The system needs to be modified to allow better control (Gilberg and Grattan 1996).

Storage

Climate conditions and standards

The control of RH continues to be an expensive and difficult challenge. In many situations, an attractive option is to control the RH within display cases instead of controlling the entire space.

Stefan Michalski, Paul Marcon, and Tom Strang from the Canadian Conservation Institute are working on a centralized module supplying filtered and humidity-controlled air to each case through small tubes (typically 6-mm diameter) without return air, relying on compensating leakage from the case. The possibility of using an Internet application to provide remote control of the module and remote monitoring of the units is being investigated.

The control of temperature and relative humidity is generally accepted as a means to prevent degradation of collections. Several guidelines are being developed, but the rationale behind these standards is not always clear.

Stefan Michalski from the CCI looked more closely at the basis of these standards and the costs of achieving them. In cooperation with the Canadian Council of Archives, the CCI created a document entitled *Environmental Guidelines for Canadian Archives.* Parts of the work have been summarized in the new chapter for engineers in *Museums, Libraries and Archives* in the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Handbook, Applications Volume, 1999 (Michalski 1998, 1999; Michalski, in press).

Determining safe ranges for the storage climate of paper and other artifacts and understanding how temperature and relative humidity conditions within this range affect the rate of changes over time are two objectives of research conducted by David Erhardt and co-workers from the Smithsonian Institution, Smithsonian Center for Materials Research and Education. Changes over time in properties such as stiffness, strength, and elasticity were examined using both naturally aged samples and accelerated-aging tests. Results demonstrated that the rate and nature of chemical degradation processes as a function of environmental conditions are correlated with the

changes in physical properties taking place in the constituent materials. On the basis of the findings, several recommendations with regard to environmental conditions were made. The research report also discusses critically some common perceptions, especially with regard to the relative humidity conditions (Erhardt et al 1999).

Lighting technique and guidelines

In the last decade, conservation scientists have given increased attention to lighting issues, particularly the damaging effects of light on artifacts. Two processes are responsible for this damage: photochemical action, which causes fading, chalking, and loss of strength; and radiant heating, which causes surface cracking and embrittlement.

In 1997, the Preservation Technology and Training Project marked significant progress toward a solution to this long-standing problem. Christopher Cuttle from Rensselaer Polytechnic Institute (Troy, New York, USA) examined an innovative lighting technique that promises to reduce rates of light-induced damage without affecting viewing satisfaction. Cuttle recorded individual, subjective evaluations of works of art displayed under different lighting conditions.

The studies suggest that light concentrated in three spectral bands (with center wavelengths of 450, 530, and 610 nm) could provide levels of illumination equal to standard broad-spectrum lighting with substantially reduced levels of damaging incident radiant energy. Three-band lighting could allow the display of artifacts for longer periods than is possible with traditional illumination sources (Cuttle 1998).

Standard light levels have been introduced over the past 30 years. Although the intent of such standards is clear, their application to broad ranges of object types has been somewhat arbitrary. Resolving the issue of visibility versus vulnerability of the object has been difficult for the preservation community.

Stefan Michalski from the CCI has been working with a technical committee of the International Commission on Lighting to develop an improved lighting guide. This guide recommends steps to ensure safe lighting of displays, including the classification of all exhibits according to a four-category scale, determination of the acceptable level of UV radiation, calculation of the annual exposures, and planning for the maximum duration of the display, both for the exhibition and for individual objects (Michalski 1997).

The main objective of a current project of the State Central Archives in Prague (Czech Republic) is the development of guidelines for the protection of all sorts of archival and library materials from the damaging effects of light during exhibitions. The planned studies include investigation into the influence of visible and UV light on the mechanical, chemical, and optical properties of paper and other materials, and into the lifetime and effectiveness of UV filters (Durovic 2000).

Materials testing program

The NARA Document Conservation Laboratory (College Park, Maryland, USA) maintains a testing program to ensure that proposed exhibit and storage materials do not cause damage to permanent records. All the tested products are listed on NARA's Web site (http://www.nara.gov/arch/techinfo/preserva/products.html). Inclusion in the list does not imply that a product is acceptable, only that it has been tested. The conservator, on basis of these results, can decide whether or not it is safe to use the particular material. In general, the laboratory uses the Oddy and photographic activity tests (PATs). However, since 1996, A-D strips, which were developed to test for film deterioration, also have been used as a quick check on whether any acidic volatiles are being emitted by the material in question. The results apply only to the specific samples tested at a given time. Each run of paper, board, plastic, or other material from a given mill or manufacturer can, and probably will, be different. Therefore, the test results may not apply to products ordered today from the same vendors. Exclusion of the testing program merely implies that the manufacturer did not bid, did not supply samples, or was not asked to supply samples.

Polyethylene foam

Polyethylene foam is used today for storing all kinds of objects. Since the ban on CFC agents, drastic alterations have been made in the production of polyethylene foam. Alarming reports from several institutions indicated the urgent need to investigate the aging behavior of the new foam products.

Scott Williams from the CCI is studying the effect of the changes in the polyethylene foam manufacturing processes and formulations in relation to the deterioration mechanism of the foam products. Degraded samples will be chemically examined, and undegraded samples will be subjected to accelerated aging and subsequent analysis (Williams 1998).

CHAPTER 6

Trends and Gaps

This survey has highlighted several new developments in preservation science research. Here, the most notable trends are described and several areas are proposed for special attention.

Trends

Shift to large-scale, passive conservation

Preservation science is moving steadily away from the investigation of individual artifacts and individual conservation problems. This trend, which began in the 1980s with large-scale studies such as the Swedish FoU-projektet för papperskonservering (Fellers et al 1989) and the European Commission's STEP project on the effects of air pollutants (Havermans et al 1994), continues today. More and more, the scientific research is tuned to large-scale, national, or international preservation activities.

At the same time, preservation managers are becoming more interested in passive measures than in active conservation and are often limiting real treatment and restoration to a very small part of their collections. Consequently, current preservation science concentrates more on damage prevention (e.g., storage conditions) than on the development of new or improved conservation techniques. An example is integrated pest management, a current approach to preventing pest infestation. Integrated pest management involves assessment of acceptable pest-population sizes, monitoring of pest populations, identification and implementation of control methods, and evaluation of all actions taken. The literature on this subject is growing rapidly (Jessup 1997; Trinkley 1997).

Parallel to the trend toward passive conservation, financial constraints limit research that is aimed primarily at individual items or

small parts of a collection. Recent funding for research has favored large-scale activities that are intended to prevent damage to the original (this includes digitization and microfilming, which can limit use of, and therefore damage to, the original). The trend toward passive conservation is bolstered by reactions to "mistakes" in previously performed treatments.

