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Each issue is concerned with one aspect of librarianship. Each is planned with the assistance of an invited advisory editor. All articles are by invitation. Suggestions for future issues are welcomed and should be sent to the Managing Editor.

Published four times a year, in summer, fall, winter, and spring. Office of publication: University of Illinois Graduate School of Library and Information Science, 249 Armory Bldg., 505 E. Armory St., Champaign, IL 61820. Entered as second-class matter under the act of August 24, 1912. Copyright 1981 by The Board of Trustees of the University of Illinois. All rights reserved; nonprofit organizations may, however, quote from or reproduce material copyrighted here by The Board of Trustees of the University of Illinois for noncommercial, educational purposes. Full credit should be given to both the author and Library Trends.

Subscription price is $16.00 a year (plus $1.00 postage for overseas subscribers). Individual issues are priced at $5.00. All foreign subscriptions and orders should be accompanied by payment. Address orders to Journals Department, University of Illinois Press, 54 E. Gregory Drive, Box 5081, Station A, Champaign, IL 61820. Editorial correspondence should be sent to Publications Office—Library Trends, 249 Armory Bldg., 505 E. Armory St., Champaign, IL 61820.

Indexed in Current Contents, Current Index to Journals in Education, Library and Information Science Abstracts, Library Literature, PAIS, and Social Sciences Citation Index.

PRINTED IN THE U.S.A.
Conservation of Library Materials

GERALD LUNDEEN
Issue Editor

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Introduction

GERALD LUNDEEN

The last issue of Library Trends devoted to conservation of library materials was published in 1956. In that issue the editor, Maurice F. Tauber, entitled his introduction "Conservation Comes of Age." From this perspective, some twenty-five years later, the title seems a bit premature. The past twenty-five years have seen much progress in conservation. This has been surveyed in an excellent article by Pamela Darling and Sherelyn Ogden in the twenty-fifth anniversary issue of Library Resources & Technical Services.1

A number of significant events took place soon after the 1956 Library Trends issue was published which were to have a major impact on development of library conservation. Certainly one of the most important events in 1956 for conservation of library materials was the founding of the Council on Library Resources (CLR). The history of the Council on Library Resources is very well related in a recent article by Gwinn.2 The Library Technology Project of the American Library Association, begun in 1959 with support from CLR, while not exclusively concerned with preservation, has contributed much in this area over the years.

The year 1960 saw the formation of a Standing Committee on Preservation of Research Library Materials of the Association of Research Libraries. The early work of this committee resulted in the funding of a project which was conducted by Gordon Williams, director of the Center for Research Libraries. The report of this project—The

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Preservation of Deteriorating Books: An Examination of the Problems with Recommendations for a Solution—did much to move libraries to action. In large measure due to the Williams report, the Library of Congress began in 1965 its Preservation Project, which evolved into the Library of Congress Preservation and Testing Office in 1972. This office, headed by John C. Williams until his recent retirement, has become the major national center for research in preservation of library materials. Williams is the author of the article on paper in this issue.

Another major event in 1961 was the founding of the Barrow Laboratory, where, with funding from CLR, William J. Barrow (an author for the 1956 Library Trends conservation issue) and coworkers did extensive research on paper aging and degradation processes, and methods for combating these processes. The Barrow Laboratory closed in 1977, ten years after Barrow's death. Much of the research in conservation of paper is being done now at the Library of Congress, the National Bureau of Standards, and the National Archives.

The publication of the National Register of Microfilm Masters begun by the Library of Congress in 1965 was a recognition of the importance of this approach to conservation, as had been recommended by Williams and by Simonton. In this issue, Don Avedon surveys the present state of microforms in conservation.

The Book Testing Laboratory at the Rochester Institute of Technology, established in 1976, is conducting very important work in testing and standards for binding methods and materials. The director of this laboratory, Werner Rebsamen, has written the article on binding in this issue.

Probably more influential than all the committees and reports in raising librarians' consciousness to preservation was the disastrous flood in Florence in November 1966. A lot was learned the hard way in the efforts to recover from that event. Many more disasters on a smaller scale have reinforced the lesson. Sally Buchanan, Preservation Officer at Stanford, has had firsthand experience in dealing with disasters in her own library. She has written the article on disaster planning for this issue.

An indication that preservation has indeed come of age is the growing number of libraries which have established offices of preservation within their organizations. These administrative positions have far-reaching involvement in library operations. Pamela Darling, a pioneer in this area, has been on leave from her position at Columbia University to study the problems of conservation administration. She is the author of the article on conservation administration in this issue.
Introduction

The creation of conservation offices in the major libraries in the country has raised several issues regarding the education and training of qualified people to fill these positions. Paul Banks addresses these in his article on conservation education. The growth in the number of library schools offering at least some courses in conservation is an indication of its becoming an established part of librarianship.

Preservation of nonbook materials has received less attention compared to books and paper, but librarians and archivists are becoming increasingly aware of the value and importance of photographs and sound recordings. Alice Swan addresses the topic of preservation of photographic materials. Walter Welch and William Storm write on the issues relating to preservation of sound recordings.

Whether or not Tauber's title was anticipating events, it seems clear that conservation has grown and matured significantly in the intervening twenty-five years.

The editor would like to thank all of the authors who contributed to this issue. In all cases, it was an additional burden on an already heavy load of commitments.

References


Creativity v. Despair: The Challenge of 
Preservation Administration

PAMELA W. DARLING

"Millions of valuable books deteriorating in nation's libraries," we were told on Valentine's Day 1978 by the National Enquirer, which might have added, "along with countless manuscripts, prints, photographs, films, sound recordings, etc." To librarians involved in the administration of preservation activities, the strident headline was scarcely news, but it neatly summarized the awesome challenge confronting those charged with preserving for future generations the collections of past and present.

There is no doubt that significant proportions of the materials housed in most libraries today are in poor physical condition, due both to the chemical and mechanical instability inherent in their nature and to damage resulting from improper storage and handling. Despite the absence of comprehensive statistics, awareness of the vastness of the problem has had an important influence on the pattern of response now discernible in the emerging field of library preservation.

Without attempting a history of that emergence, it may be observed that the literature of the field pays unusual attention to the role of administration in coping with an essentially technical crisis. The reason may be found in the early recognition that the growing availability of technical solutions—deacidification, improved binding methods, sophisticated restoration procedures, accurate reproduction processes—is only a first step toward salvaging the countless objects threatened with disintegration. We might coin the term strategies of scale to de-
scribe efforts to relate individual treatment possibilities to the needs of very large collections. The theoretical need for such administrative strategies is apparent: time is running out for many materials. A conservator or two, no matter how highly skilled, cannot meet all the needs of a collection of any size. Only through the development of large-scale programs capable of providing protection and remedial treatment for thousands, even millions, of items in a relatively short period can a cultural disaster be averted.

Related to the problem of sheer numbers is that posed by the diversity of materials and the preservation problems they exhibit. Implicit in the variations in treatment appropriate to different materials is the need for selection criteria and decision-making systems, which have little to do with the technical quality of individual treatment but everything to do with responsible and effective allocation of time and money.

A third factor contributing to the importance of administration to preservation is found in the relationship of preservation to almost every other library activity. Building plans, collection and access policies, processing procedures, and handling methods used by both staff and patrons from the moment an item arrives in the shipping room through its last trip to the discard pile, all have a direct bearing on the survival of the collections. Put another way, the responsibility for the physical care of the collections is, whether recognized or not, diffused throughout the library, at every level of the staff. The correction of practices which endanger, and the coordination of those which preserve, is an administrative challenge of no small dimensions.

The successful development of preservation programs requires a combination of administrative skills and technical knowledge, exercised within an organizational structure flexible enough to foster cross-departmental identification of problems and solution-seeking, the gradual realignment of certain functions, and the retraining of staff. The shortage of professional staff with appropriate preparation and experience to undertake this work had the predictable effect of limiting preservation program development to a relatively few libraries. In those few, the absence of tested procedures and common practices made necessary much trial-and-error inventiveness and patience in the face of false starts and the pressure of critical need.

The establishment of a conservation department or preservation office does not constitute the implementation of a program. In the early years, the preservation librarian, officer or administrator brought to the
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task either a technical background, most often in bookbinding, or
general library experience coupled with good administrative skills or
potential. For each, successful performance required much on-the-job
learning. The technical expert had to develop managerial skills and a
broad understanding of library operations if practical plans for
expanded preservation programs were to be sold to a staff accustomed to
thinking of binding and preservation as marginal activities carried on
in an obscure corner of the basement. The generalist had to master
enough technical information to earn the respect and cooperation of
technicians within the unit and to ensure that proposed changes in
methods, materials and policies affecting the care of materials were
based on the best available knowledge.

The information needs of both were difficult to fill. Technical
information about the many facets of preservation was scarce and
widely scattered in sources unfamiliar to most librarians. Procedural
guidelines, organizational models and patterns for administering pre-
servation activities were practically nonexistent. Early appointments
were almost all in large research libraries, in which institutional com-
plexities and a wide range of endangered materials compounded the
difficulties associated with systemwide planning. The field was so small
that there were few opportunities for professional contact and support.
The enthusiasm engendered by the opportunity for participation and
leadership in a vital new area of librarianship was in continuous ten-
sion with the frustration and discouragement born of working in near
isolation with too few human and material resources.

These conditions have begun to change, as we shall discuss pres-
teently. But recognition of the factors constraining the first group of
preservation administrators offers valuable insights into the nature of
developments within the field as a whole. The following observations
are based on the author's own experience as preservation administrator
and on interpretations drawn from conversations with others over an
eight-year period. Apologies are offered in advance to the historically-
minded, who may find them annoyingly unspecific; names, places and
dates are deliberately suppressed to avoid the appearance of praise or
criticism. While some efforts appear more successful than others in the
short term, all contribute to the present capability of the library profes-
sion to respond to the preservation crisis, and an understanding of these
influences ought to improve our collective ability to direct the future.
Observation: Mistrust and inadequate communication between "bench people" and "paper pushers" have delayed the development and application of new techniques.

Whether the "bench" is a repair unit, conservation workshop, commercial bindery or microform laboratory, technical knowledge of a high order and skills developed through long years of experience are essential. Furthermore, these skills are applied to materials one at a time. Attention must be narrowly focused. Production pressures and the limits of existing equipment may preclude experimentation. Change may threaten livelihood, or commercial investment, or the perceived value of a lifetime's devoted labor. Changes requested by newly-appointed administrators without technical credentials may be bitterly resisted, especially if those same paper-pushers ignore requests for support in areas recognized as important by the bench people. While the bench person seeks to perfect and execute a specialized technique, the paper-pusher worries about statistics, quotas, budgets. Communication is often to cross-purposes. It may take several years for each to learn enough about the other to overcome the initial mistrust and begin to apply their complementary abilities to the common solution of problems.

There are two critical factors: (1) the shortage of expertise—both perceived and actual; and (2) the tension between the time/cost of individual treatment and the needs of massive collections. The first can be relieved through the publication and distribution of preservation information, and through expanded training and educational programs at both technical and professional levels. The second is not so easily managed, being essentially an economic problem apparently well beyond the scope of imaginable resources. Even here, however, technical expertise applied to the development of mass procedures can produce imaginative approaches, "phased preservation" (the protective boxing or encapsulation of fragile materials as a holding action until more extensive treatment is feasible) being the most obvious, though by no means the only example.

Observation: Emphasis on cooperative approaches to preservation at too early a stage can actually retard preservation program development.

There can be little doubt that cooperation is essential to avoiding wasteful duplication in preservation microfilming activities, or that regional or network support of such centralizable services as master copy storage, disaster assistance, and provision of special preservation treatment facilities makes good economic sense. However, effective
cooperative programs can best be developed by pooling and then building upon experience and skills from within the cooperating institutions. Without a common knowledge base, needs cannot be accurately identified, nor can programs to meet those needs be intelligently planned, implemented or evaluated. The theoretical promise of solutions through cooperative action has often led to inaction at the local level. Individuals or institutions may be afraid to initiate something that might not fit into a larger system at some future time. Or, they may be reluctant to commit the time required for development of a program in the belief that they can more economically replicate a program developed and offered through some cooperative agency.

Two significant factors in this situation are first, the distinction between those activities which can best or only be performed through cooperation and those which must go forward in each institution even after cooperative programs are fully operational; and second, the matter of timing. Every library must accept the responsibility for improving its own storage conditions and handling practices, for educating itself about improvements in care and repair methods, binding, reproduction, and the myriad other technical matters involved in preserving collections. To the extent that cooperative resources—workshops, consulting or treatment services, information clearinghouses—are available, they should be exploited; but their scarcity does not negate that local responsibility. Indeed, only as institutions move forward individually without waiting for "them" to lead the way will a collective preservation capability emerge, because, of course, "we" are "they." Thus, to the issue of timing: individual and cooperative developments will take place alternately, with individual action always leading. Library A develops a method for treatment of material which is shared through some cooperative mechanism with libraries B and C. B and C adapt it, improve on it, share the results with A, and together they produce a cooperative standard of practice or even a centralized facility for this treatment which is then shared with libraries D and E. D and E try it, improve on it—and the process goes on. Cooperation is vital, but if too many institutions see themselves in the D and E category, waiting for A, B and C to start things for them, the process will be very slow.

Observation: Vision and inspiration at the highest levels of leadership are essential to the development of a profession's commitment to solve new problems, but senior leaders are seldom in a position to devise the practical methods and routines that will constitute working programs.

Preservation encompasses an almost bewildering array of technical problems. It has been observed "that 'the problem' is, in fact, an appar-
ently infinite complex of many discrete problems—of physical chemistry, of lighting design, of environmental pollution and control, of engineering, and so forth." When "the problem" first received serious attention some twenty years ago, it stimulated the development of bold schemes and imaginative proposals set in the context of national library planning. The goals of those early plans and the basic approaches outlined for meeting them remain valid. But much painstaking groundwork must be laid—by lab workers, technicians, first-line supervisors and middle managers—before the vision of top management can be brought to life. This is probably true in every field of endeavor. In preservation it has been especially true, and frustrating, because so many interrelated technical and procedural matters are involved. Furthermore, the very grandeur of the early plans may have had a discouraging effect: where to begin when everything remains to be done? This conflict between the need for broad planning and the intricate requirements of system development exists at the institutional level as well, and must be managed successfully at that level before a national program can be developed.

Two lessons emerge from reflecting on the recent history of library preservation at both the local and national levels. First, endorsement of an ideal leads to progress only when coupled with a substantial commitment of operational staff to examining and improving rather prosaic daily routines. Second, perspective, patience and good library skills are essential to the development and administration of preservation programs—perspective for understanding how each component will fit into the total scheme, patience for working through the mundane details, and good library skills to ensure that preservation activities mesh with collection goals, bibliographic systems and service responsibilities.

Observation: Interest in and planning for the preservation of library materials has been heavily weighted toward the needs of paper records, especially bound volumes, leading to a dangerous neglect of the preservation needs of other materials.

Large old collections tend to consist primarily of books and bound serials, and the deterioration of nineteenth- and twentieth-century book papers has reached crisis proportions. When resources are inadequate, it is natural to concentrate on the most apparent and urgent problems. But nonprint media collections are already large in many institutions, they are growing at a faster rate than print collections, and they are by no means immune to damage and deterioration. Some—color film and
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magnetic tape, for example—are even less stable than most paper, while the mechanical stresses associated with viewing or listening equipment can make ordinary use considerably more damaging than use of book materials. Unfortunately, the common segregation of library collections and services by format often results in media ghettos, with knowledge about the special needs of nonprint materials limited to a few specialists in units remote from the operational mainstream of the library.

There are two implications: (1) the preservation needs of nonprint media ought to be recognized and addressed before their problems reach the same proportions as those of paper records; and (2) preservation policies and programs need to be designed in such a way that nonprint media can be easily integrated with other materials. Though storage requirements differ slightly, and treatment procedures substantially, from those for paper, basic principles of care are the same, decision-making criteria and procedures can be applied to all formats, and the budgetary implications of an active preservation program affect all materials. In very large institutions, preservation staff may specialize by format; but even there, coordination is desirable, and in most institutions the same staff will have to be involved in planning and administering activities for the preservation of all formats. Because most people thus far have come to preservation work though interest in the book, special attention to learning about other materials is essential to avoid inappropriate program biases.

A common theme runs throughout these observations, which might be variously described as the information problem, the lack of expertise, the undeveloped preservation knowledge base. As with any new field, a very few people know a lot about it, more know a little, and most know nothing. Even among the few, given the variety of technical and procedural matters which fall under the rubric of preservation, knowledge and experience tend to be concentrated in subfields—such as book conservation or preservation microfilming—and what is known is acknowledged to be primitive, tentative and incomplete.

Administration involves planning, decision-making, evaluation, and supervision. Accurate information is crucial to the success of each activity. Thus, the major obstacle to the development and administration of preservation programs is the shortage, not of money, as many suppose, but of knowledge. Financial constraints are serious and will become more so; but until the preservation field reaches the point at which most people know what ought to be done and how it should be
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done, the lack of money to do it on a scale appropriate to the need is not terribly significant. The preservation administrator, therefore, must spend a great deal of time seeking, sorting and analyzing information: technical information about the physical nature of materials, the effects of environmental conditions, the pros and cons of preventive and remedial treatment alternatives, sources and costs for supplies, equipment and services; and management information about methods of identifying candidates for preservation attention, selection criteria and mechanisms, preservation policy formulation, processing, treatment and replacement procedures, organizational development and staffing requirements.

In fact, in the first years the search for such information was often fruitless, and much thought and creativity had to be devoted to the invention of guidelines, procedures and policies. This primitive phase was passing rapidly as the 1980s began, and though creativity continues to be an essential ingredient in preservation administration, it can be applied more often to adapting, building upon and expanding existing knowledge than to dreaming up wholly new ideas and approaches. The literature of the field has grown dramatically in the past few years, as recent reviews of preservation developments amply document. In variety, quantity and quality, that literature reflects the steady growth of practical efforts to respond to the preservation challenge, and itself contributes further to the collective capacity for response.

Several additional kinds of resources for alleviating the shortage of expertise have emerged above the horizon, offering important tools for preservation administration. Three examples will illustrate the present status of the field.

In 1979 Yale University Libraries began a three-year project, funded in part by the National Endowment for the Humanities, with several major components: (1) development and testing of procedures for surveying the condition of materials in a large collection; (2) refinement of techniques for the simple, economical protective treatment of materials; (3) creation of training aids for the education of patrons and the training/retraining of staff; and (4) internships for librarians and technicians seeking to enhance their preservation knowledge and skills. The materials resulting from this project will be widely available, and the experiences of the interns, taken back to their home institutions, should have a strong leavening effect, raising the level of preservation activities across the country.