Integration and cooperation in preservation management

Research has become an integral part of preservation policy and of management in general. Aware that there is "no access without preservation," collection keepers have recognized the need to make reliable diagnoses of the physical condition (life expectancy) of their holdings. This implies, for preservation science, increased attention to the scientific elaboration of damage-survey techniques, especially with respect to the required physicochemical test methodology (Hofenk de Graaff 1999). In this regard, a promising approach under the name Universal Procedure for Archive Assessment (UPAA) has been developed recently (Havermans et al 1999b). There is a great need for standards and control tools for storage conditions, selection procedures for reformatting, and conservation treatment priorities. The evaluation of the reformatting or treatment procedures themselves, combined with the development of these standards and tools, represents a full agenda for preservation science. It also induces scientists from different disciplines to work together.

The key words in preservation policy today are interdisciplinary approach, multilateral cooperation and legislation, funding, and education. Projects under way in the different programs of the European Union, in which many countries work together on a specific research theme, have shown that international, large-scale cooperation in scientific research is possible. At the same time, the programs are demonstrating cooperation between public institutions and private companies. A good example is the European "Safeguarding European Photographic Images for Access" (SEPIA) project. In it, eight European organizations have agreed to (1) promote awareness of the need to preserve photographic collections, (2) train professionals involved in the preservation and digitization of photographic collections, and (3) develop a framework under which future projects in the area of preservation and access of photographic materials can be brought together (Klijn and de Lusenet 2000).

From hydrolysis to oxidation

Although several questions about acid-catalyzed hydrolysis of paper remain unanswered, the established mass-deacidification techniques appear to have led to a common confidence that the problem of acid paper has been solved. That is why the emphasis of preservation research is shifting toward paper-deterioration processes involving oxidation. Ink corrosion and photo oxidation are the current favorite

subjects of basic research, while new treatment procedures based on antioxidants are being developed.

Backlog of film, photo, and tape preservation research

The field of film, photo, and magnetic tape preservation does not have the well-established tradition in conservation treatment that paper does. The gap in research between paper preservation and film, photo, and tape preservation is more pronounced in Europe than in North America, but it is notable on both continents. For magnetic tape, the gap is even greater than for film and photographic materials. The relative lack of experience and gap in knowledge stems from the fact that nonprint materials are newer. Although there is a will to catch up these arrears, the conservation of non-print artifacts is still in its infancy, and until now the "solutions" have been mainly based on reformatting. If the current trend to reformat analog information into digital form slows efforts to preserve the original materials, the physical forms of film, photographs, and tape may soon be completely lost by the continuing process of deterioration.

In the case of magnetic tape, digitization is considered the only means by which to preserve the recorded content, and digital mass-storage systems are now installed in radio and national sound archives. In fact, most of the financial resources for tape conservation are put into digital preservation.

Success in preserving audiovisual materials is highly dependent on the extent to which media manufacturers are willing to provide information about their products. The composition of most of the constituent materials is considered an industrial secret. Therefore, it is almost impossible to determine the life expectancy of a given audiovisual carrier. The development of archival qualities does not yet seem to be of commercial interest. Industrial research on and development of the audiovisual materials continue, especially projects that focus on miniaturization and the improvement of performance and storage capacity. Factors such as permanence and durability, however, are neglected. (One exception is the development of preservation microfilm).

All of this makes it very hard for conservation scientists to fully understand the materials involved and to give proper advice to preservation managers. This is especially true for research on magnetic tape. There is a Canadian initiative, however, that offers promise. It promotes the development of standards that would require manufacturers of videotape and optical-disk hardware to notify archivists as to when their products will be discontinued and how to migrate them without content loss. Zwaneveld argues for a standard in which the date of discontinuation (end-of-life year) of a tape or disk is stated clearly. This would allow for the creation of asset-management databases that would inform the archivist or curator when it is time to migrate the content of the tape or disk to another carrier (Zwaneveld 2000).

Gaps

The following areas merit particular attention in the near future:

- The increased focus of preservation science on large-scale damage-prevention measures comes at the expense of research into the active conservation of individual artifacts. It is causing a growing gap in that knowledge and insight that will eventually threaten our ability to safeguard our cultural heritage.
- Further research is needed on the applicability of accelerated aging and into the standardization of aging tests. Whereas accelerated-aging tests are often carried out to make prognoses, e.g., to calculate life expectancy or quantify the effects of conservation treatments, the predictive value of these tests is still seriously questioned.
- The use of solvents is well established in the practice of conservation, and they are commonly applied to remove glue and self-adhesive tape. Nevertheless, research into the effects of solvents on the materials themselves is insufficient. Two questions arise: How much of the solvent remains in the treated material? How harmful is this residue? These questions need to be answered.
- Development of nondestructive microanalytical tools to determine the condition of paper, photographs, and other materials has just begun. These new tools can be very useful in assigning priority to objects for conservation treatment. In addition, by providing an alternative means of monitoring natural aging effects, they circumvent the need to use the questionable approach of accelerated aging. Further research into microanalytical techniques should be stimulated.
- In this era of digitization, there is growing concern about the possible negative influence of the electromagnetic radiation applied in the process of scanning original material. Preservation research into this matter is needed. In addition, the risk of damage to artifacts by handling during scanning deserves more attention. In this context, it must also be noted that the increased accessibility of collections in digitized form appears to stimulate, rather than prevent, the demand to consult the original objects.
- Although mass deacidification has been incorporated into general conservation practice, the treatment criteria remain uncertain. In addition to the lack of standardized procedures to evaluate the effectiveness and efficiency of the deacidification treatment, an important question is how much alkaline reserve is needed in the paper. Another question is whether the introduction of an excess of alkaline compounds will cause adverse effects (i.e., stimulation of oxidation). Research is needed to improve our insight and to establish agreement on proper treatment standards and testing procedures.
- The great problem in the preservation of magnetic tape is the lack of knowledge about which tapes will be the first to deteriorate beyond the point at which they can be salvaged. Such knowledge is

a prerequisite for setting up a successful preservation and transfer strategy; in its absence, priorities cannot be set and a great deal of material will be lost. Life-expectancy testing is the most important and demanding challenge in this field. Although already indicated as a general area of attention, the questions regarding the use of accelerated aging for the purpose of determining permanence apply to magnetic tape in particular.

- To some degree, developing countries suffer from threats to their cultural heritage that are different from those in Western countries. Extreme temperatures and relative humidity often cause large-scale infestation of country-specific insects, fungi, and molds. In addition, non-Western written traditions, including the writing materials, are often different from Western ones. Although individual governments and multilateral institutions (e.g., Paul Getty Conservation Institute, UNESCO Memory of the World Program) give support and aid, it is usually according to Western preservation strategies. National programs for preservation, including specific research projects, are being established. Care should be taken not to impose our solutions to Western conservation problems on developing countries. Instead, preservation research should aim at a better understanding of typical non-Western conservation problems.
- A final issue is the role of the conservation scientist as an interpreter between science and conservation. The interface between preservation science and conservation practice is essential. The results of preservation science have to be translated and disseminated in order to be usable in conservation management and policy. However wonderful the discoveries of the conservation scientists are, these individuals will have wasted their time if they fail to communicate these advances to conservators and preservation administrators.