In 1980 the Association of Research Libraries Office of Management Studies launched a two-year preservation project, also funded by
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the National Endowment for the Humanities. Its products will include a self-study process enabling libraries to analyze their preservation needs and plan programs for meeting them, along with extensive compilations of technical and procedural information to support this analysis, planning and implementation of preservation activities. These materials, bringing together the results of individual efforts in many institutions, should accelerate subsequent developments, providing the raw material from which standards and effective traditions of practice can be fashioned.

Finally, in 1981 the School of Library Service at Columbia University, in cooperation with the Conservation Center of the Institute of Fine Arts at New York University, offered two new graduate programs, for the education of library conservators and of preservation administrators. (These programs, too, are funded in part by the National Endowment for the Humanities, and by the Mellon Foundation, both of which have made extraordinary contributions to the emerging field of preservation.) Combining general library education with intensive study of technical theory, laboratory instruction and a supervised internship, the three-year conservator program will begin to alleviate the critical shortage of professionals qualified to execute and direct physical treatment programs. The two-year administrator program (one year for those already holding a master’s degree) will include some laboratory experience and study of the theory and practice of preservation, providing in organized form the technical and managerial information which the first generation of administrators had to ferret out, or invent, for themselves. These graduate programs mark a new stage in the expansion of educational opportunities in the field, which before were limited to workshops, isolated courses, and a few internships and apprenticeships. These three examples, none of which would have been possible five years earlier, symbolize the acceptance of preservation within the larger field of librarianship, and hold a firm promise of rapidly expanding resources to shape and support the administration of preservation activities in the future.

Major elements to be included in comprehensive preservation programs at the local level were identified early on. Much energy has since been devoted to working out in practice the solutions to preservation problems first suggested by theory. Now another cycle begins, with practical experience reviewed, analyzed and incorporated into a more mature theoretical framework, itself to be tested, refined and expanded by further practice, in a continuing process.
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The preservation administrator stands at the intersection of theory and practice, testing the vision and wide perspective of library educators and other leaders against the realities of daily operations, while evaluating and shaping practice to meet the goals suggested by the emerging theory. Not an easy position, a delicate balance to be maintained; but the rewards are great for those who respond to the challenge.

References


Education in Library Conservation

PAUL N. BANKS

Some Historical Perspectives

The preservation of records has probably been of concern as long as there have been records; in fifth century China, paper was treated with insecticidal infusions, and medieval librarians were concerned that libraries be placed in rooms with good ventilation to reduce the threat of dampness and insects. Similarly, bookbinding, one of the primary means of protecting the codex book, is roughly concurrent with the Christian era. In any case, earlier record materials tended to be permanent and durable, and their main enemies were fire and flood, mildew and insects.

But with the Industrial Revolution came the beginnings of social, economic and technological changes that have altered the circumstances of records preservation just as profoundly as they have virtually every other facet of civilization. The proliferation of books and other records, the decline in the lasting qualities of materials, and the effects of increasing air pollution need no further comment here, but the effects of other factors such as inadequately controlled heating and air conditioning have been less noticed.

Among the socioeconomic changes that have had a bearing on the preservation of book and other record materials has been the decline of the artisan. When all manufactured goods were made by hand in small shops, the artisan had a central role in society. But as manufacturing

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became industrialized, the role of the artisan became increasingly untenable economically. One result of this is evident every day: the increasing cost, and often decreasing quality, of such services as the repairing of shoes and garments. The increasing marginalness of the artisan—or, stated another way, increasing economic pressure—has meant, over at least the past century, interrelated declines in the education, the outlook, and often the skills of the artisan.

One product of the dramatic rise in the cost (at least relatively) of handmade goods is that those few that are produced either are shoddy, are goods of high luxury, or are created and bought as virtual works of art (which are also, of course, luxury goods). In the latter category are the products of designer binders. Creative bookbinding is a field closely allied with book conservation both because of the manual skills required and because artistic bookbinders often must do conservation work in order to supplement their income. The underlying assumptions of these two branches of bookbinding, however, are quite different; indeed, they are almost opposed, as with advertising typography, whose function is to call attention to itself, versus book typography, which is successful to the degree that it is unobtrusive to the reader. Few have the talent and energy to pursue both branches entirely successfully.

The traditional training of the book artisan was by an apprenticeship which usually started at an early age that sharply limited the apprentice's formal education. While there are always exceptional people in any endeavor who achieve beyond the norm of their milieu, the declining status of the artisan combined with limited education generally led to a decline in standards for bookbinders as well as other craftsmen.

Actually, this is rather an oversimplification. In many cases (although by no means all) actual manual skills—as reflected, for example, in clean and brilliant gold tooling—improved. But on the one hand, the long historical roots of the craft were lost; neither master nor apprentice often had an opportunity to study the conspicuously sound structures of early bindings, for example. On the other hand, the technical challenges of binding, restoring and preserving newer materials—products of the rapidly changing technology of the Industrial Revolution—soon went beyond the purely empirical ability of traditionally trained craftsmen to solve.

One additional thread might be picked up here. There has gradually developed, especially in the last hundred years or so, the notion that there is an obligation to posterity to preserve, with as little alteration as possible, objects of what is now called cultural property: works of art
and artifacts that are assumed to have scholarly or cultural value for people of the present or of the future. In other words, the question of ethics has entered the field of the conservation of library and archival materials.

The science and technology that made the proliferation of records possible—and also all too often made them quite perishable—are also fundamental to any preservation efforts that provide any hope of gaining on the growing backlog of deteriorating library and archival materials. Not only are empirical solutions no longer adequate—acidic paper will deteriorate reinforcing tissue unless the paper is first neutralized—but the scale of preservation problems has escalated far beyond the ability of older, craft-oriented techniques alone to solve. (Craft remains an essential element of conservation, however, as will be discussed below.)

A somewhat similar situation evolved in the conservation of works of art. The often great value attached to individual works of art and their public visibility (in both literal and metaphorical senses) led to professionalization of art conservation earlier than has happened in the conservation of library and archival materials.

Although there had earlier been at least one small generation of remarkable pioneers, much of the groundwork for the modern discipline of art conservation, based on science and ethics as well as craft, depended on two turning points: the founding of professional societies, and the establishment of the first graduate degree-granting training program in the field. The International Institute for Conservation of Historic and Artistic Works (1950) and the American Institute for Conservation of Historic and Artistic Works (1960) have increased communication among people concerned with or practicing conservation, have promulgated a code of ethics, and have generally advanced professionalism in the field.

In 1960 the Rockefeller Foundation, responding to the report of a group of museum officials, art historians and conservators, supplied funds to establish the Conservation Center at the Institute of Fine Arts of New York University, the first graduate degree-granting education program for museum conservators in the world. The center's program, which leads to a master's degree in art history and a certificate in conservation, includes art history and connoisseurship, the history and science of art materials and techniques, ethics and philosophy of conservation, general collections protection and care, and laboratory practice in the examination and treatment of objects. One to two years of the four-year program are devoted to an internship in recognized conservation laboratories.
Similar programs have since been established by the State University of New York at Oneonta and the New York State Historical Association at Cooperstown, New York (1970), and by the University of Delaware and the Henry Francis DuPont Winterthur Museum (1974). These extensive and rigorous academic programs in art conservation seem to represent recognition of both the complexity of the conservation of cultural property and the responsibility entailed.

**Some Needs in Library Preservation**

The ultimate aim of book preservation is to make the information that the books contain available for as long as it is needed; Edwin Williams has suggested, perhaps only slightly metaphorically, that the term *dissemination* might usefully be substituted for the term *preservation*. Among the ramifications of this useful concept, however, is that books may contain more than one kind of information, and that there are difficulties in determining, or more accurately in deciding, how far into the future that information may be needed.

On the first point, it is easy enough to assert that there are books which without question have artifactual value, and albeit with somewhat less confidence, to assert that there are ones that are of value only for their intellectual content. (A book that has no artifactual value in general might have some in a particular highly specific context.) The most difficulties are caused by the large area in between: those books that have some, or potential, or unrecognized artifactual value. But that large gray area is really the topic of other papers.

It may be asserted that the point of preserving artifactual values is preserving—for dissemination to users of the future—those aspects of the book’s information that can be derived from the physical object as distinct from (but by no means necessarily instead of) its textual content. In this case, the point is to preserve the physical container of the textual content with as little alteration as possible so that physical features can be “read” as accurately as possible.

For books that are deemed (however accurate that determination may ultimately prove to be) to have no artifactual value, the specific “container” of the information is assumed to be inconsequential, so that there is no theoretical objection to changing the container, for example, by converting to film format and discarding the original. These two aspects of library conservation appear to entail, needless to say, rather dramatically different approaches: conventionally, the restoration of rare books on the one hand, and preservation microfilming programs on the other.
Truly preserving artifactual values implies avoiding any alteration to the artifact insofar as possible, whether that alteration is in the form of deterioration or of the treatment of prior deterioration. And even when intervention in the form of rebinding or other treatment is appropriate—that is, unavoidable—it is enormously expensive if it is truly to serve the ends of conservation. Although the proportion of artifactual to general materials in most collections is assumed to be small, even here the dimensions of the problem are enormous. Peter Waters has estimated that 11,500 work-years are required just to deal with the present problems of the rare book collections of the Library of Congress.\(^2\)

Similarly, while microfilming to preserve the text of badly deteriorated nonartifactual materials is cheap compared with physical restoration, there are millions upon millions of deteriorating volumes in research collections. (Some newer technologies such as videodisc are sometimes seen as offering significant cost advantages in conversion for preservation; although they probably will speed—and reduce the cost of—retrieving and distributing information so recorded, it is difficult to see how the high cost of initial capture of the information, including preparation, handling for imaging, and checking, can be significantly reduced.)

The conclusion that seems inescapable, then, is that progress in preserving research collections that is at all proportional to the dimensions of the problem can only be achieved through the application of preventive methods, such as optimum environmental control and storage and housing that benefit entire collections, in addition to more conventional approaches. In addition to the inherent benefits of slowing down deterioration, the urgency of preventive conservation is in buying time until greater resources—fiscal, human and technological—are available for the application of "conventional" solutions or until better methods are available.

These preventive methods—along with methods of actual treatment, about which more will be said later—require an engineering approach. This term has in my mind two major connotations. First, engineering in the most conventional sense is obviously fundamental to such matters as designing and operating environmental control systems and in other aspects of the design of new or renovated library buildings. The difficulties connected with this aspect of engineering seem to stem from divisions and gulls in both knowledge and responsibility. The heating, ventilating and air conditioning (HVAC) engineers who design the systems do not operate them once they are installed, and may
not have sufficient concern about operational problems; building engineers who operate the systems may not know how to fine-tune them or to operate them with whatever flexibility the design engineers have built into them; neither design nor operating engineers may have adequate understanding of the special needs of research library and archival collections; and librarians and archivists are often not sufficiently informed to be able to assure themselves that what the HVAC engineers propose will meet those needs or that building engineers are operating the systems for maximum protection of the collections. These gulfs in knowledge and experience might effectively be bridged by specialists in library and archives conservation whose training is directed in part toward accurately monitoring environmental conditions; toward being able to specify environmental parameters so as to give architects and engineers adequate guidance for new or renovated systems, and toward dealing effectively with physical plant departments in maintaining suitable conditions for preservation of collections.

The other "engineering" approach that I have in mind is the need for a systems method for a multiplicity of library conservation problems. By "systems method" I mean: (1) a thorough analysis of the problem in question in the widest possible context; (2) design of a system to meet as nearly as possible the specific criteria identified in (1); (3) a search for necessary existing methods, materials, and equipment, from other fields, if necessary; (4) an attempt, if necessary, to have materials or equipment manufactured for the system designed; and (5) the making of any necessary alterations or compromises in an ideal system as dictated by (3) and (4).

It may be useful here to cite some examples of what I mean by a systems or engineering approach to the solving of library conservation problems. Observation and common sense indicate that enclosure of items—as, for example, boxes for books—is among the most effective means of prolonging the life of materials that are valuable or vulnerable to damage or rapid deterioration. This is certainly true for single pieces of paper (e.g., manuscripts or posters) that do not have the protection afforded the leaves of a compactly bound book. The need for a better method of protecting unbound materials led the Restoration Office of the Library of Congress to the search for what became polyester encapsulation in its present form.

Analysis of the problem led to criteria that might be summarized as a system for providing at reasonable cost good physical protection for unbound materials with little or no alteration to the materials themselves. Polyester film was identified as the most nearly inert film readily
available, and it turned out to have outstanding physical characteristics as well. The initial search for a method of sealing the edges led to a stable pressure-sensitive tape, although in the meantime two machines for sealing edges, based on different principles, have been developed elsewhere. It was realized that the corners of encapsulations are sharp and potentially damaging to unencapsulated items, so simple devices to round off the corners were found. Polyester encapsulation, in common with any system, has limitations and drawbacks, but the success of this product of a systems approach to a preservation problem is attested to by the rapidity of what one is tempted to call its universal adoption.

The treatment by Roger Powell of the Book of Kells in the early 1950s is a consummate example of a systems approach to a book conservation problem. Major and irreparable damage had been done to the manuscript from previous rebindings in which the then-current binding methods were imposed without regard to the physical and historic characteristics of the manuscript. By contrast, Powell studied extensively not only the manuscript itself, but the specific circumstances of its use—in this case, frequent handling and exhibition—and environment, and made a full-scale dummy before undertaking actual treatment of the manuscript. Traditional craft techniques were then carefully adapted for the treatment of the leaves and the development of suitable binding structures and protective containers. This systems approach may indeed be said to distinguish the book conservator or conservation binder from the trade binder or book restorer, who is likely to try to impose a narrow, received set of methods regardless of their suitability to the problem in hand.

Another example of a systems analysis method applied to a conservation problem is the Library of Congress "phase box," a relatively inexpensive means of providing sturdy protective boxes for bound books, which again involved identifying materials and existing machinery and encouraging the development of a simple new machine for the system. The leaf-casting research and development laboratory at the Canadian Conservation Institute in Ottawa employs a more complex form of engineering of a sort usually associated with professional engineers.

Engineering and systems methods of tackling library and archives problems are urgently needed in such areas as mass deacidification (in which research and engineering is in fact in progress), and in improved methods of in-house mending and of library binding that genuinely contribute to the preservation of library materials at manageable cost. In addition, many kinds of non-paper-based records—audio, digital and
reprographic media—that are finding their way into libraries in increasing volume require more conventional engineering techniques in their preservation, as do the reprographic laboratories that are often an essential part of preservation programs. While highly qualified specialists in these nonbook media do exist, libraries and archives may have difficulty obtaining their services because of higher salaries in industry.

It was mentioned earlier that the two broad categories of library conservation—preservation of artifactual and replacement of nonartifactual materials—appear to require diametrically different approaches. However, it may not be evident that in at least two fundamental ways, methods that are genuinely useful for both aspects of conservation are not so different after all. First, in both cases, the problems are of so large a scale that preventive conservation is essential to slow the rate of deterioration if whole segments of our books and records are not to be lost before there are adequate means to treat or replace them. Second, whether dealing with an individual national treasure or masses of brittle books, the application of systems methods to their preservation is necessary to achieve efficiency that is adequate to the size and urgency of the problems and that results in treatments suitable for the particular condition, rather than hiding or, in the long run, worsening deterioration.

The common thread in both preventive conservation and conservation treatment might be called an engineering approach. In some respects this engineering approach is perfectly conventional in that it deals quantitatively with stresses, loads, capacities—and economics—in terms that are measurable and calculable. A more subtle issue is the form of engineering entailed in successful paper mending, book repair and rebinding, protective container construction, and the like. In this case, many of the same parameters are involved—loads, stress/strain relationships, strengths of materials—but quantitative measures are not (yet, at least) available, so that judgments must be made on an empirical basis; on the basis, that is, of visual and often tactile observations; in other words, craft.

In museums as in libraries, conservators have tended to be primarily craftspeople, as craft is the longest of the roots from which conservation has grown. The best, however, have incorporated science into their armamentaria, and have also become concerned with preventive conservation—environmental control, storage and shipping conditions, and the like. However, aptitude for treatment of objects, the predominantly craft aspect of conservation, is not always accompanied by ability for the quantitative types of engineering. Indeed, there have
begun to be calls for an “exhibition conservator” (perhaps not an ideal term), as distinct from the “treatment conservator,” who deals with conditions of exhibition, shipping, and housing. No such person has emerged yet even in the older and larger museum conservation field (although conservation scientists have to some extent filled this role), and library and archives conservation is certainly too immature thus far to support such narrow specialists, however needed their services might be.

**Current Efforts**

The conservation of the collections of libraries and archives—books, manuscripts, photographs, magnetic tapes, maps, and related records media—is, then, a vast, complex and highly technical task whose dimensions and urgency are just beginning to be appreciated. Educational efforts have thus far been inadequate to meet the preservation needs of current library and archival collections in a number of respects. Apprenticeship, upon which all full professional training has thus far been based, tends without extraordinary balancing effort to concentrate on the manual aspects of book conservation at the expense of the equally essential broader technical aspects. It was only ten years ago that the first full introductory course in preservation for librarians was offered by a U.S. library school, and there was no formal training of any sort for library and archival conservators before that which was developed by the Library of Congress for its own personnel needs at about the same time.

The situation has improved dramatically in the intervening decade. A number of library schools now have introductory courses, and seminars, workshops, programs and conferences have proliferated to the point that it is difficult to keep track of them all. Yale University has an ambitious and varied program funded by the National Endowment for the Humanities. A new apprenticeship program for conservators, again primarily to develop its own staff, is getting underway at the Humanities Research Center of the University of Texas at Austin. Another effort aimed at the professionalization of library and archives conservation is now starting at Columbia and New York universities in New York City. In summer 1978, the School of Library Service of Columbia University offered a four-week institute, with funding from the U.S. Office of Education, for graduate librarians who had, or were about to have, some form of direct responsibility for preservation. During the course of the institute, a number of specialists in various aspects of library preservation were invited to Columbia to
talk with the participants. During an informal discussion among Richard L. Darling, dean of the School of Library Service (SLS); the faculty of the institute; Norbert S. Baer, cochairman of the Conservation Center of the Institute of Fine Arts, New York University; and Frazer G. Poole, a private consultant who had been the preservation officer of the Library of Congress, the idea of exploring a full-fledged educational program in library conservation to be based at the School of Library Service was launched. Darling prepared a successful grant application to the National Endowment for the Humanities (NEH) which enabled this author to spend the second half of 1979 at SLS preparing a 100-page report outlining graduate programs for the preparation of conservators and conservation administrators.