References

Åkerlund, M. 1998. A New Swedish Book on Integrated Pest Management and Health Hazards in Museums. In *Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums September 24–25, 1998*, edited by M. Åkerlund, et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 175-78.

Åkerlund, M., et al., eds. 1998. *Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums September 24–25, 1998*, Stockholm: PRE-MAL and ICOM Swedish National Committee.

Anders, M., K. Bredereck, and A. Haberditzl. 1996. Mechanisms of Paper Ageing and Non-aqueous Paper Deacidification Combined with Paper Strengthening. In *11th Triennial Meeting, Edinburgh, September 1–6, 1996, ICOM-CC (Vol. 2)*, edited by J. Bridgland. London: James and James, 481-88.

Antonsson, M., and M. L. Samuelsson. 1996. *Effects of Repeated Freezing on Paper Strength.* SP Report 1996:19. Borås: Swedish National Testing and Research Institute, Materials Technology.

Arnold, R. B. 1996. Update: ASTM/ISR Paper Aging Research Program. *Abbey Newsletter* 20(3): 29-30.

Baker, J. M., G. E. Klechefski, and M. K. Hoel. 1998. *Risk Analysis Study for a Representative Magnetic Tape Collection.* Library of Congress Preservation Research and Testing Series No. 9808. Washington, D.C.: Preservation Directorate, Library of Congress.

Baranski, A., et al. 2000. Methodology of Kinetic Investigation of Cellulose Degradation. *Preprint of the III Congress of Chemical Technology,*

Gliwice, Poland, September 4–8, 2000. Distributed by the permission of M. Taniewski, Head of Scientific Committee of the Congress.

Bégin, P., et al. 1998. The Impact of Lignin on Paper Permanence. A Comprehensive Study of the Aging Behavior of Handsheets and Commercial Paper Samples. *Restaurator* 19: 135-54.

Bégin, P., et al. 1999. The Effect of Air Pollutants on Paper Stability. *Restaurator* 20: 1-21.

Bergh, J.-E., H. Mourier, and K. P. Poulsen. 1996. Lethal Effects of Low Pressure (vacuum) on Some Museum Pest Insects. In *11th Triennial Meeting, Edinburgh, September 1–6, 1996, ICOM-CC (Vol. 1)*. Edited by J. Bridgland. London: James and James, 3-7.

Bergh, J.-E. 1998. Current Research on Anoxic Methods in Scandinavia. In *Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24–25, 1998,* edited by M. Åkerlund , et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 4-8.

Bigourdan, J.-L., P. Z. Adelstein, and J. M. Reilly. 1996. Acetic Acid and Paper Alkaline Reserve. Assessment of a Practical Situation in Film Preservation. In *11th Triennial Meeting, Edinburgh, September 1–6, 1996, ICOM-CC (Vol. 2.),* edited by J. Bridgland. London: James and James, 573-9.

Bigourdan, J.-L. and J. M. Reilly. 1999. Preservation Strategy for Acetate Film Collections Based on Environmental Assessment and Condition Survey. In *Care of Photographic Moving Image & Sound Collections. Conference papers, July 20–24, 1998,* edited by S. Clark. Leigh, U.K.: Institute of Paper Conservation, 28-37.

Björdal, L. 1998. Effects of Repeated Freezing on Paper Strength. In *Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24–25, 1998,* edited by Åkerlund, M., et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 54-6.

Brandis, L. and J. Lyall. 1997. Properties of Paper in Naturally Aged Books. *Restaurator* 18: 115-30.

Brokerhof, A. W. and L. Gibson. Indoor Air Pollution. 2000. Detection and Prevention. In *Presentation Abstracts and Additional Notes, Instituut Collectie Nederland Meeting, August 26–29, 1999.* Amsterdam: Netherlands Institute for Cultural Heritage.

Carlsen, S. 1999. Effects of Freeze Drying on Paper. In *IADA Preprints 1999,* edited by M. S. Koch. Copenhagen: Royal Academy of Fine Arts, 115-20.

Choicy, P., et al. 1997. Non Invasive Techniques for the Investigation of Foxing Stains on Graphic Art Material. *Restaurator* 18: 131-52.

Conyers, S. In press. System VELOXY® and its Applications. In *Proceedings of the Meeting "NOOX Anoxic Environment, Oxygen Scavengers and Barrier Films, Their Use in Museums, Libraries and Galleries," November 29–30, 1999.*

Couture, R. 1999. Challenges in Mass Deacidification. *National Library News* 31(7-8): 8-10.

Cuttle, C. 1998. *Museum Lighting Protocol Project.* PTT Publications No. 1998-31. Natchitoches, La.: National Center for Preservation Technology and Training.

Daffner, L. A., D. Kushel, and J. M. Messinger II. 1996. Investigation of a Surface Tarnish Found on 19th-Century Daguerreotypes. *Journal of the American Institute for Conservation* 35(1): 9-21.

Daniel, F., F. Flieder, and A. Demarque. 1998. La Conservation des Documents Encapsulés Sous Vide. *Nouvelles de l'Arsag* 14: 16-8.

Daniel, F., S. Copy, and F. Flieder. 1999a. La Désacidification de Masse à la Bibliothèque Nationale de France: Un Peu Plus de Magnésium, s'il Vous Plaît. In *Les Documents Graphiques et Photographiques: Analyse et Conservation. Travaux du CRGDG 1994–1998.* Paris: Direction des Archives de France, 9-24.

Daniel, F., A. Demarque, and F. Flieder. 1999b. Effet de l'Encapsulation Sous Vide du Papier par la Méthode «Archipress.» In *12th Triennial Meeting, Lyon, August 29–September 3, 1999, ICOM-CC (Vol. 2)*, edited by J. Bridgland. London: James and James, 495-500.

Daniel, F., et al. 1999. Étude de l'Efficacité d'un Nouveau Produit d'Archivage: le MicroChamber. In *Les Documents Graphiques et Photographiques: Analyse et Conservation. Travaux du CRCDG, 1994–1998.* Paris: Direction des Archives de France, 25-50.

Destiné, J. N., et al. 1996. The Photodegradation of Milled-wood Lignin. Part I. The Role of Oxygen. *Journal of Pulp Paper Science* 22(1): J24-J30.

Dignard, C., et al. 1997a. An Overview of Laser Cleaning in Conservation. Paper presented at the Annual Conference of the Canadian Association for Conservation of Cultural Property, Ottawa, Canada, May 30–June 3.