The report was the basis for a series of grant proposals prepared by Darling that resulted in a grant of $375,000 from NEH to establish the Columbia programs. In addition, grants of $350,000 from the Andrew W. Mellon Foundation, $50,000 from the Carnegie Corporation, $25,000 from the Morgan Guaranty Bank of New York, and $10,000 from the H.W. Wilson Foundation have been received for matching the NEH grant and for capital costs that the federal grant does not cover. These funds are primarily for renovation and equipping the laboratories and for faculty and staff salaries, student stipends, supplies, and guest lecturers for the first three years of the programs. With virtually all of the funding in hand, the Conservation and Preservation Education Programs of the School of Library Service, Columbia University (as they are called formally) will start with the autumn 1981 school term.

For the conservator students, the curriculum includes four semesters of coursework, two summer semesters of field projects, and a two-semester internship in a recognized library or archives conservation laboratory, for a total of three years. Six of the nineteen courses are laboratory courses in book paper conservation treatment. Of the remaining courses, eight deal with the history, technology, structure, and science of library and archival materials, and the remaining five include introduction to library and information science, archives administration, the administration of preservation programs, history and philosophy of conservation, and the protection and care of library and archival collections. Sixty points are earned in the coursework and twelve additional points in the summer projects and internship.

The summer projects are intended to expose the students to the working environment of libraries or archives, usually ones that do not have highly developed conservation programs, partly as a balance to the inherently somewhat idealistic tenor of academic instruction. At least one of the summer projects will be in a library mending and shelf-
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preparation unit, where the pressures and realities of everyday library operations will be particularly evident. The internship will be in a conservation laboratory of recognized merit, so that the students can continue learning treatment practice under expert supervision in a real-world situation that also provides a different viewpoint from the labs in which they have received their initial instruction.

Conservator education is a joint program with the Conservation Center of the Institute of Fine Arts, New York University (NYU) (which, like the School of Library Service, is the original graduate school in its specialty). The Conservation Center has been instrumental in serving as a role model and in advising and assisting the progress of the library conservation programs from the outset, and the all-important conservation science courses, and one or possibly two of the laboratory courses, will be taught there. The conservator program leads to a master of science degree granted by Columbia University, and a Certificate in Library and Archives Conservation awarded jointly by SLS and the Conservation Center at NYU.

The sixty-point, two-year curriculum for preservation administrators includes courses in management and administration, as well as about half the number of specialized conservation courses required of the conservators. Of these, one is a laboratory course to introduce the students to problems of the physical treatment of books and related materials. The emphasis in the specialized courses is on understanding the technology and structure of the materials about which preservation decisions will have to be made in libraries and archives, and about broad aspects of their care. Other parts of the curriculum concern aspects of bibliographical control and networking that are vital to national preservation programs. There is one field work course to introduce the aspiring administrators to real-world problems. Because of the realities of the job market, more flexibility is built into the administrator than the conservator program so that students can take courses in related areas which, it is hoped, will enable them to take jobs that have other components in addition to preservation. For librarians who already have a master's degree from an accredited library school, an advanced certificate in library conservation can be obtained in one year, with the curriculum concentrated entirely in required, specialized courses. The regular teaching of both the conservator and administrator programs, in some cases separately and others collectively, will be supplemented with guest lectures and short seminars on specialized topics that will bring new viewpoints to the students and will permit them to meet people working in the field.
Applicants for the Columbia conservation programs are screened by the school's Committee on Admissions, on which the director of conservation programs sits for this purpose. In addition, applicants for the conservator program must be interviewed, submit a portfolio of some form of craft or other creative work, and pass a special aptitude test developed at the Preservation Office of the Library of Congress. A maximum of six students a year are admitted to the conservator program, while twelve can be accommodated in the administrator program.

In addition to the present faculty of the SLS, two new full-time people are participating. This author is director of conservation programs and will teach four of the specialized courses. Gary Frost, formerly of the Newberry Library Conservation Department, will teach the laboratory courses at SLS and manage its conservation laboratory. To be appointed are two adjunct faculty members to teach preservation administration and manuscript conservation treatment and, at NYU, the science courses for conservators. Antoinette King, Adjunct Professor at the Conservation Center of NYU and Conservator of Drawings at the Museum of Modern Art, will teach the course in flat paper treatment.

The SLS conservation laboratories consist of space vacated when the biology department moved into new quarters. Although their location across campus from the library school's quarters in Butler Library is unfortunate from both practical and philosophical viewpoints, the facilities, under renovation at the time of this writing, will be far better than could have been provided in Butler, which in any case does not have capacity for the necessary plumbing and wiring. In addition to the main book and paper laboratories, there are smaller rooms for a stockroom, a workshop for dirty work, a documentation room, and a darkroom. Approximately $125,000 is being spent on renovating the space and equipping the labs with standard bindery equipment, a processing sink, water treatment system, microscopes, cameras, and fume hoods. The labs have good natural light and a pleasant view of New York's Amsterdam Avenue. Gas, compressed air and distilled water are bonuses acquired with the space.

The science and flat paper treatment course, and possibly the manuscript treatment course, will be taught in the Conservation Center's new building on East 78th Street in Manhattan. This building, designed specifically for the needs of the center, will be one of the finest conservation teaching facilities in the world when it is completed in autumn 1981.
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Substantial financial aid is available for students in the conservation programs. Conservator students, because of the duration and consequent cost of the program in relation to salary expectations, may be eligible for stipends somewhat more generous than SLS's usual scholarship funds provide.

Conclusion

The challenges of preserving mankind's records are great and are growing with the increasing volume, variety and often impermanence of records media. These challenges have elicited little in the way of educational programs to prepare people to meet them until very recently. Now, however, many introductory courses, seminars and the like are helping to educate librarians and archivists about the broad aspects of conservation.

In addition, programs are being launched to prepare conservation specialists. Apprenticeship programs at the Library of Congress and the University of Texas, designed primarily to meet those institutions' own staffing needs, emphasize (but are not limited to) training in treatment practice. New graduate-level, degree-granting programs based at the School of Library Service, Columbia University, will educate specialists in both the administration of preservation programs and the technical aspects of records conservation. The latter, the conservator program, will attempt to give roughly equal emphasis to conservation treatment practice and to broader aspects such as environmental control and other kinds of preventive conservation.

References

Handmade paper of the Middle Ages and earlier, housed in the rare book rooms of libraries, is often in excellent condition. The machine-made paper of the last 150 years, in the general collection, is as often brittle and crumbling. The failure of machine-made paper to endure has been a disaster for the records of this civilization. Recently, however, methods of making long-lasting paper on the paper machine have been developed. Now there is reason for optimism.

The new paper not only shows improved life, but is more economical to produce, causes less erosion of the paper-making equipment, and gives a cleaner effluent, or none. Companies have been changing to the new methods, particularly in Europe. American producers are lagging behind. This situation must not be allowed to continue. The problem of caring for disintegrating books in American libraries is already unmanageable and should not be allowed to grow larger. Now is the time for librarians, bibliophiles and, indeed the paper-makers to unite to ensure that long-lasting paper is again available and used in publishing.

The Condition of Paper in Libraries

Paper fails by gradually losing flexibility and finally becoming brittle. The change is apparent to the librarians only when the pages begin to crack and break as the book is used. Folding endurance mea-

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measurements, however, can show the progressive loss of flexibility. To follow the condition of paper from the initial good properties to its final useless and degraded state would take a long time. Even poor paper lasts for twenty-five years, while the best paper has already been in existence two thousand years. Exposing paper to higher temperatures—accelerated aging—speeds the process of degradation so that it can be studied in the laboratory.

Folding endurance is generally measured by the Technical Association of Pulp and Paper Industry (TAPPI) MIT folding endurance test. A strip of paper 1.5 centimeters wide is put under one kilogram tension and folded by machine over a specified radius $135^\circ$ to the right and $135^\circ$ to the left. The number of folds required to bring the initial tensile strength down to the applied load, where the strip must break, is recorded as the "folding endurance." Tensile strength remains essentially constant while the folding endurance drops toward zero, so the folding endurance change accurately gives the increase in brittleness.

William Barrow, who did important work in the field of conservation, considered that when folding endurance had dropped to a value of one, the book was in the restoration category and was essentially unbindable. In one experiment he studied 500 recent books. Those published from 1900 to 1939 were composed of paper so weak that he employed a specially built fold tester, one that folded the test strip through only a 90-degree angle. Thirty-nine percent of the samples showed a median fold of 3 or less, which put them in his "very weak" category; 49 percent showed a median fold of 24 or less, falling in his "low strength" category; 9 percent showed 24-75 folds, which he termed "medium strength"; and 1 percent gave 200 folds, for his "high strength" rating. "That the figure of 200 folds for high strength classification is not too high can be shown by the fact that random tests of modern rag papers and old rag papers of the 16th, 17th, and 18th centuries often show from 300 to 4000 folds, even on the MIT tester which is much more severe than the special tester used for the samples." Paper made in the 1940s had aged only seven to eleven years at the time the tests were made, yet 57 percent were already in the low strength category.

Tomer examined 500 books, published from 1777 to 1969, from the Freiburger Library of Case Western Reserve University. Of these books, 74 percent were from the twentieth century. Two test strips were cut from the margin running the length of the pages. The standard fold angle was used, but with only 0.5 kilogram tension on the strip. Tomer reported: "The folding endurance of the paper in the sample was generally low. Only five percent of the papers had retained a high degree
Paper Quality and Paper Chemistry

of strength (more than 200 folds). Ninety-two percent of the samples exhibited relatively low levels of strength (less than 24 folds) and sixty-nine percent had deteriorated to extremely low levels of strength (3 folds or less). He agreed with Barrow that modern paper is in deplorable condition.

Magrill and Rinehart sampled books at the University of Michigan Library and concluded that 45 percent of the collection in Western European literature required immediate attention. Frazer Poole reported that a sampling at the Library of Congress made in 1972 indicated that: “perhaps as many as 6 million volumes, out of some 17 million books in the total collection, are in the advanced stages of deterioration. In thousands of instances the paper has become so brittle that to turn a page is to break it off.”

According to Reprographics Quarterly, France’s national library is experiencing similar difficulties. The chairman of the Bibliothèque Nationale reports:

90,000 volumes are in extremely poor condition, 7,000,000 pages of periodicals have deteriorated to the point where they can no longer be consulted while 36,000 maps, 375,000 prints and 300,000 photographs together with manuscripts and musical documents are in a critical condition. The major factors blamed for this situation all relate to the poor quality of modern paper. Modern papers apparently include numerous impurities one of which—lignin (comprising between 20 and 30 percent of poor grade papers like newsprint)—decomposes when exposed to daylight. Even better quality papers tend to contain acidic elements used in the sizing operation which can sharply reduce life expectancy. The Library proposed two courses of action to deal with the problem: like the British Library it is to expand its microfilming programme, secondly a massive preservation programme is to be initiated. The preservation programme is to concentrate on the development of a suitable process for the large scale deacidification of paper. Probably the major issue about preservation efforts of this kind is the danger that they will fail to keep pace with the problem—while money is being expended on deteriorated material, other material, at present in usable condition, is subject to the same process. It is a paradox of the present time that expendable packaging seems to be made of indestructible plastics while the World’s knowledge is stored on materials with a short life expectancy.

There are many more such comments on paper quality in the literature, some not so restrained.

What Went Wrong with Paper?

Paper quality dropped in the seventeenth and eighteenth centuries. The supply of rags from which paper was made could not keep up with
the demand. The discovery of chlorine by Scheele in 1774 allowed colored and stained rags to be bleached and used, but bleaching harmed the fiber. As demand continued to grow, the paper-maker was forced to find fibers elsewhere. Wood was at hand in abundance; however, in wood the fibers are firmly bonded together by lignin. Wood can be directly ground to produce the low-grade lignocellulose fiber used in newsprint. In processes developed in the nineteenth and twentieth centuries, lignin is chemically dissolved and is washed away from the cellulose fiber. The fibers are then bleached. The chemical treatments used are vigorous, and the cellulose fiber is degraded in the process. It would be logical to blame the short life of modern paper on this degradation, which is partly true. However, Barrow has shown that reasonably long-lasting paper can be made from refined wood fiber.7

Another, more serious mistake has been made by the paper-makers. Paper made from pure cellulose fiber is like a blotter. It absorbs water readily, swelling in the process. When it is written on with ink, the ink line feathers out in a disconcerting way. The early paper-makers of Italy9 corrected these defects by dipping or "sizing" the paper in dilute gelatin solutions. This made paper like vellum and parchment, and was much more acceptable to the scribes; thus gelatin-sized paper became the standard for centuries.

In 1807 Moritz F. Illig disclosed that when rosin soap is stirred into beaten fiber and precipitated by adding alum solution, the paper made from this mixture becomes sized merely on drying.9 The invention allowed sized paper to be made conveniently and directly on the paper machine. This method continues in use. Unfortunately, the amount of alum ordinarily added leaves the paper acid, and acid cellulose becomes brittle in twenty-five to fifty years. People have come to believe that this embrittlement is a characteristic of refined wood fibers, and that only rag will give long-lasting paper. These beliefs are strongly held even today, and are quite untrue.

At the turn of the century, several investigators placed the blame where it belongs: on the acidity of paper. In 1903, Winkler demonstrated that papers soaked in dilute solutions of sulfuric or hydrochloric acids after a few years lost all resistance to rubbing or creasing.10 Herzberg showed that paper degraded more rapidly at high temperatures.11 Kohler and Hall brought together these techniques in landmark studies.12 Degradation of paper was accelerated by the use of the 100° oven, to bring investigations into a reasonable time frame. They recognized folding endurance as the most sensitive indicator of degradation. The acidity resulting from the use of rosin-alum sizing was shown to be responsible for rapid degradation.
Studies by Van Royen and by Barrow indicated that seventy-two hours at 100° are approximately equal to twenty-five years at ambient conditions. This relation has been used to predict the life of paper from data obtained using accelerated aging. While not everyone agrees with the relation and procedure, it gives reasonable and conservative predictions which are in accord with what is known of paper from the past, i.e., that a good-quality alkaline paper lasts over a thousand years, while highly acidic paper is brittle in fifty. The latter figure can be validated by a study in one's personal collection.

An interesting long-term experiment was initiated by Edwin Sutermeister at the S.D. Warren Company in 1901—five rosin-sized, clay-filled papers of various mixtures of rag and refined wood fiber were set aside for observation. A sixth paper composed wholly of refined wood fiber with a calcium carbonate filling was added to the series. The sized clay-loaded papers were acid, with pH values ranging from 3.6 to 4.3. The calcium carbonate paper was not rosin-sized, since alum and calcium carbonate are incompatible. The pH of this paper was 8.9. The presence of the alkaline salt, calcium carbonate, ensured that it would remain alkaline. When Sutermeister examined the samples in 1929, he reported that all the acid samples were badly discolored and were absolutely without strength. The calcium carbonate paper had remained white and seemed as strong as when it was made. In this experiment, the rag papers failed and the refined wood fiber paper lasted, which shows that the common belief that rag is necessary for permanence is wrong.

For a thesis at the Institute of Paper Chemistry, Hanson studied a copy of a text on physics and natural science dated 1576. Some sheets had aged considerably and were brown and weak, while others were white and still possessed considerable strength. The fibers of the two sheets appeared to be identical; neither sheet was sized. The white sheets contained around 2.5 percent calcium carbonate, while the degraded sheets had none. The water extract from the white sheets had a pH of 7.5, while that of the brown sheets was 4.9. Hanson concluded: "The results obtained in this investigation suggest that, at least in the case of a CaCO₃ filled sheet, the effect of the filler in maintaining a favorable pH within the sheet may be the explanation of the increased permanence. If there is sufficient CaCO₃ present, it can act as a buffer and resist the changes in pH resulting from the formation of acid degradation products of cellulose." (And acid from polluted atmospheres.)

Jarrell, Hankins and Veitch in 1932, working with an unfilled and unsized all-rag paper, brought sheets to various pH values with hydrochloric and sulfuric acids, and with aluminum sulfate solutions.
The papers were then given seventy-two hours in the 100°C oven, and after being reconditioned, the folding endurance was determined. The folding endurance of the neutral paper did not change in the aging period. The more acid papers dropped substantially. At pH 4.5, one-half the folding endurance was lost, and at pH 4 the loss was complete. The results are shown in figure 1. Again, a rag paper is seen to be impermanent if acid. A great deal of library paper is at pH 4.5 or below, and will have the rapid rate of degradation shown in the figure. In 1936, the same researchers noted that, "incorporation in paper of suitable materials, such as a basic filler,...prolongs the life and serviceability of...book and record papers."

Fig. 1. The Effect of 72 hours at 100°C on the Folding Endurance of Paper
Surprisingly, acid hydrolyzed cellulose fiber is used commercially. Battista and Smith hydrolyzed the fiber and then worked it vigorously in water. The fiber fell apart into a short microcrystalline cellulose, which has proved useful as a commercial thickening agent for aqueous material.¹⁸

Production of Long-Lasting Paper Rediscovered

Barrow, following extensive experiments on the deacidification of acid paper to lengthen and improve its life span, proceeded to make sized alkaline wood fiber paper on the paper machine:

The specifications include initial strength of fold and tear, acceptable deterioration of fold and tear under artificial aging, and minimum acidity. To meet these specifications it appears necessary that papers contain a high percentage of long and stable fibers and be sized with a material compatible with alkalinity. It also appears desirable that they be filled with an acid buffer such as calcium carbonate.

Evidence indicates that most modern papers have a reasonable life expectancy of about fifty years. It is estimated that papers manufactured under new specifications will have a comparable expectancy of more than four hundred years.¹⁹

This was a great step forward in the history of paper-making, one made by a conservator rather than a paper-maker! This solved the problem which has been with the industry since the time of Illig; but the paper industry has not responded to the solution!

The major portion of the American paper industry has continued to make rosin-alum-sized acid impermanent paper. European paper-makers, however, have been more responsive. Gestetner Papers Ltd. in Scotland is producing excellent calcium carbonate filled papers. Hugh Bryson, Process and Technical Manager for Gestetner, has been helpful and generous in sharing his experiences:

The considerable upsurge in the last five years of non-rosin derivatives for neutral sizing of paper, coupled with the use of calcium carbonate fillers, has opened a new realm of papermaking. Neutral-sized, calcium-carbonate-loaded papers are now firmly established in the European market, not only, as was originally thought, for specialty lines, but competing successfully in the popular lines of lithography (stationery sizes as well as conventional litho sheets), industrial papers, chart papers, continuous stationery, archive text, photocopying, and coated stock (on machine-blade and off-machine coated).

What has the technique of neutral, i.e., non alum-rosin sizing to offer? The answer is very simple, better paper at a lower cost.²⁰

In a letter, Bryson added:
JOHN WILLIAMS

Economics—Brilliant!—and getting better each year as the cost of energy rises, that is in comparison with nonalkaline paper-making. At present, we see a 32% reduction in energy in comparison with acid paper-making. [There is] a reduction in the number of drying cylinders one would normally use for acid paper-making due to the ease of drying the increased carbonate filler one can more readily carry in an alkaline system. The reduction in oil, water and steam makes the picture an even greater financial success, and the big punch line [is] no capital investment to change to neutral sizing and carbonate filled papers.

Special equipment—Paper-making-wise—none; laboratory-wise—nothing that is not normally found in progressive technical laboratories, whether they are acid or alkaline paper mills.

Samples of Gestetner paper have been given accelerated aging tests at the Library of Congress Preservation Research and Testing Laboratory and found to have an excellent life span.

Hoppe and Karle wrote an instructive account of a German paper mill's successful changeover to an alkaline system. The mill now makes 250,000 metric tons per year of "an offset-paper with the best printability and runability containing approximately 25% filler." A substantial drop in energy requirements and water consumption was realized.

Penniman expressed the situation well:

The evidence is now in. The calcium carbonate-alkaline size paper-making process offers overwhelming benefits as compared with the traditional alum-rosin size process. It requires less energy, is significantly cheaper, produces a much better product, is easier to control and creates a great deal less waste.

The latest report from Europe. It is actually becoming embarrassing to continue to have an endless stream of European visitors come over here and lecture us on the merits of the calcium carbonate process while we take so little action to implement it and realize the benefits.

Alkaline paper-making was considered at a paper-makers conference held in Boston in 1979. Riddell of Wolvercote Mill in England stated that alkaline paper-making not only pays off in material costs, but there are hidden benefits, such as cleanliness, reduced down-time, improved runability, and lower energy and effluent costs. "There is no way that we would ever attempt to go back to acid paper-making," he said. Similar experiences were recounted by a spokesman for American Israeli Paper Mills, who reported a saving of $27.50 per ton of paper. Dumas of Hercules, Inc. listed advantages of alkaline sizes and calcium carbonate filled paper as: (1) a better, stronger sheet is made so that a reduction basis weight is possible; (2) expensive, high-brightness pigments may be replaced, and increased filler loadings are possible;
Paper Quality and Paper Chemistry

(3) There is reduced energy consumption in refiners and driers; (4) there is reduced effluent load, and white-water closure is possible; and (5) there is improved productivity, with less down-time and maintenance.26

These impressive statements do not even mention the librarian’s interest, that the alkaline paper made is long-lasting. Paper-makers themselves should be interested in permanence. According to Williams, acid paper degrades so rapidly that it is scarcely worth recycling.27 Fifty percent of the vast quantity of garbage that is taken out of American cities is fiber. This would be a valuable resource if the paper were properly made so that fiber strength was retained!

Changing the Industry: The Informed Customer

In the several years that the Preservation Office of the Library of Congress has specified alkaline paper for file folders, film jackets, film boxes, etc., it has been brought from a curiosity to a standard item of supply. Vendors now feature alkaline paper in their catalogs and dwell on its virtues. More purchasers should specify alkaline paper. More purchasing agents should be familiar with the appropriate specifications.

The Annual Book of ASTM Standards28 covers the following:

D3290-76 Bond and Ledger Papers for Permanent Records
D3458-75 Copies from Office Copying Machines for Permanent Records
D3301-74 File Folders for Storage of Permanent Records
D3208-76 Manifold Papers for Permanent Records

Methods of analyzing for calcium carbonate content are given.

The National Historical Publications and Records Commission subvention programs asks for the following quality:

All volumes for which subsidies are requested must be produced under the following standards:

**Paper**

- Book text paper should have:  
  - minimum pH of 7.5 (cold extraction, TAPPI method T-435)
  - minimum alkaline reserve (calcium or magnesium carbonate or both) of 2%, based upon oven dry weight
  - minimum C.D. (Cross Direction) folding endurance of 30 double folds at 1 kilogram tension (25 replicates, TAPPI method T-511)

**Printing**

Inks which contain acids or chlorides should not be used in the production of these volumes.

**Binding**

Books should be Smyth-sewn and casebound and have acid-free
endpapers, no synthetic fabrics, and no polyvinyl chloride adhesives. Volumes published after December 31, 1981, shall have no pyroxylon fabrics.

Barrow Research Laboratory published condensed specifications for permanent/durable book papers:

The following specifications are recommended for uncoated permanent and durable papers; it is shown that there are commercial papers which meet them.

A. Minimum cold extraction pH of 7.5 (TAPPI method T-435).
B. Minimum C.D. folding endurance of 30 at 1 kg. tension (MIT, 25 replicates, TAPPI method T-511).
C. Minimum M.D. tear resistance (Elmendorf, 10 replicate 8-ply tears, TAPPI method T-114) of 70 grams for 60-lb. (25 x 38"—500) paper and proportionally more for heavier weights. For lighter weights:

<table>
<thead>
<tr>
<th>Basis Weight</th>
<th>Minimum Acceptable M.D. Tear</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>40.0 gm</td>
</tr>
<tr>
<td>45</td>
<td>47.5</td>
</tr>
<tr>
<td>50</td>
<td>55.0</td>
</tr>
<tr>
<td>55</td>
<td>62.5</td>
</tr>
</tbody>
</table>

D. Minimum retention of M.D. folding endurance after 24 days of aging at 100°C in a forced circulation oven (as calculated from multipoint regression line) of 50 percent or M.D. folding endurance of one or more after 118 days of aging as determined by extrapolation.

"Permanence," in paper vocabulary, indicates a high degree of chemical stability as evidenced by very slow deterioration. The retention of 50 percent machine-direction folding endurance after twenty-four days aging at 100°C is a difficult requirement. Not all alkaline papers will meet this. The degree of oxidation of the cellulose fiber is probably the deciding factor.

The National Union Catalog carries the properties of its paper on the front page:

The paper on which this catalog has been printed is supplied by P.F. Bingham Limited and has been specially manufactured by the Guard Bridge Paper Company Limited of Fife, Scotland. Based on requirements established by the late William J. Barrow for a permanent/durable book paper. It is laboratory certified to meet or exceed the following values:

- Substance 89 gsm
- pH cold extract 9.4
- Fold endurance (MIT ½kg. tension) 1200
- Tear resistance (Elmendorf) 73 (or 67 x 3)
- Opacity 90.3%

LIBRARY TRENDS
Paper Quality and Paper Chemistry

Every book printed on alkaline paper should carry the information on the title page, since the individual purchaser cannot test pH as he buys the book. The information would have definite sales appeal, and this will increase as the public becomes more educated on the subject. The statement will have other value, e.g., it will allow good-quality books in the library to be separated from the acid volumes being taken for deacidification treatment. The term acid-free should not be used. This phrase is subject to too many interpretations. The calcium or magnesium carbonate content and the pH of the paper as made are key points.

Theory of Paper-Making

Cellulose, A Natural Polymer

Polyethylene, nylon, polyester, etc., are familiar materials, which have resulted from recent advances in polymer chemistry. In such polymers, many small molecules are linked together to make larger molecules which exhibit new properties, including strength. The number of small molecules linked is termed the degree of polymerization, or “D.P.” Nature has been dealing in advanced chemistry for ages. Cellulose is a natural linear polymer made up of linked anhydroglucose units. The D.P. of cotton and flax cellulose is in the 7000-12,000 range. Refined wood cellulose which has been separated chemically from the lignin binder in wood, and bleached, is in the 2000-3000 D.P range.

The Cellulose Fiber

The fiber is made up of cellulose molecules lined up in a high-density crystalline array. Occasionally, the regular arrangement fails and lower density, more open, amorphous regions occur. Crystalline cellulose is not highly pliable. However, the amorphous regions absorb moisture from the atmosphere, and this imparts greater flexibility to the fiber. An extensive discussion on these matters is given by Housmon and Sisson.

Beating or Macerating Cellulose Fiber

Cellulose fibers become self-adhesive when worked or beaten in water. Tapa of the South Sea Islands, papyrus of Egypt, huun and amatl of the Mayans and Aztecs, and paper are all prepared by beating fiber. Paper is unique in this group, being the only one in which the fibers have been beaten, dispersed in water, and formed into the desired sheet by filtering the dispersion through a screen.

Beating develops a microfibril fuzz on the surface of the fibers. As the sheet is dried, the surface tension forces the fibers together and the
microfibrils make a bond. If the wet, freshly formed sheet is frozen and then dried while frozen, this mechanism does not operate and the dried sheet has little or no strength.

**Predicting the Life of Paper; Types of Degradation**

Acid from polluted atmospheres or from alum-rosin sizing can enter the low-density, open, amorphous regions of the fiber and cut the polymer chain by hydrolysis. This releases the molecules from restraint, and the cut ends are free to crystallize. The degree of crystallization thus can go up during degradation and the water-holding power of the fiber go down. Under the influence of acid, water molecules may split out between cellulose chains, giving a cross link, which also drops water absorption.

Oxidation of the cellulose polymer introduces side groups, aldehyde and ketone, which make the molecule more easily hydrolyzed. Free radicals generated by oxidation or by light can also cut the cellulose chain. The presence of catalysts such as copper, cobalt or iron compounds can step up the rate of oxidation. Tang has shown that foxing degradation in paper can be produced by iron compounds. In some foxed spots, there is a central particle of iron oxide which was originally struck off, as a metal particle, from the beater bed plate.

The fiber-to-fiber bond in paper does not disappear as folding endurance is lost. The microfibrils form a bond with a crystalline character. When new paper is torn, there is a fiber fringe at the tear. The strong fibers pull out of the fiber-to-fiber bond. When degraded paper is torn, the tear edge is sharp. The fiber-to-fiber bond holds but the brittle fibers break.

**Importance of the Alkaline Reserve**

Figure 1 shows that paper at a pH of 5.5-7 is quite stable, with good lasting qualities. Such paper is often sold as "acid free." However, in the absence of an alkaline reserve such as 3 percent calcium carbonate, the pH can readily fall into the danger zone of 4.5 and below, by acids either absorbed from polluted air or generated in the paper by oxidation. If sulfur dioxide is absorbed, and oxidation catalysts are present, it can be readily oxidized to sulfur trioxide and hydrated to nonvolatile sulfuric acid, with a consequent drastic drop in the pH of the paper. This action can be seen to have taken place in the degraded margins of book paper. Langwell has written on inactivating the catalysts; Tang and Troyer discuss their removal. Williams considered that oxidation is more in evidence under humid conditions.
Paper Quality and Paper Chemistry

Libraries, including the Library of Congress, have installed systems to remove sulfur dioxide from the air. Very thorough early studies on the subject have been given by Kimberly. Data to show the effectiveness of the systems are generally lacking, perhaps due to difficulties with the air analysis in the past. At the present time a number of instruments giving direct readout of gaseous sulfur dioxide are on the market. These have been rated and compared in a recent article. Certainly, libraries in large cities should control the sulfur dioxide in their buildings.

The Arrhenius Equation

In accelerated aging, folding endurance changes rapidly. To use the rate of change established at 100°C to predict the useful life of paper, the rate must be reduced to the much slower rate at room temperature. The Arrhenius equation has been used for the purpose:

$$\log \text{rate} = \frac{-E}{2.303RT} + \text{constant}$$

where E is the activation energy, R is the gas constant, and T is the absolute temperature. This equation has been successfully applied to chemical reactions. Its use to follow change of rate of loss in folding endurance with temperature implies that this change depends on a single chemical reaction. Such a reaction could be the acid hydrolysis which destroys water-holding amorphous regions and reduces the plasticizing action of water. To use the equation, the activation energy must be shown to be a constant. Depending on conditions, E has been shown, for certain papers, to be essentially constant from 120°C down to 80°C. At the lower oven temperatures, the experiment becomes too long to carry out, so it is necessary to assume the constancy at lower temperatures.

Values of E from 16 to 34 k cal/mole have been reported. The variation is at least partially due to using different (and changing) pH values, and different conditions of humidity and ventilation. The relation that seventy-two hours at 100°C represents twenty-five years at room temperature calculates out to an activation energy of 21.8 k cal/mole. High values of E expand the relation so that seventy-two hours at 100°C is made to represent several hundred years. The 21.8 value therefore gives conservative and, as has been mentioned, reasonable predictions. Excellent articles on the application of the Arrhenius equation to paper life have been written by Browning and Wink and by Gray.

The curve of figure 1 is quite definite in showing that acid paper is unstable. Arrhenius determinations should, therefore, best be carried
out on paper with an alkaline reserve, in the pH range of 7.5-9.5, where accurate prediction of life is of most interest. According to Golova and Nosova, the state of oxidation of the cellulose has a great deal to do with its stability on the alkaline side: "The dominant effect of carbonyl groups on the degradation of oxidised cellulose in an alkaline medium is evident also from the conversion of alkali-unstable oxidised celluloses into stable materials by reduction with sodium tetrahydroborate in a weakly alkaline medium, i.e., under conditions such that aldehyde groups are converted into alcoholic groups. The stability of oxidised celluloses is considerably enhanced also when carbonyl groups are oxidised to carboxy groups."42

The difficult part of the Barrow Laboratory specification for alkaline paper is that folding endurance should not drop more than 50 percent after twenty-four days accelerated aging in the 100°C oven. Tang and Troyer have shown that treating paper or fiber with sodium borohydride allows this test to be passed with ease.43 In other words, the treatment greatly extends the life of alkaline paper.

Storage at Low Temperatures

The Arrhenius equation clearly indicates that paper will last longer if stored at low temperatures. This was proposed earlier by Gordon Williams, director of the Center for Research Libraries:

It also occurred to us, at that earlier time that, since the standard test of paper permanence involved heating it to accelerate the aging process, it would be logical to assume that cooling the paper would slow the rate of deterioration. Therefore, Barrow was asked to investigate this assumption and, indeed, it turned out to be the case. The Barrow Laboratory, in continuing to investigate this process, has had a sample of books under cold storage for some time. The general indication at the moment appears to be that the longevity of any particular paper will be increased about seven and a half times for each drop of 36°F Fahrenheit in the temperature of the atmosphere in which it is stored. By combining deacidification with low temperature housing, the untreated life expectancy of a paper probably can be increased about 40-fold. For example, a book with a present life expectancy of only 25 years if untreated, and left in a normal library stack, would have a life expectancy of about 600 years if deacidified and stored at 84°F Fahrenheit. This figure would increase to over 4000 years if the paper were deacidified and stored at -2°F Fahrenheit.44

Treatments for Acid Paper

Deacidification of acid paper should be carried out as soon as possible, before the paper has lost its strength and flexibility. The
necessary alkaline agent is applied from water or solvent solutions, or as a vapor. The procedure selected must be first tested to see that it will not harm the artifact.

**Aqueous Deacidification**

The paper, supported on a plastic screen, is washed to remove products of degradation. Barrow immersed the paper first in dilute calcium hydroxide solution and followed this with calcium bicarbonate solution. He also used a single solution, spray or dip, of magnesium bicarbonate. A satisfactory solution can be made using eight grams of basic magnesium carbonate powder per liter of water and dissolving this by bubbling with carbon dioxide. The paper, still supported on the plastic screen, is immersed in the solution until saturated; it is then air dried. The paper will pick up 1-2 percent of magnesium carbonate, which is a respectable alkaline reserve. (Accelerated aging of treated and untreated paper is shown in figure 2.)

A method of deacidification which avoids the use of carbon dioxide is described in U.S. Patent 3,898,356. The paper is first immersed in a calcium chloride solution, dried, and then immersed in ammonium carbonate solution. This precipitates calcium carbonate in the paper. The byproduct salt, ammonium chloride, is then washed out of the paper. Loadings of 10 percent of calcium carbonate can be obtained by this method; the calcium chloride and ammonium carbonate solutions are easily made up and are stable.

The use of aqueous solutions involves taking the book apart, treating and drying the paper, and then rebinding the book. This may easily cost two or three hundred dollars per book. There is however, the advantage that the paper is washed and brightened in the process. The paper swells slightly, and often there is a 10 percent increase in folding endurance, which is not seen in other methods.

**Solvent Deacidification**

Baynes-Cope deacidified paper using 1 percent barium hydroxide in methanol. His data showed the treatment to be as effective as magnesium bicarbonate. Barium compounds, however, are quite toxic and should be used with care.

R.D. Smith disclosed in U.S. Patent 3,676,182 the use of magnesium methoxide in Freon/alcohol solutions. The solvent was chosen to be one which would have little effect on colors or inks. George B. Kelly of the LC Preservation Research and Testing Office was granted U.S. Patent 3,939,091 for methyl magnesium carbonate which he also uses in...
Fig. 2. Effect of Deacidification on Deterioration

Source: W.J. Barrow Research Laboratory. Permanence/Durability of the Book II: Test Data of Naturally Aged Papers. Richmond, Va.: 1964, fig. 2.
the alcohol/Freon solutions. This material shows an improved tolerance for the water of humidity in paper. The magnesium/solvent-based treatments are available from Wei T'O Associates in Chicago in spray cans. Smith has been applying similar materials for a mass deacidification treatment being developed for the Public Archives of Canada. The books are immersed for a period, the solution is drained away, and the residual solvent in the books removed by vacuum evaporation.

Koura and Krause immerse paper in liquid ammonia or concentrated ammonium solutions to deacidify and improve folding endurance, perhaps by cellulose decrystallization. This method holds promise, but needs more investigation.

**Vapor Phase Deacidification**

Kathpalia deacidified paper with ammonia gas. He considered the treatment to be effective for thirteen years. Langwell's U.S. Patent 3,472,611 disclosed the use of cyclohexylamine carbonate. This is sold in packets which may be folded into books. The vapor permeates the book in the course of several weeks to deacidify the paper. Barrow Laboratory, U.S. Patent 3,771,958, described a process of impregnating books with morpholine in a vacuum chamber. The books are set on their feet on a shelf with covers interleaved. The pressure in the chamber is oscillated between 35 and 40mm which makes the leaves pulsate and gives excellent exposure. The morpholine process was summarized by Walker. It may be licensed from Research Corporation in New York City.