Dignard, C., et al. 1997b. Overview of Laser Cleaning in Conservation. Poster presented at the Annual Conference of the Canadian Association for Conservation of Cultural Property, Ottawa, Canada, May 30–June 3.

Dignard, C. , et al. 1997c. *Nd-Yag Laser-Cleaning at CCI. Experiences, Results and Directions.* Report to the Canadian Conservation Institute management, Ottawa, Canada.

Dobrusskin, S. 1999. Frühe, Nichtphotographische Kopier- und Vervielfältigungstechniken. In *IADA Preprints 1999*, edited by M. S. Koch. Copenhagen: Royal Academy of Fine Arts, 195-205.

Dupont, A.-L. 1996a. Degradation of Cellulose at the Wet/dry Interface. I. The Effect of some Conservation Treatments on Brown Lines. *Restaurator* 17: 1-21.

Dupont, A.-L. 1996b. Degradation of Cellulose at the Wet/dry Interface. II. An Approach to the Identification of the Oxidation Compounds. *Restaurator* 17: 145-64.

Dupont, A-L., and J. Tétreault. Cellulose Degradation in an Acetic Acid Environment. *Studies in Conservation* (submitted).

Durovic, Michal, State Central Archives, Prague, Czech Republic. 2000. Personal communication.

Edge, M. In press. Techniques for Monitoring the Breakdown of Film and Sound Materials. In *Image and Sound—Archiving and Access. The Challenges of the 3rd Millennium. Proceedings of the 5th Joint Technical Symposium* (Paris, Jan. 19–22, 2000), edited by M. Aubert and R. Billeaud. Paris: Centre National de la Cinématographie and Commission Supérieure Technique de l'Image et du Son.

Elert, K. and M. Maekawa. 1997. Rentokil Bubble in Nitrogen Anoxia Treatment of Museum Pests. *Studies in Conservation* 42(4): 247-52.

Erhardt, D. and M. Mecklenburg. 1995. Accelerated vs. Natural Aging. Effect of Aging Conditions on the Aging Process of Paper. In *Materials Issues in Art and Archeology IV, Materials Research Society (Vol. 352)*, edited by P. Vandiver et al. Warrendale, Penna.: Materials Research Society, 247-70.

Erhardt, D. , et al. 1996. New Versus Old Wood. Differences and Similarities in Physical, Mechanical, and Chemical Properties. In *11th Triennial Meeting, Edinburgh, September1–6, 1996, ICOM-CC (Vol. 2)*, edited by J. Bridgland. London: James and James, 903-10.

Erhardt, D., et al. 1997. The Determination of Appropriate Museum Environments. In *The Interface Between Science and Conservation*. Occasional Paper No. 116, edited by S. Bradley. London: British Museum, 153-63.

Erhardt, D., C. S. Tumosa, and F. Mecklenburg. 1999. Material Consequences of the Aging of Paper. In *12th Triennial Meeting, Lyon, August 29-September 3, 1999, ICOM-CC (Vol. 2)*, edited by J. Bridgland. London: James and James, 501-6.

Feber, M. de, J. Havermans, and E. Cornelissen. 1998. The Positive Effects of Air Purification in the Dutch State Archives. Part I: Experimental set-up and air quality. *Restaurator* 19: 212-23.

Fellers, C., et al. 1989. *Aging/Degradation of Paper. A Literature Survey* Report No. 1E. Stockholm: FoU-projekter för papperskonservering.

Gialdi, E. 1998. Project SAVE ART. In *Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24–25, 1998*, edited by M. Åkerlund et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 78-9.

Gilberg, M., and D. W. Grattan. 1996. A Dynamic System for Removing Oxygen from Air Using an Electrochemical Cell. *Studies in conservation* 41(3): 183–6.

Gilmour, I. In press. Pigment Binder Degradation and Life Expectancy of Magnetic Tapes. In *Image and Sound—Archiving and Access. The Challenges of the 3rd Millennium. Proceedings of the 5th Joint Technical Symposium* (Paris, Jan. 19–22, 2000), edited by M. Aubert and R. Billeaud. Paris: Centre National de la Cinématographie and Commission Supérieure Technique de l'Image et du Son.

Grijn, E. van der, A. Kardinaal, and H. Porck, H. 1996. The 1845 Paper Crisis in the Netherlands. An Historical-Technical Study into the Dutch Paper Market and into the Nature and Extent of the Inferior Quality of mid-19th Century Paper. In *IPH Congress Book (Vol. 11)*, edited by R. Teygeler. Marburg, Germany: International Association of Paper Historians, 153–63.

Grijn, E. van der, A. Kardinaal, and H. Porck. In press. The Evaluation of Paper Degradation: The Historical and the Scientific Approach. Paper presented at Congress 24 of the International Association of Paper Historians (September 1998), Porto, Portugal. IPH Congress Book, Vol. 12.

Guttman, C. M., and W. R. Blair. 1996. *Protection of Archival Records from Pollutants. IV. Absorption Studies of Archival Box Boards and Model Papers Exposed to uL/l and nL/L Concentrations of Nitrogen Dioxide.* NISTIR 5876. Gaithersburg, Md.: National Institute of Standards and Technology.

Hanus, J., M. Komorníková, and J. Mináriková. 1996. Changes in Some Mechanical Properties of Paper During Ageing in an Archival Box. In *11th Triennial Meeting, Edinburgh, September 1-6, 1996, ICOM-CC (Vol. 2.)*, edited by J. Bridgland. London: James and James, 510-6.

Hanus, J., et al. 1999. Comparison of Two Different Methods of Head Space Gas Chromatography for Determination of Residual Ethylene Oxide in Sterilised Papers. In *12th Triennial Meeting, Lyon, August 29–September 3, 1999, ICOM-CC (Vol. 2)*. London: James and James, 507-12.

Havermans, J. B. G. A., et al. 1994. *The Effect of Air Pollutants on the Accelerated Aging of Cellulose Containing Materials—Paper.* EC/DGXII/STEP Project CT 90-0100. Delft: TNO Institute of Industrial Research, Paper Production Technology.

Havermans, J. 1995. Effects of Air Pollutants on the Accelerated Ageing of Cellulose-based Materials. *Restaurator* 16: 209-33.

Havermans, J. 1996. Brittle Paper and Plasma Treatment. Experts Meet in Delft to Consider Potential of New Treatment. *Abbey Newsletter* 20(1): 16.

Havermans, J. B. G. A. 1997. *A Study of the Cause of Damage on Pairs of Books.* TNO-Report BU2.97/009063-1/JH. Delft: TNO Institute of Industrial Research, Paper Production Technology.

Havermans, J. B. G. A. and J. Dufour. 1997. Photo Oxidation of Paper Documents. A Literature Review. *Restaurator* 18: 103-14.