Ammonia and the amines will leave paper under humid conditions. A library filled with books treated with these chemicals may prove to be a health hazard to librarians and patrons. The Library of Congress Preservation Office has been studying the deacidification of books using gaseous diethyl zinc. The method is described in U.S. Patent 3,969,549 and by Kelly. The compound is pyrophoric and must be handled by trained operators using the proper equipment: books are first thoroughly dried under high vacuum, then the diethyl zinc is introduced into the chamber. Three days are required for the gas to penetrate the closed books and to react with the cellulose. After the reaction is complete, the unused diethyl zinc is distilled off and saved. Carbon dioxide gas and water are introduced to convert the zinc cellulose to zinc carbonate. Final pH is around 8. Two percent zinc carbonate is left in the paper as an alkaline reserve. Results obtained on oven-aging a commercial paper, treated and untreated, are shown in table 1. Runs of four hundred books have been carried out at the General Electric Space Center at Valley Forge, Pennsylvania. A run of five
# Table 1

**Folding Endurance, DEZ-Treated Foldur Kraft Paper**

<table>
<thead>
<tr>
<th>Days Aging</th>
<th>Control&lt;sup&gt;3&lt;/sup&gt; CD</th>
<th>MD</th>
<th>Control&lt;sup&gt;3&lt;/sup&gt; CD</th>
<th>MD</th>
<th>Treated&lt;sup&gt;4&lt;/sup&gt; CD</th>
<th>MD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Humid Oven</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>747.0 ± 117.0</td>
<td>935.0 ± 194.0</td>
<td>582 ± 215</td>
<td>877 ± 289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>158.0 ± 20.0</td>
<td>190.0 ± 52.0</td>
<td>564 ± 164</td>
<td>642 ± 112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>181.0 ± 10.0</td>
<td>32.0 ± 14.0</td>
<td>342 ± 104</td>
<td>509 ± 125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>10.4 ± 2.7</td>
<td>4.0 ± 0.7</td>
<td>281 ± 77</td>
<td>284 ± 73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>4.4 ± 0.5</td>
<td>2.0 ± 0.0</td>
<td>206 ± 48</td>
<td>258 ± 42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1.0</td>
<td>1.0</td>
<td>105 ± 39</td>
<td>96 ± 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dry Oven</strong>&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>747.0 ± 117.0</td>
<td>935.0 ± 194.0</td>
<td>582 ± 215</td>
<td>877 ± 289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>152.0 ± 48.0</td>
<td>288.0 ± 49.0</td>
<td>426 ± 138</td>
<td>527 ± 134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>54.0 ± 21.0</td>
<td>38.0 ± 8.0</td>
<td>161 ± 48</td>
<td>325 ± 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>21.0 ± 9.5</td>
<td>5.3 ± 1.3</td>
<td>131 ± 54</td>
<td>153 ± 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>3.8 ± 0.6</td>
<td>2.0 ± 0.0</td>
<td>77 ± 19</td>
<td>70 ± 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>2.0</td>
<td>1.0</td>
<td>37 ± 11</td>
<td>19 ± 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>90°C, 50% r.h.

<sup>2</sup>100°C, no added moisture

<sup>3</sup>pH 4.8

<sup>4</sup>pH 7.8

Source: George B. Kelly, Preservation Office, Library of Congress.
thousand books is planned; however, it is first necessary to find a large vacuum chamber for this purpose.

**Conditions in the Library**

From the preceding discussions it is clear that the library should be as cool as is consistent with comfort, 65-68°F, and at a low relative humidity, 40-45 percent. Humidity above 70 percent is quite dangerous because it permits mold growth. Very low humidities extend the life of paper, but stiffen it slightly.

Cycling conditions of temperature and humidity have been considered by many to speed degradation. There is not a great deal of information on the subject. A paper by Kelly, Williams, Mendenhall and Ogle shows that chemiluminescence—an indicator of oxidation—is increased as temperature is cycled. Williams, Verna and Stannett have shown that changing humidity can create free radicals in paper, which contribute to degradation.

Disasters: a broken pipe, fire or flood can lead to many wet books. First aid for a wet book is to freeze it immediately, usually at a local food locker, so that it does not mold. The frozen book can then be freeze- or vacuum-dried.

**Conclusions**

For the first time in many years there is reason to believe that paper-makers will change their process and start to make lasting paper again. There are so many advantages to them in the new process that this must come about. To speed the change to alkaline paper, every paper consumer, every magazine subscriber, every librarian, and every purchasing agent must make their voices heard.

In regard to the great masses of acid paper on hand, the library community is waiting for and needs an operational mass deacidification method. While much progress has been made, further work is required.

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25. Ibid., p. 16.

26. Ibid., pp. 16-19.

Paper Quality and Paper Chemistry

31. *National Union Catalog*. Chicago: ALA (paper quality information is carried on the front page of the catalog).
JOHN WILLIAMS


53. Langwell, "Permanence of Paper."


Additional References

Binding

WERNER REBSAMEN

The need to communicate with each other is as old as the existence of man. Our early ancestors drew pictures on walls, the Babylonians created a form of alphabet and drew their records on clay tablets which they baked for permanency. The Egyptians were the first ones to develop a thin material known as papyrus and which is generally considered the forerunner of paper. Scrolls of papyrus or parchment could hardly be called “bindings.” Such continuous strips of records were not easy to handle, that is, to find or retrieve information. With increased record keeping, it was necessary to find a better solution. Rewinding scrolls was eliminated by arranging the strips into accordion folds. Later, stitches were run through the folds and over leather or vellum straps to fasten the folds on the back margins. These created the forms of “binding” without covers.

The first bindings with “boards” originated in the fourth century. Leather thongs were laced through plain oak boards to protect the valuable contents. As the art and skill of bookbinding developed, binders started to conceal the thongs and spine. Later the boards were covered entirely with leather, setting the stage for rich decoration of the covers. All of these bindings had one thing in common. The boards were an integral part of the book, that is, they were laced on by means of cords or thongs which were extensions of the sewing process. Even after the invention of movable type and printing, the method of binding did not vary greatly until the nineteenth century. It is in this period when some

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of the finest examples of bindings originated. Those works, book covers magnificently decorated with gold-leaf impressions, have never been surpassed in appropriateness in both artistic conception and execution.

As the demand for books increased, bindings sewn on cords and bound in leather proved to be too expensive, difficult to execute, and impractical for edition works. Binders started to sew books on sunken cords, which is many times faster than carefully lacing linen thread once or twice around a raised cord. Boards were no longer attached to the book block. Instead, the covers were made as a single, separate unit, setting the stage for case bindings. Leather became scarce and expensive, and binders started to use cotton instead. Cloth bindings were produced as early as 1812 at the John Clark's Sons Edition Bindery in Philadelphia. The binders had to prepare the cloth themselves to make it suitable for binding. With the introduction of calico as a binding material and of a heavy-duty hot-stamping press, binders started to produce edition book covers imitating earlier masterpieces, lavishly decorating them with genuine gold leaf and blind-embossing false, raised cords on the spine.

The Industrial Revolution started to affect edition binders in the latter part of the nineteenth century. Guillotine cutters replaced the slow plow and press. The first sewing machines employed wire stitches instead of thread and were followed by thread sewing machines. Around 1890, the slow process of hand sewing became obsolete. Further improvements in machines and materials followed rapidly, resulting in speedier book production from decade to decade.

Today's edition bindery is capable of producing hardcover bindings at the incredible speed of 100 books a minute. Binding 30,000 paperbacks an hour is common with sophisticated perfect-binding equipment. Some book production lines include printing as well. Printing and hardcover binding from a mill roll of paper to the finished, jacketed book is no longer utopian. There are no human hands employed in such operations, except those tending the complex machinery. This author had the privilege to manage the set-up of such a sophisticated facility, the world's first complete, in-line book production system, in 1973. This belt press, connected to an automated binding line, is located in Fredericksburg, Virginia.

As we get closer to the twenty-first century, binding plays an important part in our increased need for communication. Soon we will have "printing on demand," personalized books and periodicals featuring geographic and demographic materials of interest to the individual reader. A bindery today must implement computers and optical


Binding

scanners to cope with these increasingly difficult but challenging assignments.

Contemporary Methods of Binding

The heart of a library is the written word contained in a book. Despite extensive advances in electronic communication, the book is here to stay as one of the most efficient information storage tools. Libraries have accumulated large quantities of written material. The primary function of any library is to provide materials for its patrons in the form they want them and at the time they need them. Thus, the starting point for a sound maintenance-of-materials program requires constant appraisal and reappraisal of the condition of the collection. Printed material must be evaluated, and types of bindings selected on the basis of the end use of the volume and its condition. For most members of the library profession, the art of binding is a rather elusive matter; most lack an understanding of binding processes. Yet all libraries, large or small, have a need for binding periodicals, archival restoration, prebinding new edition books, and rebinding worn, circulated materials. There are many methods of binding, and the purpose of this article is to categorize them in an understandable manner and explain their function.

Librarians who are concerned with the physical preservation of printed material should distinguish the following methods of binding:

Hand binding:
Archival restoration
Job binding
Design and custom binding
Protective box making

Edition binding:
Paperback binding
Hardcover binding, including “reinforced” library editions
Religious
Limited and deluxe edition binding

Publication binding:
Magazines
Saddle-stitch
Adhesive-bound
Textbook binding:
   Sidesewn
   Smyth-sewn

Single-sheet binding:
   Loose-leaf
   Mechanical

Library binding:
   Oversewn
   Sidesewn
   Sewn through the fold
   Adhesive
   Cleatlacing

Hand binding

Good, well-trained hand bookbinders are a rare species. One must be skillful with his hands, should have complete coordination between his mental process and his actions, and must possess an appreciation of quality, design and fine workmanship. Hand binding is considered irreplaceable training ground for fine craftsmanship in all bookbinding. Bookbinding workshops specialized in hand binding utilize all modern labor-saving tools, such as guillotine cutters, board shears, leather-skiving machines, and others.

Archival restoration and binding requires extensive knowledge of all old-time and contemporary hand-binding techniques. Bibliophile works may not be entrusted to any binder. It is the duty of a rare book librarian to investigate the capability and reputation of a hand binder thoroughly. Librarians must advise the binder what is of value, what is to be restored, and what may just be rebound for protection. Restoration means to save a valuable book or document. While binding such a bibliophilic item, the hand binder must be extremely careful to do as little damage as possible. If the original sewing of a rare book is not severely damaged, the volume should not be taken apart. Instead, the original method of fastening pages should be retained, and old, brittle glues removed with utmost care. To reattach loose boards and construct the proper endpapers and hinges requires advanced skills. The archival binder has many options which may differ for each volume to be restored. Only Japanese paperstrips, acid-free reversible materials, and adhesives may be used. If a book is to be taken apart and resewn, the decaying paper may be deacidified. Parts of an old leather cover on the
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spine or boards must be carefully removed, preserved and remounted. Binders entrusted with such delicate, valuable work should have extensive knowledge of contemporary preservation techniques.

Job binding means that a hand binder does miscellaneous bindings of various sizes and styles. This may be individual volumes or small, special edition works and other unusual articles. Such hand-bound books are constructed in a manner to protect the text with a certain degree of permanence. No time is spent on special design, decorating bindings or "restoring" the original volume. This work is similar to that of a library binder, except that it is mainly handwork, whereas library binding is mechanized.

Design and custom binding requires that no time, cost or trouble is spared to custom-design each volume and bind it into a superb example of the bookbinder's art. The design and execution of such bindings are of the highest form of craftsmanship, and are to be considered equal to that of fine jewelry or cabinetmaking. Today's materials, most often exotic leather, cost a small fortune for one book alone. There is no leeway for errors when the covers are sculptured, decorated with genuine gold leaf, colored inlays and onlays, or with semiprecious stones. A fine binder must be sure in his conceptions and meticulous in their execution. Contemporary design binders experiment with plastics, acrylics and other materials to practice binding as an art.

Protective box making-A set of single sheets, maps, drawings and similar items are not adapted to binding. Rare objects such as these also need protection from the elements in our environment and from careless handling. The making of protective boxes is a considerable part of the hand binder's work. There are many styles of slipcases and boxes, too numerous to permit a thorough discussion here. Basically, the binder is required to cut boards accurately, assemble the pieces with fast-setting adhesives, and cover them with cover materials. The lining may be a soft flannel or, most often, an acid-free paper. Slipcases for hand-bound books are usually custom-fit for individual volumes. More elaborate slipcases are sometimes made partially covered with leather. However, a slipcase offers only partial protection, since the spine is exposed to damage and the bleaching effect of light. One of the favored protective boxes requested by librarians is the "clam-shell" construction. Its simplest form consists of three-sided boxes, one made to fit over the other, contained within a cover. The more complicated versions are constructed with fillets and do not overlap, but their edges meet when closed. Some boxes have rounded spines, imitating the shape of a book. Portfolios, pockets and scroll cylinders are just a few other protective
"containers" hand binders may construct for libraries interested in preserving their collection by all possible means.

**Edition Binding**

High-volume binding for publishers is much different than that of just a decade ago. Publishers and book manufacturers alike are caught in a tight squeeze of high material and labor costs in an intensified, competitive market. Expensive money promotes "printing on demand," which means that publishers no longer fill their warehouses with unsold books. Rather, they pay a premium to the manufacturers and have small orders printed and bound. It is difficult to say at this point how this factor has affected libraries. It may explain undue delays when orders for certain titles are placed.

Approximately 70 percent of all books published are now marketed in paperback bindings. From a marketing point of view, it is difficult to understand why there is such a trend toward paperback binding. The difference in manufacturing cost between a paperback binding and a hardcover binding is only twenty-five to forty cents, according to Robert R. Hackford, president of the Book Manufacturer's Institute. The prices publishers charge for hardcover binding, however, is two to three times that for paperbacks.

*Paperbacks* are printed usually on high-speed web presses in two-up impositions. This means that the direction of the paper grain is in most cases transverse to the binding edge. The result is poor "openability" and "waves" on the fore-edges. If illustrations are placed at the exact center, the book was imposed "coming and going," i.e., the printer was able to do the job with half the number of plates and twice the press run, as compared to other methods. Paperbacks are almost exclusively adhesive-bound with hotmelts. The type of paper and the materials used are not expected to last beyond a few readers. More desirable paperback books are printed on coated paper stock in multiple color, are sometimes sewn instead of adhesive-bound, and are covered with a higher grade of cover material.

*Hardcover bindings* have changed from sewn volumes to that of adhesive binding. It is estimated that approximately 80-85 percent of all hardcover books are now adhesive-bound, either in single sheets or by utilizing new techniques such as burst- or perfo-binding. The trend has been generally away from cloth. Ten years ago, there were eight cloth mills in the United States; now we have two, and one is primarily involved in the making of window shades. There are high-quality
nonwovens on the market, such as Type II papers (reinforced by saturation with resinous materials) and Type III papers (which are of synthetic nature). Unfortunately, most publishers now use the least expensive colored Kraft papers for their hardcover bindings. To save further on costs, publishers have increasingly begun to use low-density cover boards. A decade ago, most book papers used to be free of groundwood pulp. Today, the trend is away from high-quality paper to cheaper grades and lighter basic weights. The only good news in edition hardcover binding is that hotmelts are being replaced with cold-emulsion polyvinyl acetate (PVA), a thin, water-based translucent film applied to the spine and carried deep into the structure of the paper stock, therefore achieving a better linkage of paper fibers than the hotmelt process.

Publishers' "reinforced" library editions are no match to books bound according to the rigid specifications of the Library Binding Institute Standard. There are no specifications set for publishers' "library bindings." Some may reinforce the endpapers, use better grades of cover materials, and best of all, charge a lot more for these than for the regular editions. Many publishers have abandoned the once-lucrative market of "library editions." The best advice I can offer librarians is to obtain the regular edition and have it bound in accordance with the LBI Standard.

Religious books come in an array of binding styles. Large pulpit Bibles are bound with heavy embossed covers. Other books, mainly Bibles, are bound limp style, i.e., flexible covers in imitation or genuine leather. Lately, some books have been bound in "bonded" leather, which is recycled leather fibers cast into sheets of "leather." Many of these books are gilded, mostly with imitation gold, on high-speed, fully automated gilding machines. Other flexible covers may be furnished with zipper closings or with wide, overlapping edges; these are called "divinity circuit binding." The most expensive binding style in this category is a flexible, leather-lined binding. High-quality leather, either top- or plate-grained, is lined with thin leathers (skivers) on the inside. No boards or papers of any kind are used inside or between the leathers. A leather-lined cover is made only from leather; the outer leather is turned in over the leather lining. Most of these binding styles have rounded corners. The covers are usually gold stamped with florentine borders which reflect beautifully off the gilded edges. Today, some pin-seal morocco leather-lined Bibles command prices of up to a hundred dollars. Such work requires the highest form of craftsmanship in any edition work. There are only a few qualified establishments capable to do such work.
Limited and deluxe edition bindings were always produced on a small scale. The popularity of owning beautiful custom-bound books increased when the Franklin Mint in 1975 offered a fine collection of luxury bound books. These “Masterpieces of American Literature” are reproductions of regular editions, but are impeccably crafted, bound in full- or half-grain leather, gilded and lavishly decorated with 22 karat gold. The endsheets of each volume are of fine moiré fabric. These “collector items” were produced 40,000 books at a time, 150,000 a month! Special machinery embossed the raised hubs on the spine, another machine formed a head cap. The gilded book blocks and the beautifully gold-stamped leather cover were joined on a regular three-wing casing-in machine. In 1979, Easton Press offered a competitive version of similar bindings at a much lower price, “sumptuously bound and decorated with graceful golden accents.” These bindings were praised as being bound “with a beautiful material made of bonded-leather-fibers...achieving the look, smell, and feel which can come only from the pure leather fibers which are its principal ingredient. This luxurious material effectively achieves the prized qualities of expensive top grain cowhide.” (In other words, they did not want to say that these books were bound in recycled leather scraps!)

Publication Binding

This type of binding requires substantial investments in sophisticated machinery to allow high-speed, economical and mechanized production. Pamphlets may be small catalogs, annual reports or small periodicals. They may consist of a folded flyer, a saddle-stitched signature, or a number of saddle-stitched signatures inserted into each other, with or without separate covers.