Havermans, J. B. G. A., et al. 1999a. Emission of Volatile Organic Compounds from Paper Objects Affected with Iron-gall Ink Corrosion. In *12th Triennial Meeting, Lyon, August 29-September 3, 1999, ICOM-CC (Vol. 2)*, edited by J. Bridgland. London: James and James, 513-6.

Havermans, J., P Marres, and P. Defize. 1999b. The Development of a Universal Procedure for Archive Assessment. *Restaurator* 20: 48-55.

Hinterhofer, O., et al. In press. Minimal-invasive Approaches to Magnetic Tape Life Expectancy Testing. In *Image and Sound—Archiving and Access. The Challenges of the 3rd Millennium. Proceedings of the 5th Joint Technical Symposium*, (Paris, Jan. 19–22, 2000), edited by M. Aubert and R. Billeaud. Paris: Centre National de la Cinématographie and Commission Supérieure Technique de l'Image et du Son.

Hofenk de Graaff, J. H. 1999. Waves of Knowledge. Trends in Paper Conservation Research. In *IADA Preprints 1999*, edited by M. S. Koch. Copenhagen: Royal Academy of Fine Arts, 9-13.

Jessup, W. C. 1997. Integrated Pest Management. Not a Fad or a Fancy Term but a Valid Operation Strategy. *AIC News* 22(3): 1-5

Johansson, A. 2000. Air Pollution and Paper Deterioration. Causes and Remedies. Ph.D. thesis, Göteborg University, Department of Chemistry, Göteborg, Sweden.

Kaminska, E., et al. 1999. *ASTM/ISR Research Program on the Effects of Aging on Printing and Writing Papers. Accelerated Aging Test Method Development.* Draft Final Report to the ASTM Advisory Committee on Paper Aging Research.

Kautek, W., et al. 1998. Laser Interaction with Coated Collagen and Cellulose Fibre Composites: Fundamentals of Laser Cleaning of Ancient Parchment Manuscripts and Paper. *Applied Surface Science* 127-129(1-4): 746-54

Keneghan, B., and E. Martin. 1998. The Use of Molecular Sieve for Extending the Life of Cellulose Acetate Photographic Negatives. In *Care of Photographic Moving Image & Sound Collections. Conference Papers, July 20–24, 1998,* edited by S. Clark. Leigh, U.K.: Institute of Paper Conservation, 25-7.

Kidder, L., T. Boone, and S. Russick. 1998. Bookkeeper Spray for Use in Single Item Treatments. *Abstracts of the Twenty-Sixth Annual Meeting of the American Institute for Conservation,* (Washington, D.C., June 1–7, 1998), 67. Washington, D.C.: American Institute for Conservation.

Klijn, E. and Lusenet, Y. de. 2000. *In the Picture. Preservation and Digitisation of European Photographic Collections.* Amsterdam: European Commission on Preservation and Access. Also available from www.knaw.nl/ecpa/publ/picture.pdf

Kolar, J. 1997. Mechanism of Autoxidative Degradation of Cellulose. *Restaurator* 18: 163-76.

Kolar, J. and M. Strlic. 1998. Aging Stability of Laser-treated Paper. Presentation at *Laser Cleaning of Paper and Parchment. LACLEPA Workshop '98, October 29–30, 1998.* EUROCARE project EU 1681. Berlin.

Kolar, J., et al. 1998. Aging and Stabilization of Alkaline Paper. *Journal of Pulp Paper Science* 24(3): 89-94.

Kolar, J. and M. Strlic. 1999. Stabilisation of Iron-gall Ink Corrosion. Paper presented at the European Workshop on Iron-Gall Ink Corrosion, December, 16–17, 1999. The Hague: General State Archives.

Kolar, Jana, National and University Library, Conservation Department, Ljubljana, Slovenia. 2000. Personal communication.

Kolar, J,. and M. Strlic. 2000. Laser Cleaning of Paper. Immediate and Long-term Effects. Presentation at Laser Cleaning of Paper and Parchment. LACLEPA Workshop 2000 (January 10–11, 2000, Vienna). EUROCARE project EU 1681.

Kolar, J., M. Strlic, and M. Marincek. 2000. The Effect of Nd:YAG Laser Radiation at 1064 nm on Paper. *Restaurator* 21: 9-18.

Kolar, J., et al. 2000. Near-UV, Visible and IR Pulsed Laser Light Interaction with Cellulose. *Applied Physics A—Materials Science and Processing* 71(1): 87-90.

Kolar, J., et al. In press. Near-UV Pulsed Laser Interaction with Paper. In *Lasers in the Conservation of Artworks III. LACONA III Conference, April 19–22, 1999,* edited by F. Fabre. Paris: Elsevier.

Kolmodin-Hedman, B., and S. Flato. 1998. Health Risk in Museums. Possible Risks and Prevention in Sweden. In *Infestation Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24-25, 1998,* edited by M. Åkerlund et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 124-8.

Lavédrine, B. 1999. The Blue Pink Scale: A New Dosimeter for the Exhibition of Photographs and Sensitive Artifacts. In *Care of Photographic Moving Image & Sound Collections. Conference papers, July 20–24, 1998,* edited by S. Clark. Leigh, U.K.: Institute of Paper Conservation, 121-8.

Levart, A., et al. 1999. Determination of Volatile Cellulose Degradation Products by HPLC, IEC and CE Using Cryo-trap Sampling. Poster at *Balaton Symposium '99 on high-performance separation methods. September 1–3, 1999,* Siofok, Hungary.

Louvet, A., and M. Gillet. 1999. Les Clichés Photographiques sur Supports Souples: Contribution à L'étude de Leur Stabilité. In *Les Documents Graphiques et Photographiques: Analyse et Conservation. Travaux du CRCDG, 1994–1998.* Paris: Direction des Archives de France, 109-59.

McCormick-Goodhart, M. 1996. Conservation Forum. The Allowable Temperature and Relative Humidity Range for the Safe Use and Storage of Photographic Materials. *Journal of the Society of Archivists* 17(1): 7-21.

McCormick-Goodhart, M. 1999. Methods for Creating Cold Storage Environments. In *Care of Photographic Moving Image & Sound Collections. Conference Papers, July 20–24, 1998,* edited by S. Clark. Leigh, U.K.: Institute of Paper Conservation, 19-24.

McCrady, E. 1999. ASTM/ISR Paper Permanence Research. *Abbey Newsletter* 23(1): 1, 4-6.

Mecklenburg, M. F., and C. S. Tumosa. 1996. The Relationship of Externally Applied Stresses to Environmentally Induced Stresses. In *Proceedings of the First International Conference on Composites in Infrastructure,* edited by H. Saadatmanesh and M. R. Ehsani. Tucson: University of Arizona, 956-71.

Michalski, S. 1997. The Lighting Decision. In *Fabric of an Exhibition, Preprints of Textile Symposium '97.* Ottawa: Canadian Conservation Institute, 97-104.

Michalski, S. 1998. Climate Control Priorities and Solutions for Collections in Historic Buildings. *Historic Preservation Forum* 12(4): 8-14.

Michalski, S. 1999. Museums, Libraries and Archives. In *ASHRAE Applications Handbook.* Atlanta: American Society of Heating, Refrigeration and Air-Conditioning Engineers, 20.1-20.13.

Michalski, S. In press. *Environmental Guidelines for Canadian Archives.* Ottawa: Canadian Council of Archives and the Canadian Conservation Institute.

Müller-Hess, D., et al. 1999. Reinigung ist so gut wie ihre Kontrollierbarkeit. In *Konservieren-Restaurieren, Mitteilungen des Österreichischen Restauratorenverbandes. 14. Tagung des Österreichischen Restauratorenverbandes (ÖRV) "Schmutz-Zeitdokument oder Schadensbild," Band 7/ 2000.* Vienna: Österreichischen Restauratoren-verbandes.

Neevel, J. G., and B. Reissland. 1998. The Ink Corrosion Project at the Netherlands Institute for Cultural Heritage. *Paper Conservation News* 85: 10-3.

Neevel, J. G., and C. T. J. Mensch. 1999. The Behaviour of Iron and Sulphuric Acid During Iron-Gall Ink Corrosion. In *12th Triennial Meeting, Lyon, August 29–September 3, 1999, ICOM-CC (Vol. 2).* London: James and James, 528-33.

Nguyen, T-P., B. Lavédrine, and F. Flieder. 1997. Effects of NO_2 and SO_2 on the Degradation of Photographic Gelatin. *Imaging Science Journal* 45(3-4): 239-44.

Pauk, S., and H. Porck. 1996. *Land om Land. Verslag van de Bestudering van Identieke Boekenparen, die Onder Verschillende Omstandigheden Zijn Bewaard.* The Hague: Koninklijke Bibliotheek.

Pedersoli Jr, J. L., and J. Hofenk de Graaff. 1998. Paper Degradation and Light Emission. Possibilities for the Application of Chemiluminescence to the Investigation of Paper Oxidation. Paper presented at the April 20–22 1998 ICOM-CC Interim Meeting of the Working Groups on Graphic Documents and Photographic Documents, in Ludwigsburg, Germany.

Pedersoli Jr., J. L. 1999. The Development of Micro-analytical Methodologies for the Characterisation of the Condition of Paper. In *IADA Preprints 1999,* edited by M. S. Koch. Copenhagen: Royal Academy of Fine Arts, 107-14.

Petersson, K. 1998. Freezing as an Insect Control Method on a Large Clothes Moth. In *Infestation Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24–25, 1998,* edited by M. Åkerlund et al. Stockholm: PRE-MAL and ICOM Swedish National Committee, 71-5.

Porck, H. J. 1996. *Mass Deacidification. An Update of Possibilities and Limitations.* Amsterdam: European Commission on Preservation and

Access and Washington, D.C.: Commission on Preservation and Access.

Porck, H., E. van der Grijn, and A. Kardinaal. 1996. Analysis of Paper Destabilizing Factors in Mid-19th Century Paper Production. A Contribution to the Development of a Conservation Policy. In *IPH Congress Book (Vol. 11)*, edited by R. Teygeler. Marburg, Germany: International Association of Paper Historians, 164-7.

Porck, H. J. 2000. *Rate of Paper Deterioration. The Predictive Value of Artificial Aging Tests.* Amsterdam: European Commission on Preservation and Access.

Rakotonirainy, M., M-A. Raisson, and F. Flieder. 1998. Evaluation of the Fungistatic and Fungicidal Activity of Six Essential Oils and their Related Compounds. In *25 Years School of Conservation. The Jubilee Symposium. Preprints 18–20 May 1998*, edited by K. Borchersen. Copenhagen: Konservatorskolen, Det Kongelige Danske Kunstakademi, 121-30.

Rakotonirainy, M., et al. 1999. La Désinfection des Papiers par les Faisceaux d'Électrons et les Micro-ondes. In *Les Documents Graphiques et Photographiques. Analyse et Conservation. Travaux du CRCDG 1994–1998.* Paris: Direction des Archives de France, 159-72.

Rakotonirainy, M., F. Fohrer, and B. Lavédrine. In press. Traitement des films cinématographiques contaminés par les moisissures. In *Image and Sound—Archiving and Access. The Challenges of the 3rd Millennium. Proceedings of the 5th Joint Technical Symposium*, edited by M. Aubert and R. Billeaud. Paris: Centre National de la Cinématographie and Commission Supérieure Technique de l'Image et du Son.

Reilly, J. M., D. W. Nishimura, and D. Burge. 1998. *Condition Survey of Motion Picture Holdings in the Library of Congress. Evaluation of Storage Environments for Motion Picture Collections.* Library of Congress Preservation Research and Testing Series No. 9807. Washington, D.C.: Preservation Directorate, Library of Congress.

Reissland, B., and S. de Groot. 1999. Ink Corrosion. Comparison of Currently Used Aqueous Treatments for Paper Objects. In *IADA Preprints 1999*, edited by M. S. Koch. Copenhagen: Royal Academy of Fine Arts, 121-9.

Rempel, S. 1996. *Zeolite Molecular Traps and Their Use in Preventive Conservation.* Springfield, Va.: Conservation Resources International.

Rudolph, P., et al. 1998. Laserreinigung von Pergament und Papier: Experimente an Modellsystemen und historischen Originalen. *Restauro* 104(6): 396-402.

Rychly, J., L. Matisova-Rychlá, and M. Strlic. In press. Kinetic Aspects of Chemiluminescence Response to Periodic Changes of Temperature During Thermal Treatment of Cellulose. *Polymer International.*

Shahani, C. J., et al. 2000. *Accelerated Aging of Paper. I. Chemical Analysis of Degradation Products. II. Application of Arrhenius Relationship. III. Proposal for a New Accelerated Aging Test.* Draft report provided to the Institute for Standards Research of ASTM. Washington, D.C.: Preservation Directorate, Library of Congress.

Smith, A. W. 1997. Effects of Aqueous Treatments on the Mechanical Properties of Paper. In *The Interface Between Science and Conservation,* edited by S. Bradley. Occasional Paper No. 116. London: British Museum, 59-65.

Strang, T. 1998. Integrated Pest Management (IPM). Another Brick in the Wall. In *Infestation Proceedings of the 3rd Nordic Symposium on Insect Pest Control in Museums, September 24–25, 1998,* edited by M. Åkerlund et al. Stockholm: PRE-MAL and ICOM Swedish National Committee.

Strlic, M., and B. Pihlar. 1997. Determination of Reducing Carbonyl Groups in Cellulose in the Solvent System LiCl/N, N-dimethylacetamide. *Fresenius' Journal of Analytical Chemistry* 75: 670-5.