Magazines may be saddle stitched if fewer than ninety-six pages or less than one-quarter inch thick. Thicker publications should be side stitched or adhesive-bound. Magazines and periodicals have made a great comeback. There are more specialized publications than ever before. Modern, computerized technology allows the insertion of geographic and demographic materials, and even personalized messages. If the U.S. Post Office would permit it, we could even insert invoices and renewal notices into a subscriber’s copy. This could be done automatically from continuous computer printouts.

Saddle stitching is the least expensive form of binding. Signatures are automatically opened in the center and fed on to a chain where they are laid on top of each other. Cards and other supplements are tipped into position on the chain-gatherer. Wire stitches in various weights are
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then driven through the bindfold and clinched. The saddle-stitched publications then move into an automated three-knife trimmer, where the folds are cut open. Thereafter, loose cards may be blown in, addresses are ink-jet printed to the covers; and stacks are automatically sorted by zip code.

Adhesive bound publications are increasingly popular because they allow more freedom to "customize" a magazine with all sorts of gimmicks. Material to be bound no longer requires a bindfold to put stitches through. Adhesive binding has been the fastest-growing binding method in recent years. It is generally expected to continue its growth, at the expense of other binding techniques. A good example is TV Guide, which is changing from saddle stitching to adhesive binding to allow more efficient handling of the various editions and the insertion of promotional materials. Computers assist bindery managers to cope successfully with this trend.

Textbook Binding

There are considerable differences in the quality of textbook binding. College textbooks have no standards to follow and may be adhesive-bound, furnished with the least expensive cover materials, and may be cased in, tight- or loose-back. Sometimes it seems that publishers deliberately choose inexpensive paper-hardcover binding quality to reduce the resale of used books on campuses. To the contrary, el-hi books are produced in most states with rigid standards to assure good quality and long life expectancy.

Sidesewn books have muslin-reinforced endpapers. The book blocks are usually side-wire-stitched when coming off a gathering machine. Depending on the thickness of the book block, they are either Singer-sidesewn or McCain-sewn. Singer sewing machines sew directly through the paper. The stitch is locked on the underside by passing the bobbin thread through a loop made in the needle thread. Thicker volumes are sewn on a McCain or Moffett sidesewing machine which employs rotating drills and vertically-operating hook needles. Since the entire book block is drilled and laced through the side, "openability" is jeopardized. This method requires margins of one inch or more. Side-sewn books must be cased in "tight-back," that is, the spine is also glued to the cover.

Smyth-sewn bindings offer good openability because the signatures are sewn individually next to each other. This technique is similar to that of hand sewing except that its process is fully mechanized. The signatures are opened at the center and placed over a saddle. A series of
holes are punched through the bindfold. Sewing needles pull the thread through the fold, and with the aid of hook needles and loopers, one signature is sewn to the other. The sewn book blocks then must be glued to secure the thread. On textbooks, the first and last signatures, including the endpapers, are reinforced with cambric cloth.

_NASTA_ textbook specifications were issued by the National Association of State Textbook Administrators to assure textbook manufacture of the highest quality. These specifications cover paper, minimum margins, endsheet construction, reinforcements, sewing, lining-up, cover boards, cover materials and cover coatings. The various classifications cover hardcover textbooks, nonconsumable softcover texts, and ancillary materials. NASTA bound textbooks may be sidesewn, Smyth-sewn, and, on a trial basis, also adhesive-bound. All books without exception must be cased in "tight-back."

**Single-sheet Binding**

Individual sheets of paper may be secured by mechanical means. There are many styles and methods available to fasten single leaves. Basically, one must divide them into two categories: (1) the mechanical binding systems, in which single sheets are fastened into what is essentially a permanent system; and (2) the loose-leaf binding systems which allow the contents to be changed at will. These bindings are being used for manuals, cookbooks and the like. The advantages of these binding systems are that they open flat and allow the binding of stiff materials. The disadvantages of these bindings are that plastic pins or combs become brittle and wire bindings become bent.

*Loose-leaf* binding systems allow single sheets to be exchanged. Ring binders with two or three rings give little control to the leaves. Constant turning of the sheets will result in torn leaves. Multiple rings give better sheet control and are well worth the additional cost.

Post binders are made of various materials and can be lengthened by addition of other sections. Openability, however, is jeopardized, and wide margins are essential for these binding methods. There are many other types of loose-leaf binding systems, such as thong metal, velobind, ledger binders, prong binders, magazine and directory binders, etc.

*Mechanical* binding styles are spiral, twin wire or plastic comb. These binding elements secure the pages and make an exchange of pages difficult, if not impossible. Some systems allow the punching of T-shaped slots for the addition of extra materials without opening or destroying the mechanical element.
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Spiral binding is the least expensive method. Wire or plastic is formed into a spiral of the proper diameter and length. The sheets must be punched and the spiral is then inserted and "tucked-in" at the ends. When a spiral bound volume is opened, a vertical shift may be noticeable.

Twin wire is double-looped wire that is premanufactured. The sheets must be punched with holes or slots and are then permanently sealed into the binding element.

Plastic combs are perhaps the most widely used mechanical binding style. The combs are premanufactured in the desired diameter and color. Elongated slots are punched into the sheets. The flexible plastic comb is then held open with a special device, and the punched sheets are inserted and the comb closed.

Library Binding

It has already been noted that printed material is bound for the purpose of its end use. Publishers and book manufacturers produce books to sell them—not for increased circulation. Most edition work is therefore geared for the individual reader. Today's hardcover bindings no longer assure durability. This physical collapse of bindings leaves librarians with tremendous problems. No matter how much worse edition books will get, one basic fact remains clear for librarians: books destined for circulation must last long enough to provide low-cost readership among the number of readers. Library books, like all other products in the public interest, must find a level guided by sound economics. This level has been established by the number of times bound books and magazines must circulate to provide the lowest reasonable cost per reader.

Binding for a library can never be done on a mass-production basis. Judgment, knowledge and experience must enter the process at every stage. A library binder is still a craftsman and, above all, a manager. No other binder could cope with such a mixture of individual bindings, follow exact specifications in the preparation of materials, and bind books so economically. The Library Binding Standard, developed and constantly improved since 1915, is now undergoing several changes to cope with new technology and materials.

Oversewing was developed out of the necessity for binding and rebinding books for heavy-duty end use. This form of sewing is practically indestructible and has become the foundation of the Library Binding Standard. An oversewing machine sews single leaves of signatures obliquely through small sections, itself forming a lock stitch with
each separate section and independent lock stitches the length of the back. This type of sewing is much different from side sewing, where a heavy thread is laced through the entire book block at once. Oversewing requires extensive training. To sew books in this fashion is time-consuming. The advantage of overcasting by hand or oversewing by machine is that there are no folds to be reinforced or repaired. Endpapers are sewn to the book block through the inner leaf and reinforcing cloth strip. This method of sewing through the edge in sections allows for reasonably good “openability” and maximum strength. Oversewing should only be used on volumes where extending the life potential is the principal objective. A minimum of one-half inch margin space is required so as not to infringe on the print. There are many arguments for and against oversewing. Piercing or perforating holes in the edges of an archival volume is aesthetically wrong. For these books, more expensive hand-sewing methods should be used.

Side sewing is used on small books which bulk less than one-half inch. Singer sewing machines side stitch with heavy thread, the sewing extending the full length of the volume and through the reinforcing fabric. The difference between a Singer sidesewn edition or textbook binding and that of a library bound volume is in the construction of the endpapers. A library bound volume requires a reinforced endpaper that is folded back flush so that it will hinge from the binding edge and not pull on the sewing. Most small, prebound library books are sidesewn and are almost indestructible, an important factor when binding books for small children.

Sewing through the fold may be done if folded signatures are present. This method of binding may be done by hand on a sewing frame or by machine. Hand sewing is time-consuming and therefore expensive. This process is mainly used on rare books or on music books where good openability is essential. A substantial amount of saddle-stitched periodicals can now be sewn on the National sewing machine. This heavy-duty sewing machine is able to sew through 160-180 pages, depending on paper thickness and quality. Properly sewn with special spine-strengthening tapes and glued-off with specially formulated polyvinyl acetate adhesives, this “sew-through-the-fold” method assures excellent openability, copyability, and leaves the option to rebind again (and again) at a later date if necessary. This method of binding is truly a conservation-oriented process.

Adhesive binding is the fastest growing commercial binding process, as mentioned earlier. This process is used for many periodicals. Paper prices have quadrupled since the 1960s. Publishers increasingly
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save paper by reducing margins. Such narrow-margin materials are not suitable to be side- or oversewn for circulation. The library binder has no choice but to adopt an adhesive binding method which will tolerate even the smallest margins. Double-fanning the sheets in both directions and applying a special water-based, internally plasticized, copolymer polyvinyl acetate emulsion adhesive is now the accepted method for rebinding and prebinding narrow-margin library material. This method—again time-consuming—gives the highest quality obtainable in adhesive binding. The double-fan adhesive-binding process allows the adhesive to be applied between the pages while fanning/gluing each individual sheet—first one side, then the other—to provide extra strength and durability. Some of the factors which may influence the quality of double-fanned binding are: paper quality, grain direction, format of the book, thickness of the volume, etc. Unfortunately, a library binder has little or no control over these critical factors. Librarians have noted the excellent copyability of a double-fanned library bound book.

Cleatlacing is the newest method of binding developed especially for library binding. Operating a cleatlacing machine is simple and does not require extensive training as does oversewing. Books to be rebound must be prepared the same as for oversewing, that is, all old glue must be removed and the pages separated. The volume to be bound is then inserted into a clamp, and thereafter everything is fully automatic. Parallel dovetail slits (cleats), approximately one-eighth inch wide and one-eighth inch deep, are cut into the backbone at opposite angles. The machine determines the proper number of cleats throughout the height of the book to be laced. After cutting the dovetail cleats, a thread carrier then separates thin sections of the backbone in order to lace (not sew) a single pasted thread through and around the cleats, one at a time, in a figure eight. This pattern is repeated for each pair of dovetail cleats. No piercing of paper is taking place.

The cleatlacing machine is three times faster than an oversewing machine. The result is a more economical binding. The final strength, however, must come from a heavy coat of PVA adhesive. Cleatlaced books are not as strong as oversewn volumes and therefore the method is adopted for lesser-used library materials which are not subjected to rough treatment.

Summary

What binding, then, is best for library usage? Which volumes should be bound to last? Is there material in the collection which should
be bound for occasional use only? What is an inexpensive, good storage binding? Which binding style is best to be used on the copy machine? These and many other questions should be answered by librarians. It is they who must decide what is best for their collections. A sound binding program should be part of an overall library effort to prolong the useful life of materials which by nature deteriorate.

Books and periodicals have a wide variety of sizes, shapes, methods of binding, kind of paper used, margins, etc. These represent some of the problems both the librarian and the library binder must face today. In addition, librarians and binders alike are faced with tremendous economic challenges. Librarians want to maintain their materials in the best and most economical fashion possible, and binders want to produce as economically as possible for the library. Experience indicates that books either rebound or prebound according to the Library Binding Standard will provide a hundred or more circulations. With approximately 80 percent of all new hardcover bound books now being adhesive-bound, new edition bound volumes will probably last only ten to fifteen circulations. Thus, library binding is a cost-saving device because it reduces the cost per circulation.

The library binding industry has dramatically changed over the past several years with the introduction of new materials, new methods of binding, and sophisticated new machinery. For example, on a recent visit to five certified library binderies on behalf of LBI's Quality Control Program, I found that four of these binderies used computerized hot-stamping equipment! Years ago, when paper was less expensive, most margins were adequate for oversewing. Unfortunately, this is no longer the case, and the result has been a significant growth of adhesive-bound library volumes. However, oversewing is still the basic method of affixing pages to build strength into a library binding, and it is used whenever possible. Reinforced-paper and synthetic cover materials are now competing successfully with cloth. How do librarians and library binders cope with these new trends? Are some of these new materials and binding methods equal in strength and performance to those of books bound according to the present LBI Standard? To answer these and many other questions, the Library Binding Institute established a Book Performance Testing Laboratory at the Rochester Institute of Technology. This unique, educational testing laboratory is part of RIT's School of Printing bindery management training facility, which houses some of the most sophisticated bindery machinery available. This includes equipment such as computerized cutters, perfect binders, folding machinery, inserter-saddlestitch-three-knife-trim combination
machines, etc. The adjoining LBI Book Testing Laboratory utilizes gadgets and testing machinery such as a Tumbletester, a Universal Book-tester developed by the Barrow Laboratories, an aging-oven, a Stoll abrasion tester, and an array of sophisticated page-pull and page-flex testers. Testing is constantly done to evaluate the performance of new materials and methods of binding. Graduate students find the testing laboratory extremely useful for conducting tests and basic research. The evaluation of strength and openability of three binding methods used in library binding—oversewing, cleatlacing and double-fan adhesive binding—on three different kinds of paper was part of a master's thesis. The results are to be published in Library Scene. Another test, the scanability of hot-stamped ISBNs on cover materials, is underway. OCR-coded identification on book covers could aid librarians in checking out books and other materials. Other tests and evaluations done for various certified library binders will ultimately result in specifications for alternative methods of affixing pages, bindings which are not subjected to the normal rigors in library use. Thus, librarians will know exactly what is being sold, and what kind of quality and performance they may expect from a certain category of binding.

To aid in the preservation of library collections, which should include a sound program of book maintenance, librarians are invited to contact the Library Binding Institute for information on their free examination service, the Book Testing Laboratory, publications on binding and preservation, etc.

References

4. For some of the best examples of such creativity, see Smith, Philip. New Directions in Bookbinding. London: Studio Vista, 1974.
7. Library Binding Institute, Suite 633, 50 Congress St., Boston MA 02109. tel. (617)227-7450.
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Disaster: Prevention, Preparedness and Action

SALLY BUCHANAN

Conservation of library and archival materials embraces a broad spectrum of problems and concerns. As librarians try to grapple with poor paper, brittle collections, mutilation, insects, hostile environment, air pollution, and lack of funds, there is the ever-present danger that disaster may affect the collections they have been trying to build and maintain. Thus, disaster prevention and preparedness become part of conservation concern.

But the field of disaster prevention and action is not one in which much experimentation has happened. Nor is it one where difficult problems can be tested in practice often enough to devise sound methods of operation. In the aftermath of the Florence flood in 1966, in the frantic need to dry massive numbers of valuable items, several experimental drying methods were tried—most proved to be unsuccessful. But one conclusion seemed clear. An organized approach to disaster prevention and action would save more material than a haphazard one. In the intervening years there have been enough library disasters with enough losses to emphasize this point. This paper will reiterate what has been learned (to the extent that it seems appropriate to state anything). These points seem applicable to large or small collections, in libraries and archives, with a concern to be prepared for any eventuality.

A disaster is described by Webster as a "sudden calamitous event bringing great damage, loss, or destruction." For libraries and archives the disaster can be devastating and irreversible to the fragile contents of their collections. The results of the Florence flood emphasize again the

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impermanence of the records of man's history and culture. Through articles by Waters, Tribolet, Horton, and Ogden, the library world was made cognizant of the need to consider the possibility of disaster and to make plans as part of sound fiscal and collection management. In the past decade there have been numerous library disasters in the United States. The Corning Museum flood, the Klein Library fire, the damage from Hurricane Agnes to scores of libraries, the flood at Case Western Reserve University, and the water damage at University of Corpus Christi and at Stanford University all emphasize that disasters do happen in massive ways.* But even small incidents can be devastating to smaller libraries or collections, or to unique items. The telephone log book at the Conservation Office at the Stanford University Library attests to the weekly calamities which befall collections. The awareness stimulated by well-publicized disasters has resulted in the development of prevention and preparedness plans and in better techniques for coping responsibly if the worst happens.

Prevention

Obviously, the great natural disasters cannot be prevented, but plans to reduce the effects if such disasters strike can be most effective. In addition, steps may be taken which can, in fact, eliminate or reduce the possibility of trouble. Because of the many calls for help, it appears that more prevention is in order for libraries and archives in the United States.

If libraries are situated in severe weather areas where hurricanes, tornadoes, or earthquakes are a possibility, understanding ways to reduce stress on buildings or the contents of buildings is important. Flood gates and sandbagging techniques can help in flood-prone areas. Libraries in hurricane or tornado areas should understand the dynamics of air pressure and high winds, those stresses on buildings, and what may be done to alleviate the stresses. Libraries in earthquake country should understand what happens to book ranges even in a mild quake, and consider bracing shelves, both top and bottom, so they will ride with the quake and not twist and buckle, dumping books to the floor. If equipment like flood doors is provided, management must make sure that they are available for use, and will be used, at the first sign of

*As evidence that even those who have disaster plans can suffer more than once, Stanford University Library on March 9, 1981, experienced another water pipe break, probably due to the recent small earthquakes producing stress on old plumbing. Eight thousand bound dissertations were wet; and at the time this was written, 5000 were air-drying, and 3000 were being dried by Lockheed in its vacuum chamber.
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trouble, no matter how inconvenient to staff. The Hurricane Agnes accounts offer graphic evidence of damage caused by hurricanes or great storms. Allen Veaner has written about earthquake damage after the earthquake which hit the University of Santa Barbara recently.8

Both national and local civil defense agencies offer a wealth of helpful ideas for protecting people and the contents of buildings. The American National Standards Institute and state and national fire protection agencies also have published prevention materials.9 Understanding the natural hazards of an area, anticipating problems, and maintaining buildings and grounds to withstand disaster may make a difference between total loss and damage. The hazards of some areas of the country are so great as to increase the possibility of disaster. Being realistically prepared will save collections if the worst happens.

Good building maintenance and surveys can be important ways to prevent problems.10 Proper cleaning of storm drains, sewer lines, and roof areas will prevent leaks. Steam and water lines should be checked regularly and have pressure alarms to indicate trouble. Drips or unusual condensation should be reported and dealt with before they become symptoms of a greater problem. Fire extinguishers must be checked regularly, and staff should be trained how to use them properly. Trash and flammable materials must be kept cleaned up and out of storage closets and basement areas where air circulation is poor.

Practical prevention can be achieved by storing more valuable materials on upper shelves or upper floors to avoid water damage. If materials must be stored temporarily in basements or lower levels, raising them on bricks and boards off the floor is a sensible precautionary measure. Fragile items such as phonograph discs may require elastic cords across the fronts of shelves to help prevent loss during earthquake, flood, or storms.

In older buildings, plumbing and wiring are often hazardous and should be inspected. Repairmen and contractors must understand the need for care when they work with pipes, welding equipment, and flammable materials. Cigarette use by staff and public must be carefully controlled. The great fire at the University of Texas Library was caused by a welder’s torch, or at least by the contracting work going on in the building.11 An intelligent assessment of potential problems can often prevent terrible results. The disaster prevention plan published by Hilda Bohem’s committee for the University of California system and the one published by Cornell University are examples of the approach preventive hazard surveys can take.12
Fire prevention for libraries is an extremely important consideration. Fire not only destroys books, but introduces the possibility of massive volumes of water. In addition, heat and smoke may destroy books fire does not even reach, due to the high temperatures of modern fires fueled by plastics and man-made fibers. As always, prevention is the best alternative. But fire prevention in libraries introduces the old controversy of taking the risk versus the introduction of water or chemicals into the library environment. The National Fire Prevention Agency and most insurance underwriters have current statistics indicating the alarming incidence of arson in this country. Libraries are not exempt from this hazard. The San Diego Aerospace Museum and Library were totally destroyed by an arson fire in 1978. These sobering facts coupled with a number of recent disastrous library fires will point out the wisdom of careful prevention plans geared to a library's contents, needs and finances. Two of the best resources in this consideration are the ALA publication "Protecting the Library and Its Resources" and Managing the Library Fire Risk by John Morris. The latter publication contains a fine bibliography of resources for library fire prevention and information.

Keyes Metcalf in Planning Academic and Research Library Buildings says: "The removal or lessening of hazards will not stop fires altogether. The question of fire detection, alarm, and extinguishing must be considered." There are a variety of heat- or smoke-detection and alarm systems available to a library. The best ones are wired into a central fire alarm which is monitored by fire or facilities personnel. A self-contained alarm is effective only if there is someone around to hear it.

A number of automatic systems for putting out fires are available on the market and serve a variety of needs and purposes. No longer do all sprinkler heads go off when fire is detected. The failure rate of sprinkler heads is now one per million installed. Increasing sophistication in the industry can provide wet or dry pipe systems, pre-action systems, pre-action "Firecycle" systems, on-off, and gas systems. All of these options are fully explained in Managing the Library Fire Risk. It is important for librarians and archivists to realize that even tightly packed books will burn and will be heavily damaged by smoke and soot. If a fire starts and it must be put out by a fire department, as much as 11,000 gallons of water per minute can be poured into a library. The possibility of coping with such a disaster makes the prospect of dealing with several hundred books wet by a sprinkler head almost insignificant.
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Just as smoke-detection systems can alert authorities to the presence of fire, so can water-detection systems be tied into alarm mechanisms. These warning devices are simply constructed and may even have self-contained alarms if they cannot be wired into a central system. Basically, they detect the presence of an unusual amount of water before it can harm library materials. The alarms are marketed by several firms for use in libraries, archives and computer facilities.

Disaster prevention makes sound fiscal sense and helps alert staff to the need for vigilance and care. In the event of disaster, the steps taken to prevent trouble will at least help lessen the effects.

Preparedness

Preparedness by its very definition indicates thoughtful planning and decisions in advance about how emergencies will be handled. Assigning specific tasks, knowing sources of supplies and how to obtain them even on holidays, and having correct lists of phone numbers for police, fire services, and library personnel are an integral part of disaster strategy. Stanford University now has two emergency trailers fully equipped to handle the immediate needs in a fire or water disaster. They can be pulled on site at any time, and are summoned through a 24-hour emergency number. Examples of preparedness plans are numerous and offer a variety of approaches for specialized collections.

Preplanning also includes establishing priorities for materials to be saved first and those to be abandoned if necessary. In establishing priorities, catalogs and shelf lists should be considered. Loss of records will add to the confusion of recovery if large numbers of materials are affected. In addition, preplanning includes decisions about whether particular collections are important because of intellectual value only or artifactual value also. Preserving the intellectual content of books is much less expensive than restoring the books. The alternatives of microfilming, photocopying and replacement are often practical solutions for many collections. But understanding that, with care and expert advice, much material can be saved with relatively little cost is also important. The cost of one large-scale operation may be seen in the report from Stanford about its flood recovery. There, 50,000 moderately wet books were put back on the shelves at an average cost of $4.90 per book. The people who will be involved in making decisions about salvage efforts should be aware of options open to them or whom to call to obtain advice.
A general plan for the proper handling of fire- or water-damaged materials is advisable, at least for the personnel assigned to a disaster team. Peter Waters's *Procedures for Salvage of Water-Damaged Materials* is an invaluable resource in this respect, as is Willman Spawn's "After the Water Comes."22 Also, as part of preparing wisely, one person should be designated to receive the disaster call, assess the situation, and initiate the proper procedures if necessary.

Finally, consideration should be given to the finances of a recovery operation if that becomes necessary. Librarians should be aware of the insurance on the building and its collections, and what restrictions there may be when disaster strikes. Often, insurance companies want to be notified immediately so that they may assess the situation as it is, before cleanup starts. If the library or archive has no insurance coverage, some thought needs to be given to the source from which financial help will come for disaster recovery. If there seems to be no resource, then responsible management should consider whether the risk of no insurance as opposed to the premiums is worth it. Some large libraries are self-insured up to a point in order to be able to afford insurance. Smaller libraries may find their insurance is not expensive, or may be covered by state or local insurance funds. More and more, insurance companies are insisting that libraries have fire protection systems or the library will not be insured, or the large body of the college or university will not be insured. In some counties or states tough new fire regulations will demand fire protection systems in new buildings or in remodeled ones. This may reduce insurance premiums and thus pay for the system in savings in a few years.23

**Action**

When disaster strikes a library, fire or water are almost always involved. Knowing what action to take will save time, personnel, costs and contents.

In case of fire, firemen will take charge, and ideally will have been apprised of the library's priorities, concerns and needs. Whenever possible, ranges should be covered with salvage tarps to help lessen water damage to peripheral areas. Libraries should have on hand rolls of plastic sheet which can be thrown over ranges where heat is not a problem to protect books from unexpected water damage, often quite far from the actual fire or water problem. When premises are finally safe, fire experts will allow inspection. In a large fire this may not happen for twenty-four to forty-eight hours after the fire is extinguished. A graphic
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description of fire damage may be read in accounts of the Jewish Theological Seminary Library fire and of the University of Toronto Fleming Library fire.24 These same accounts also give evidence of the water damage accompanying a fire. For the effects of major water damage, there are the accounts mentioned earlier in this article.

The first step after access is gained to a building is to assess the damage as precisely and completely as possible. Librarians or bibliographers familiar with the collections should assist in damage evaluation. Careful notes and photographs will aid in planning and in insurance settlements. Be sure to notify the insurance carrier, or the risk management office. The building must be well ventilated, with heat turned off and everything possible done to reduce temperature and humidity. (Preplanning will have identified sources for fans, pumps, dehumidifiers, wet-dry vacuums and other first-step cleanup supplies.) Exposed materials should be covered if roof areas are missing or if water is draining through the building. Plans to provide temporary protection against the weather should be put into effect. Protection of property should be arranged with security. Then, from a designated command post, all disaster action plans can be initiated.

Wet paper tears easily, swells rapidly, and distorts. Wet leather and vellum swell, split, and may turn black. Glues wash out, boards and covers disintegrate. Wet books continue to swell until stabilized, and if not removed from shelves within a few hours, will expand and wedge so tightly they are almost impossible to remove without damage. Stanford University Library reported problems with this during its flood clean-up.25 After forty-eight hours there is danger of mold development. Temperatures and humidity must be kept under 70°F and 70 percent relative humidity to prevent mildew infestation.26 Wet material must be removed from the area as soon as possible to facilitate drying.

Instructions for handling charred or wet material may be found in Cunha and Cunha and in Waters.27 Charred paper must be supported on a flat card or paper to protect it. Burned film or photographs are usually irretrievable, but wet ones can often be saved. The Rochester Institute of Technology can give advice in this matter. Sources to check are the newsletter Photographic Conservation, the Corning Museum flood report, and Preservation of Photographs.28 Wet film may be soaked in clean water and sent to a Kodak processing laboratory notified ahead of time. It is important not to let wet film dry in a roll or stack.

There are several ways to dry wet paper material. If the amount is relatively small, and if the exposure to water is slight to moderate, air-drying can be successful. A word of caution is needed. Coated paper,
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often used in journals and art books, must not be allowed to dry without special attention or it will stick permanently; Cunha, Waters and Spawn describe this method.\textsuperscript{29} Extreme care must be exercised to avoid mildew.

However, if space is limited or material must be held for decisions, it is best to freeze it at -15°F or colder. Freezing does not harm paper, and will retard chemical and biological deterioration. Then the appropriate drying technique may be employed. Basically, freezing provides time to investigate alternatives and costs.

Besides air-drying, there are several other techniques which have been tried with greater or lesser success. The Corning report mentions dielectric drying as one means which helped their recovery.\textsuperscript{30} Thomas and Flink report in \textit{Restaurator} on microwave drying tests.\textsuperscript{31} Fischer writes about dielectric and microwave experiments in drying books.\textsuperscript{32} Koesterer and Geating, Corning, McDonnell Douglas, and Stanford University all report on tests and experience with vacuum drying.\textsuperscript{33} The vacuum-dry process involves subjecting frozen books to a high vacuum in the presence of heat. This causes the physical process known as sublimation, which means that ice crystals turn to vapor without first melting and rewetting the books. At the present time, the vacuum-dry technique seems to be the most efficient and economical way to dry large numbers (two thousand or more) of wet books. Lockheed, General Electric and McDonnell Douglas have all been involved in testing this process. The special restrictions for each process, as well as any instructions for preparation of the materials, are included in the articles mentioned.

There are currently at least two private firms who employ vacuum-dry techniques for drying books and records. One of these firms has the ability to move its equipment on site to avoid shipping damage to fragile material.

As disaster action continues with removal of damaged items, control of environment must be monitored by sling psychrometer or hygro-thermograph. This monitoring indicates the temperature and humidity conditions over time, and whether other steps need to be taken. If mildew appears in the damage area, fumigation must be undertaken by a professional service. Thymol is one chemical which has been employed successfully. If mildew appears in large numbers of water-damaged books, fumigation in a vacuum chamber such as a Vacudyne is advisable.\textsuperscript{34} Individual interleaving with thymol-impregnated sheets may be done with a moderate number of books if mold is suspected. The technique is clearly explained in Waters’s booklet. Fischer also writes
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about sterilization and fumigation in *Preservation of Paper and Textiles of Historic and Artistic Value.*35

After damaged material has been removed, the remaining collections must be watched carefully for several months to ensure that mold growth will not be a problem. Keeping temperatures cool (65°F) and humidity low (40 percent) will lessen the probability of infestation.

One of the major problems after water damage is with coated paper sticking badly. Corning found that wetting, refreezing and vacuum-drying helped.36 Stanford tried several other techniques, and had some success with microwaves.37 A more exotic but apparently successful approach is reported with the use of enzymes by Segal and Cooper,38 and by Wendelbo and Fosse.39 The use of enzymes is expensive and tricky, and should be handled only by trained paper conservators.

The organization and staff required for a major disaster cleanup is critical. A carefully planned program for the cleaning, repair, rebinding, restoration, and reshelving of materials is essential if a timely termination and outcome is to be expected. Seeking advice from conservators who have had experience with library disasters will aid with recovery. Librarians who have dealt with disaster are also a gold mine of information and advice. Disaster action, then, includes assessment, protection, decision and choice of alternatives, supervised execution, on-going evaluation and change, and finally, an analysis of the whole project with modifications needed for the disaster plan.

Current News

Due to the growing awareness of the need for readiness in case of disaster, and the publicity afforded disasters in the last ten years, there has been a great deal of activity in disaster planning, prevention and action. The Library of Congress published Waters's booklet, Corning Glass Museum and Library published its detailed report, Stanford University Library issued a flood report, and many libraries and archives have published their own detailed disaster plans.

The Special Libraries Association Chapter of Princeton-Trenton, New Jersey, sponsored a seminar in 1979 which addressed disaster prevention among other issues. Stanford University Library held a two-day conference about disaster prevention and coping in May 1980. In April 1980, the University of Oklahoma Library and School of Library Science organized a conservation colloquium which addressed disaster prevention and action as one critical aspect of conservation. The Western States Materials Conservation Project surveyed with grant
help the western regional states' needs in conservation to discover that help with disaster prevention and action was a high priority. As a result, several western states are providing workshops and training sessions for librarians and archivists. In March 1981, Utah held such a workshop, supported by the Utah Museum Association, Conference of Intermountain Archivists, and the Special Libraries Section of the Utah State Library Association. The Bibliographical Center for Research, Inc., held a two-day workshop in May 1981 to train representatives from each of the seven mountain-plain states it serves in disaster prevention and recovery. They will then return to their states and hold a series of workshops to train others. There are several organizations offering disaster recovery assistance, including the regional Northeast Document Conservation Center. The Society of American Archivists has a grant to hold a series of conservation training workshops, including disaster prevention and action. The American Association of State and Local History has produced in its series a technical leaflet about disaster prevention.

The Systems and Procedures Exchange Center (SPEC), operated by Association of Research Libraries Office of Management Studies, has a three-year grant for conservation. As part of this grant, it has produced SPEC Kit No. 69: Preparing for Emergencies and Disasters.

Many libraries and archives are realizing that disaster prevention and action planning is a relatively easy and cost-free conservation activity which can reap big benefits if disaster strikes. Fine plans have been written in Wyoming, Idaho, Arizona, at the libraries of Cornell, New York Public and Rochester, University of California at Berkeley, University of Toronto, Houston, and for the National Library of Medicine. Many more are written, or are being written, as the result of growing awareness of the need. Each of these is different, is geared to the library's needs, and is practical. There are also individual efforts by conservators to educate those responsible for library and archival management. Jack Thompson in the Pacific Northwest has offered such regional workshops in the past three years.

Gradually, as conservators, librarians and archivists share experiences, innovations and experiments, the body of literature available in the field to aid in disaster prevention, preparedness and action is growing. New techniques and ideas are implemented, and recovery from disaster becomes not only a possibility but a probability. Since the Florence flood, enlightened caretakers of the treasures of man's mind have taken more time and care to plan carefully so that the greatest proportion of their collections can be saved in case of disaster.
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42. *Preparing for Emergencies,* SPEC Kit No. 69.
Microforms as Library Tools

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Micrographics dates to 1839; however, it was not until the late 1930s when libraries began making microfilm copies of rare documents for public use and also began converting newspaper files to microfilm as a means of conserving storage space and preserving newsprint, which generally has a rapid decomposition rate in its original form. By the 1950s, there was a widespread realization that microfilm could be used not only for the preservation of back files and oversized documents, but as an integral part of active information systems (as opposed to archival storage). Microform technology came into its own in the 1960s. During that decade, the micrographic industry became a $500 million/year endeavor, largely as a result of improvements in equipment and materials. Less expensive readers and reader-printers were made available, enabling libraries and business firms to make active use of microforms. Advances in optics and equipment design made microform readers easier to operate and use. Also in the 1960s, micrographic technology and data processing were combined to permit the output of computers to be recorded directly on microforms rather than on paper. This is called computer-output microfilming (COM). In the educational field, significant increases were made in the availability of microforms through expansion of commercially produced micropublications and through efforts of the U.S. Office of Education.

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By the early 1970s, portable microform readers, referred to as "lap readers," began to appear on the market, enabling people to utilize microforms in the classroom, at home, and in other places, as well as in the library. Standardization of microforms made significant headway early in the decade. By 1972, micropublishing was receiving unprecedented emphasis with more than $50 million of microforms being produced annually. Microform hardware and services accounted for millions of additional dollars.

In the early 1980s, micrographics is today being combined with many other technologies—data processing, word processing, facsimile transmission, electronic mail, information retrieval systems, etc. Micrographics has become a subsystem of a total information transfer system. We see this trend continuing and micrographics being a part of the so-called "office of the future."

What is Micropublishing?

Micropublishing is a communications technique which uses photographic processes to miniaturize printed or graphic material. It involves four phases:

1. **Photographing** the material,
2. **Duplicating** or reproducing the microcopies for distribution,
3. **Retrieving** stored microimages by means of manual or automatic devices, and
4. **Displaying** images on a reader screen for viewing and using a reader-printer for producing hard copies.

Micropublications can be issued in black-and-white and in full color. They come in several forms and sizes: roll film, in 16mm or 35mm width; and microfiche (a sheet of microfilm containing multiple microimages in a grid pattern—usually 105 x 148mm with 98 images). Publications in microform are divided in three basic categories:

1. **Micropublishing**—to issue new (not previously published) or reformatted information in multiple-copy microform for sale or distribution to the public. The following are some examples of true micropublishing. Verbatim transcripts of CBS News television broadcasts are available only on microfiche. **CORE (Collected Original Resources in Education)**, a journal for the educational researcher, is published only on microfiche. Articles are collected from many newspapers on a specific subject (e.g., abortion, solar energy, child abuse) and are organized and indexed. This is material
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previously published in hard copy that is reformatted and published on microfiche.

2. **Micro-republishing**—to reissue material previously or simultaneously published in hard copy in multiple-copy microform for sale or distribution to the public. Two common examples of micro-republishing include: (1) newspapers, hundreds of which are filmed on 35mm roll microfilm and sold to libraries all over the world; and (2) many popular magazines such as *Flying, Boating, Stereo Review, Popular Electronics,* etc., which are published in hard copy and in microform simultaneously.

3. **Microprinting**—to make single or multiple copies of proprietary information in microform. The Western Electric Company microfilms engineering drawings and disseminates microforms of these drawings to hundreds of telephone company engineering offices. This information is *not* available to the public. Most insurance companies microfilm policy material that is *not* available to the public.

What are the benefits of micropublishing? These include:

1. **Reduced printing costs**—Microforms can be produced for about one-tenth the cost of printing on paper.

2. **Quicker dissemination**—Turnaround time to prepare and disseminate information on microforms instead of paper can put the material in the hands of the user in one-fourth the time.

3. **Easier retrieval**—Microforms provide fingertip accessibility. All one does is select the desired microform and insert it in a reader.

4. **Lower cost distribution**—Six microforms can be sent by first-class mail coast to coast for only eighteen cents; the equivalent amount of information on paper mailed the same way would cost over eight dollars.

5. **Space savings**—Microforms give compactness. Over 10,000 pages can be stored on microform in an area 105mm x 148mm x 25.4mm (4" x 6" x 1").