Strlic, M., et al. 1998. Evaluation of Size-exclusion Chromatography and Viscometry for the Determination of Molecular Masses of Oxidised Cellulose. *Journal of Chromatography A* 805: 93-9.

Strlic, M., and J. Kolar. 1999. Use of a Model Fenton System for Studies of Paper Antioxidants. Presentation at European Workshop on Iron-Gall Ink Corrosion, December 16–17,1999. The Hague: General State Archives.

Strlic, M., J. Kolar, and B. Pihlar. 1999. The Effect of Metal Ion, pH and Temperature on the Yield of Oxidising Species in a Fenton-like System Determined by Aromatic Hydroxylation. *Acta Chiminica Slovenica* 46: 555-66.

Strlic, M., et al. In press. Chemiluminescence During Thermal and Thermo-oxidative Degradation of Cellulose. *European Polymer Journal* 36.

Tétreault, J. 1999. Coatings for Display and Storage in Museums. CCI Technical Bulletin No. 21. Ottawa: Canadian Conservation Institute.

Trinkley, M. 1997. Integrated pest management. Just for the big guys? *Ethnographic Conservation Newsletter of the Working Group on Ethnography Materials of the ICOM Committee for Conservation* 15: 5-7.

Turovets, I., M. Maggen, and A. Lewis. 1998. Cleaning of Daguerreotypes with an Excimer Laser. *Studies in Conservation* 43(2): 89-100.

Vilmont, L.-B, G. Gervason, and A.-C. Brandt. 1996. Étude Comparative des Procédés de Renforcement Mécanique des Papiers par Thermocollage et Clivage (Comparative study of mechanical reinforcement methods for paper by thermal gluing and splitting). In *11th Triennial Meeting, Edinburgh, September 1–6, 1996, ICOM-CC (Vol. 2.)* edited by J. Bridgland. London: James and James, 552-9.

Vohrer, U., et al. 1996. Plasmatechnologie in der Restaurierung. Eignet sie Sich Auch für Papier und Gemäldeoberflächen? *Restaurator* 1:40-3.

Wächter, W., J. Liers, and E. Becker. 1996. Paper Splitting at the German Library in Leipzig. Development from Craftmanship to Full Mechanisation. *Restaurator* 17: 32-42.

Wang, J., C. Heiner, and S. J. Manley. 1996. The Photodegradation of Milled-wood Lignin. Part II. The Effect of Inhibitors. *Journal of Pulp Paper Science* 22(2): J58-J63.

Ware, M. 1999a. *Cyanotype: The History, Science and Art of Photographic Printing in Prussian Blue.* London: Science Museum for the National Museum of Photography, Film & Television.

Ware, M. 1999b. Cyanotypes: their history, chemistry and conservation. In *Care of Photographic Moving Image & Sound Collections. Conference Papers, July 20–24, 1998* edited by S. Clark. Leigh, U.K.: Institute of Paper Conservation, 115-35.

Weissman, K. 1999. Acid Detection Strip Shoot-out. Paper presented at the Association of Moving Image Archivists 1999 Conference, November 1–9, 1999. Montreal, Canada.

Williams, S. 1998. Ethafoam and Other Polyethylene Foams in Conservation. In *Conservation On-Line.* Available at http://palimpsest.stanford.edu/byauth/williams/foam.html.

Zou, X., T. Uesaka, and N. Gurnagul. 1996. Prediction of Paper Permanence by Accelerated Aging. I. Kinetic Analysis of the Aging Process. *Cellulose* 3: 243-67.

Zou, X., et al. 1998. *Canadian Co-operative Permanent Paper Research Project: The Impact of Lignin on Paper Permanence.* Final Report. Ottawa: Pulp and Paper Research Institute of Canada/ Canadian Conservation Institute.

Zwaneveld, E. H., and J. P. Imbeau. 1999. Triacetate Film Acid-detection Shoot-out. Paper presented at the Association of Moving Image Archivists 1999 Conference, November 1–9, 1999. Montreal.

Zwaneveld, E. H. 2000. Archivists Need Input in Audio-video Standards. *Electronic Engineering Times.* New York (April 3).

APPENDIX I

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APPENDIX II

Index of projects noted in survey, by institute

Australia

National Library of Australia
- *Study of accelerated aging and rate of degradation (6)*

Screensound Australia
National Film and Sound Archive
- *Testing of magnetic media (34)*

Austria

Institut für Papierrestaurierung
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Österreichisches Kunststoffinstitut Arsenal
- *Study of life expectancy studies of magnetic tape (33)*
- *Studies of how to estimate life expectancy of magnetic tape (34)*

Österreichisches Museum für Angewandte Kunst
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Österreichisches Staatsarchiv
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Phonogrammarchiv der Österreichische Akademie der Wissenschaften
- *Life expectancy studies of magnetic tape (33)*
- *Studies of how to estimate life expectancy of magnetic tape (34)*

Canada

CCI
Canadian Conservation Institute
- *Study of accelerated aging (5, 7)*
- *Study of impact of acid-emissive materials on cellulose-containing materials (10)*
- *Monitoring of paper degradation (11)*
- *Preparation of draft permanent paper standard for Canada (13)*
- *Study of effects of laser radiation on surfaces of natural organic materials (17)*
- *Development of suction devices for conservation treatment (22)*
- *Investigation of suitability of polystyrene products for archival storage (32)*
- *Research on disaster recovery of modern machine-readable information carriers (35)*
- *Quantification of effects of controlled-atmosphere fumigation and thermal treatments for pest control (37)*
- *Design of prototye solar-heated extermination bag (38)*
- *Investigation of prototype oxygen-scavenging cell (40)*
- *Development of a module to supply filtered and humidity-controlled air to reach interiors of display cases (40)*
- *Development of improved guide for lighting displays (41)*
- *Study of effect of changes in polyethylene foam-making process on deterioration mechanism of foam products (42)*

National Film Board of Canada
- *Comparison of effectiveness of acid-detection strips (27)*

Czech Republic

State Central Archives
- *Study of techniques of EtO disinfection (14-15)*
- *Study of nonaqueous treatment of ink corrosion (16)*

- *Development of guidelines for protection of archival and library materials from light during exhibition (41)*

Denmark

Dancan International Sales
- *Development of acid-detection technology (27-28)*

Royal Library
- *Study of effects of freeze-drying on strength and stability of paper (16)*

Technical University of Denmark
Department of Biotechnology
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

France

Centre de Recherches sur la Conservation des Documents Graphiques (CRCDG)
- *Study of paper disinfection techniques (14-15)*
- *Study of disinfecting capacity of beta radiation and microwaves (15)*
- *Investigation of different stages in Wei T'o deacidification procedure (19)*
- *Comparison of protective quality of MicroChamber with that of other archival papers (22)*
- *Study of effects of polyester film encapsulation on paper (23)*
- *Study of degradation of photographic gelatin caused by nitrogen dioxide and sulfur dioxide (25)*
- *Study of causes of decay of nitrate and acetate film (26-27)*
- *Study of main species of fungi responsible for film degradation (28)*
- *Study of a new light dosimeter for exhibition of photos and sensitive artifacts (31-32)*
- *Study of antifungal properties of essential oils (38)*

Musée du Louvre
- *Studies of foxing stains (9-10)*

Université de La Rochelle
- *Studies of foxing stains (9-10)*

Université de Technologie de Compiègne
- *Studies of foxing stains (9-10)*

Germany

Bundesanstalt für Materialforschung und-prüfung (BAM)
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Bayerische Staatsbibliothek
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Bundesarchiv
- *Investigation into research needs for magnetic tape preservation; evaluation of ongoing programs (33)*

Freie Universität Berlin
Kunsthistorisches Institut
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Staatsbibliothek zu Berlin-Preussischer Kulturbesitz
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Zentrum für Bucherhaltung GmbH (ZFB)
- *Development of mass-conservation system for loose sheets of paper (21)*

Italy

Istituto Centrale per la Patologia del Libro
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

MASTER S.r.l.
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

Resource Group Integrator S.r.l.
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

Israel

Hebrew University
- *Development of laser cleaning technique for daguerrotypes (29)*

Israel Museum
- *Development of laser cleaning technique for daguerrotypes (29)*

The Netherlands

Koninklijke Bibliotheek
National Library of the Netherlands
- *Study of accelerated aging (6)*

Multipak BV
- *Development of polyester film encapsulation (23)*

Netherlands Institute for Cultural Heritage (NICH)
- *Study of accelerated aging and rate of degradation (6)*
- *Study of iron and sulfur migration from ink (10)*
- *Study of effects of iron gall on emission of volatile organic compounds from paper (11)*
- *Development of microanalytical methods for characterizing the condition of paper (11)*
- *Study of chemiluminescence (12)*
- *Study of wet/dry interface phenomenon (13-14)*
- *Research on treatment of ink corroded paper (16)*

Shell Research and Technology Centre
- *Study of iron and sulfur migration from ink (10)*
- *Study of effects of iron gall on emission of volatile organic compounds from paper (11)*

TNO Institute of Industrial Research
Paper Production Technology
- *Study of accelerated aging and rate of degradation (6)*
- *Study of air polllution and deacidification (8)*

Poland

Jagiellonian University
- *Study of accelerated aging (5)*

Slovak Republic

Slovak National Archives
- *Study of accelerated aging and rate of paper degradation (6)*
- *Study of EtO disinfection (14-15)*

Slovenia

University of Ljubljana
- *Development of analytical approaches to elucidation of cellulose degradation (12)*
- *Study of chemiluminescence (12)*
- *Study of oxidative processes in paper (12)*
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

National and University Library
Conservation Department
- *Development of analytical approaches to elucidation of cellulose degradation (12)*
- *Study of oxidative processes in paper (12)*
- *Study of nonaqueous treatment of ink corrosion (16)*
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

Spain

Consejo Superior de Investigaciones Biologicas (CSIC)
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

Sweden

Göteborg University
- *Study of effects of air pollution and climate on paper stability (8)*

Karolinska Institute
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

National Museum
- *Investigation of role of oxygen in ink corrosion (11)*

National Museum of Science and Technology
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

Skokloster Castle
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

Swedish National Testing and Research Institute
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

Swedish Museum of Natural History
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

Swedish University of Agricultural Sciences,
Department of Environmental Assessment
- *Participation in PRE-MAL investigations of pest control methods on insects, artifacts, and humans (39)*

Switzerland

Berner Fachhochschule
- *Study of early non-photographic copying techniques (21)*

United Kingdom

Central Science Laboratory
- *Participation in SAVE ART oxygen reduction and pest control project (39)*

Manchester Metropolitan University
- *Development of new techniques for monitoring breakdown of polyester film (26)*

Victoria & Albert Musuem
- *Study of molecular sieves for extending life of cellulose acetate photo negatives (32)*

Ware, Mike
- *Study of conservation of cyanotypes (28)*

USA

American Society for Testing and Materials (ASTM)
- *Development of accelerated-aging tests (6-7)*

Buffalo State College, Art Conservation Department
- *Study of surface tarnish on daguerreotypes (27)*

Carnegie Mellon Research Institute
- *Study of migration of degradation products (10)*
- *Chemical studies of beneficial effects of calcium-enriched wash water in conservation treatment (20)*

Cornell University
- *Study of effects of neem products on treated materials (20)*

Getty Conservation Institute
- *Testing of enclosures for nitrogen fumigation of pests (38)*

Image Permanence Institute (IPI)
Rochester Institute of Technology
- *Development of risk audits for nitrate and safety-based film collections (26)*
- *Studies of the effect of storage environments on film stability and longevity (29)*
- *Study of how storage environment and storage enclosures can be used to extend life of films (30-31)*

Library of Congress
- *Study of accelerated aging (6-7)*
- *Study of role of acid formation in paper aging (9)*
- *Study of effects of aqueous and non-aqueous deacidification treatments on manuscripts with iron gall ink (17)*
- *Investigation of deacidification of paper artifacts with Bookkeeper (19)*
- *Study of effects of deacidification on life expectancy of paper-based collections (20)*

Metropolitan Museum of Art
- *Study of surface tarnish on daguerreotypes (27)*

NARA Document Conservation Laboratory
- *Study of impact of previous deacidification on conservation and care of paper artifacts (20)*
- *Study of effect of nitrogen dioxide on archival box boards and model papers (23)*
- *Testing of exhibit and storage materials (42)*

National Center for Preservation Technology and Training
- *Investigation of prototype oxygen-scavenging cell (40)*

National Media Lab (NML)
- *Development of risk audits for magnetic tape collections (26)*

Old Town Editions Inc.
- *Evaluation of three methods of cold storage for photographic materials (30)*

Rensselaer Polytechnic Institute
- *Examination of lighting technique to reduce rates of light-induced damage on artifacts (41)*

Smithsonian Institution
- *Study of accelerated and natural aging of paper (6)*
- *Study of suitable conditions of RH in the museum environment (24)*
- *Study of allowable temperature and RH ranges for safe use and storage of photographic materials (30)*
- *Investigation of safe ranges for storage climate of paper and artifacts, and of effects of temperature and relative humidity (40)*

University at Buffalo, School of Dental Medicine
- *Study of surface tarnish on daguerreotypes (27)*

Vikwood Botanicals
Vikwood Ltd.
- *Development of Margosan-O (20)*

Vatican City

Biblioteca Apostolica Vaticana
- *Participation in Laser Cleaning of Paper and Parchment Project (17-18)*

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