6. **Ease of handling**—No longer is it necessary to juggle cumbersome catalogs and manuals, or fumble through stapled, dog-eared pages, often misfiled.

7. **File uniformity**—Each microform is produced to a standard format which eliminates the handling of documents, books and periodicals of many shapes and sizes.

8. **Increased durability**—Microforms can withstand much more rugged handling than paper.
9. **Rapid updating**—Microforms reduce updating delays. Instead of having dozens of pages to file when updated material is received, only one or two microfiche need be slipped in the file.

**Microforms**

The term *microform* is generic for any form, either film or paper, which contains microimages. The following is a description of the various microforms and an indication of the advantages and disadvantages of each.

**Roll Film**

Roll film is a length of processed microfilm on a reel or in a cartridge or cassette. Roll microfilm is most commonly 16mm or 35mm wide. The traditional standard length of roll film is 100 feet and has a thickness of 5 mils. However, lengths of up to 140 feet are becoming more common as new, thinner-base films are used. The longer lengths are housed on the same size reel or cartridge.

Roll microfilm is nonperforated—that is, it does not have sprocket holes. There are three very common formats for arranging the images on roll microfilm: (1) the simplex-comic orientation, where a single line of images are lined up side by side, like a comic strip; (2) the simplex-cine orientation, where a single line of images is continuous, quite like motion-picture film; and (3) the duplex mode, where the front and back of a document appear side by side, forming two channels of images down the length of the film.

Reels are flanged plastic holders for processed roll microfilm. Cartridges and cassettes are plastic enclosures that protect the film and simplify inserting the film into readers, reader-printers and retrieval devices. Cartridges have a single core and cassettes have two cores.

Roll microfilm is the least expensive to produce, provides excellent packing density, and, depending on the indexing, retrieval can be quite fast for locating information. It is easy to produce hard copy from roll microfilm, and roll film provides outstanding file integrity. The shortcomings of roll film are the inability to update the information easily, and it cannot be duplicated by the user.

**Aperture Cards**

An aperture card is a card with a rectangular hole or holds specifically prepared for the mounting or insertion of a chip or strip of microfilm. The most common size of aperture card is EAM (electric
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accounting machine) tab card size, 3 1/4" x 7 3/8". The typical aperture accommodates a 35mm x 2" chip of film containing one frame (one image). There are many other sizes of aperture cards and aperture arrangements available. The film may be held in place by either pressure-sensitive tape or by insertion into a transparent sleeve.

Copy cards are aperture cards containing unexposed chips of raw film for contact duplication purposes. Image cards are cards containing a processed image.

The cost of aperture cards is reasonable, packing density is good, and the ease of updating and retrieval is excellent. The aperture card can be duplicated and hard copy produced very easily. File integrity can, however, be a problem.

**Microfiche**

Often referred to as simply “fiche,” microfiche is a sheet of microfilm containing multiple images in a grid pattern. Microfiche is produced in a number of sizes and formats. The most common and standard size is the international “A6,” 105 x 148mm (approximately 4 by 6 inches). For microfilming source documents, the most common format is 7 rows by 14 columns, providing 98 frames, which is usually produced at a 24X reduction. For computer-output microfilm, the standard format is 15 rows and 18 columns providing 270 frames of the equivalent 11 by 14 inch document at a reduction of 48X. Microfiche with very large quantities of images at high reductions (e.g., 3200 pages reduction) are called “ultrafiche.” Regardless of size or format, microfiche contains an eye-readable heading that identifies the contents. The heading area may be color-coded to aid retrieval.

The cost of microfiche is good; packing density and ease of updating is very good. Retrieval of fiche is excellent, as is the ability to duplicate and make hard copy. The capability of reproducing hundreds of images quickly, simultaneously and at low cost by duplicating a single fiche is very important. File integrity can be a problem. There are new, “updatable” microfiche systems in which images can be subsequently added to a master fiche.

**Jackets**

A jacket is simply a transparent plastic carrier with single or multiple sleeves or pockets made to hold strips of microfilm cut from rolls. Jackets may contain 16mm film, 35mm film, or both. Jackets are usually either tab size or 4 by 6 inches (105 by 148mm). Jackets, like fiche, have eye-readable headings which may be color-coded and/or notched to aid retrieval. Duplicates of jackets look like microfiche.
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The cost of producing jackets is fair, the packing density is good, and retrieval is excellent. Jackets can be updated by removing and/or adding selected strips of film. Hard copy and duplicates are produced the same way as from fiche. There is much manual labor involved in producing and updating jackets.

Micro-opaques
Similar to microfiche in configuration, micro-opaques are, as their name implies, images on opaque stock. Therefore, images may be stored on both sides. Unlike microfiche, where transmitted light is used for blowback, opaques use reflected light. Today, micro-opaques are only used by one micropublisher, and equipment availability is quite limited.

The Film in Microfilm

 Obviously, one of the most important components of a micrographic system is the film itself, although only a supply item. Film is used for two functions in the system: (1) for recording by a camera, COM or updatable system; and (2) as the duplicating medium for distribution copies. Microfilm may be duplicated through several generations, and both the camera film and the duplicates may have either positive- or negative-appearing images in any generation. The polarity of microfilm is determined by its appearance and not by what it is made from. Most business documents and library material are made up of dark text on a light background, exactly like this page. This is a positive-appearing image. A negative-appearing image is just the opposite—light text on a dark background.

There are seven different types of microfilm which fall into three categories, as follows:

Camera films
1. Silver-gelatin
2. Dry silver
3. Transparent photoconductor (TPC)

Duplication-Reversing
4. Silver-gelatin
5. Vesicular

Duplication-Nonreversing
6. Silver-gelatin direct duplicating
7. Diazo
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Silver-gelatin camera film may have a positive or a negative image, depending on how it is processed. Dry silver film produces a negative image. Transparent photoconductor films produce positive images. The reversing duplicating films produce a positive image from a negative or a negative from a positive. Nonreversing duplicating films produce negatives from negatives and positives from positives.

Silver-gelatin film is film that is coated with a silver-halide emulsion. Silver-halide is a compound of silver and one of the following elements, known as halogens: chlorine, bromine or iodine. Silver-gelatin film is both a camera film and a duplicating film.

Dry silver film is a nongelatin silver camera film that is exposed by light and is developed by application of heat.

Transparent photoconductor film is a camera film that includes a photoconductive layer which, in combination with a special electrostatic image system, permits the adding of new images or overprinting existing images onto an existing photoconductor film.

Vesicular film is a duplicating film in which the light-sensitive component is suspended in a plastic layer. On exposure to ultraviolet energy, the component creates optical vesicles (bubbles) in the layer. These imperfections form the latent image. The latent image becomes visible and permanent by heating the plastic layer and then allowing it to cool. Duplicating with vesicular film may be done in an ordinary room.

Silver-gelatin direct duplicating film has the same makeup and properties as those described for silver-gelatin film.

Diazo film is a duplicating film, sensitized by means of diazonium salts, which, after exposure to ultraviolet light (strong in the blue to ultraviolet spectrum) and after development by ammonia, forms an image. Duplicating with diazo film may be done in an ordinary room.

Sensitized Layer and Base

Microfilm can be broken down into two components: (1) the support, usually referred to as the base; and (2) the sensitized layer, which on silver films is called the emulsion. Microfilm relies exclusively on acetate and polyester bases; both are classified as safety films—that is, they will not support combustion.

Acetate film is a cellulose derivative with its main advantages being good clarity and a low propensity for static generation. (Static discharge inside a camera can fog film.)

Polyester base is a petroleum derivative that is rapidly growing in popularity. A high propensity to static generation has limited this base
to the duplicate film market, but recent developments in static control have allowed polyester to make inroads as a camera film. Polyester film has demonstrated superior performance in the following areas:

- It maintains dimensional stability.
- It resists heat, humidity and most chemicals.
- Polyester film does not tear, break or curl.
- It does not yellow or become brittle with age.
- Because of its strength, polyester permits the use of thin bases which allow high information-packing densities.

**Size and Thickness**

Standard microfilm widths are 16mm, 35mm and 105mm. Roll microfilm is available in lengths of 100 feet (30m) and multiples thereof. Microfiche (cut sheets of film) is available in 105mm x 148mm. Microfilm and microfiche are produced in thicknesses of 2.5, 4.0, 5.0, and 7.0 mils (with metric equivalents of 0.06mm, 0.10mm, 0.12mm, and 0.17mm, respectively).

**Archival Quality and Permanence of Microfilm**

Archival quality film is of fundamental importance to the micrographic field. However, archival quality is little understood and frequently the subject of heated debate, arising from the need to know how long a film will last. The basic definitions and criteria for evaluation have been established by the American National Standards Institute (ANSI).

ANSI defines archival record film as "a photographic film composed and treated so that under archival storage conditions...it is suitable for the preservation of records having permanent value." Three important points emerge from this definition:

1. the film by itself is not archival; it can, however, become "suitable" for the preservation of records of permanent value, if
2. the film is stored under archival conditions, and if
3. the film has been properly manufactured, processed and handled.

The interdependence of these factors is highlighted in the foreword to the ANSI PH1.41 standard:

Everyone concerned with the preservation of records on photographic film should realize that specifying the chemical and physical characteristics of the material does not, by itself, assure archival behavior. It is essential to provide proper storage temperature and humidity, and protection from the hazards of fire, water, fungus, and certain atmo-
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Spheric pollutants. Archival record films must be stored under the conditions specified in pertinent American National Standards (...PHI.43-1979).\(^2\)

From the above, it is apparent that, even when film qualifies as archival record film, no guarantee is given of the time period for which the film will last, only that it is suitable for storing permanent records. Moreover, the very nature of the standards is such that test procedures must be defined in order to establish the criteria by which a film can be judged to have been properly manufactured and processed. Such tests have traditionally taken the form of chemical and/or accelerated aging tests, and ANSI has been instrumental in designing test procedures and establishing criteria. To date, only criteria for silver film have been established.

In order for silver film to be classified as archival, the amount of thiosulfate ion (fixer) remaining on the film after processing must be measured, using either the methylene blue or the silver densitometric test methods specified by ANSI PH4.8.\(^3\) If the amount is less than 0.7 micrograms per square centimeter, the film can be certified as archival. Consequently, archival quality is not a property that can be imparted to a film either at the time of manufacture or at the time of processing. Rather, it is a combination of factors, all of which require proper manufacturing, processing, storage and handling. If these steps are accomplished properly and the film is stored for archival purposes, this is the best guarantee that the film will last for the longest possible period.

In designing a micrographic system, it is important to consider whether it is necessary for the microfilm to be archival record film. In a majority of cases, archival quality will not be a systems requirement, and the matter is purely of academic interest. If however, archival quality of film is a prerequisite, then the subject merits considerable study oriented toward the requirements of the system.

Before getting into the technical aspects regarding the keeping characteristics of microfilm, consideration should be given to the following three important points:

1. The span of time the information on the microfilm will be required;
2. Whether the microfilm will be used frequently for research or can be stored for posterity with very little use; and
3. Whether replacements for the microfilm are readily available.

It is now widely accepted that the terms archival and permanent (forever) are synonymous. It costs money and requires special effort to
produce and maintain archival microfilm; therefore, before specifying that your microfilm must be archival, consider your requirements. For example, computer output of everyday business records which are updated weekly or monthly usually doesn't need archival microfilm, since the material is replaced often. However, microfilm of the items in a rare book collection are likely required to be kept permanently. Therefore, every effort should be made to have archival quality film for this purpose. If you buy microfilm from a reputable commercial or government micropublisher, the microfilm is almost always replaceable, so there is no real need to worry about archival permanence.

When archival silver-gelatin microfilm is required, keep in mind that to be truly archival, it must be stored under controlled conditions and very rarely used. The everyday working copy should be an expendable duplicate, which is normally made on a nonsilver film, such as diazo or vesicular. It is possible to use silver-gelatin duplicates; however, it also should be noted that the emulsion tends to scratch more easily than the nonsilver film.

"Archival permanence" means the ability of the entire processed microfilm to retain its original characteristics and to resist deterioration over time. The entire processed microfilm refers to the base material, the emulsion, and the processing used. The method of handling and storing the film also affects its life. It must be emphasized that the concept of "archival" involves much more than just the chemistry of processed microfilm. Additional characteristics of concern include: folding endurance, viscosity, ignition, burning rate, curl, and brittleness. In the past, when one used the word archival, the question of time was always raised. Now, the Archivist of the United States says the term archival means forever. In practice, however, "archival permanent microform has come to refer to film which will last as long as 100 percent rag-stock paper. Rag-stock paper is claimed to have a life of hundreds of years. Recent changes in the standards have established three classifications, as follows:

Medium-Term—These are microforms which will have a useful life of ten years. Change in the photographic image is acceptable provided that it is still usable by the consumer.

Long-term—These microforms must have a useful life of 100 years. Again, the criteria of usability is important, since some image change is acceptable.

Archival—These microforms are intended for indefinite keeping and for the preservation of records having permanent value. Usability is
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not the only criteria for microforms having this classification, since they also must have permanent image-keeping properties.

Safety Film

All microfilm, both processed and unprocessed, should meet minimum requirements with respect to hazards from fire. In order to be classified as Safety Photographic Film, a photographic film must: (1) be difficult to ignite, (2) be slow-burning, and (3) produce a limited amount of toxic oxides of nitrogen during the decomposition. The detailed requirements for Safety Photographic Film are covered in American National Standard PH1.25. These requirements apply equally to polyester- and cellulose-based films. A film that meets this standard may have the word “safety” or the symbol “S” included in the edge printing, but this is not mandatory.

Processed Microfilm

Processed microfilm on cellulose-based materials should meet the requirements of American National Standard PH1.28. The equivalent for polyester-based film is ANSI PH1.41. These standards specify those criteria (ignition rate, viscosity, etc.) that make the film capable of meeting archival requirements.

The procedures, chemicals, temperatures, and wash practices used in processing microfilm are critical in obtaining “archival” microfilm. The effect of residual chemicals on film can seriously affect the life of the image. For archival life, the residual thiosulfate (sometimes called “hypo” or fixer) should not exceed 0.7 micrograms per square centimeter. Although not a requirement for medium- and long-term storage, it is a good practice to wash the film to these limits. If the microfilm is to be used and discarded within a very short time, it can be considered expendable and the above requirement disregarded.

Until recently, the most commonly used test for residual thiosulfate has been the mercury bromide (Ross-Crabtree) method. This method is now obsolete, and has been replaced by the methylene blue and the silver densitometric methods. Both of these methods are specified in American National Standard PH4.8. The methylene blue method is extremely reliable and gives repeatable results at the low level of thiosulfate required for archival processing of microfilm. The silver densitometric method is not as precise as the methylene blue method at the low level of thiosulfate required for archival processing of microfilm; however, the silver densitometric test is good for an everyday quick check.
Storage of Microfilm

American National Standard PHI.43 covers the recommended storage conditions for medium, long and archival storage. Consult the standard for complete requirements. Table 1 gives some general storage recommendations.

**TABLE 1**

<table>
<thead>
<tr>
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<th>Medium-term</th>
<th>Long-term &amp; Archival</th>
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<tbody>
<tr>
<td><strong>Relative Humidity</strong></td>
<td>Maximum of 60 percent</td>
<td>15-40 percent</td>
</tr>
<tr>
<td>Cellulose base</td>
<td>Maximum of 30-60 percent</td>
<td>50-40 percent</td>
</tr>
<tr>
<td>Polyester base</td>
<td>Maximum of 25°C (77°F),</td>
<td>Maximum of 21°C (70°F),</td>
</tr>
<tr>
<td>Temperature</td>
<td>preferably below 20°C (68°F).</td>
<td>Additional protection may be</td>
</tr>
<tr>
<td></td>
<td>Peaks for short periods shall</td>
<td>obtained at lower temperatures.</td>
</tr>
<tr>
<td></td>
<td>not exceed 32°C (90°F).</td>
<td></td>
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</tbody>
</table>

Technical Characteristics

There are many technical items regarding film, such as resolution, acutance, density, gamma, and contrast. Which space limitations prohibit from being covered in this article. Let me just say that reputable manufacturers produce good-quality film. Where special applications require knowledge of these topics, consult the references cited here and the manufacturers.

Conclusion

Microforms are a very viable way to preserve information. Archival permanence can be provided when needed; however, the permanence of the image depends not only on using the film that is capable of meeting archival requirements, but also on the manner in which it is processed and stored.

References

2. Ibid., p. 4.
7. __________, *Specifications* (pamphlet No. PH1.41).

**Additional References**


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Conservation of Photographic Print Collections

ALICE SWAN

The conservation of photographic materials is an extremely new field; its current primitive state is not at all surprising. Like all other conservation specializations, it has not sprung forth fully formed; but unlike the well-developed conservation specialties, photographs have not been in existence long enough for a craftsmanly restoration tradition based on trial and error over time to have developed. Further, over the approximately 140 years of photography's existence, very few individual prints have been perceived to hold enough intrinsic value as objects for the application of conservation techniques to be seriously considered or attempted; even 20 years ago photographs were "conserved" primarily by copying—and frequently the original photographs were altered, damaged or endangered by the process of making the copies. Since the early 1960s, with increased awareness of conservation generally and with greatly increased market values of some photographs, that situation has changed; curators and archivists are now committed to preserving collections of original photographs, and copying is thought of as an adjunct technique to document and publish collections and to reduce the handling of original material.

This rapid change in approach has created a sudden demand for conservation and restoration techniques applicable to all kinds of photographs, and for people capable of applying them. Clearly, this is a large demand—perhaps unreasonably large, given its suddenness and the enormous complexity and diversity of the materials involved.

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The only pre-existing restoration methodology had been developed in the photographic processing literature, and consisted of formulas designed for use by amateur and professional photographers to correct the results of poor processing or mistaken exposure/development on their own new gelatin materials.¹ These were relatively drastic, last-resort formulas to intensify or reduce the image density of otherwise unprintable negatives, and to remove various stains from negatives and prints. Nevertheless, they were taken over without modification for use on age-weakened, irreplaceable prints in the earlier articles on restoring photographs, which typically provided formulas and instructions for such operations as intensifying calotypes and other prints, removing stains by bleaching and redevelopment, or removing surface "silvering" with strengthened hypo solutions.² In practice, these formulas are impossible to apply successfully to prints of value for a variety of reasons—the reactions are uncontrolled and irreversible, for instance, or image structure, particle size and color are significantly changed—and they remain fascinating theoretical possibilities which may be developed into useful treatments in the future only after considerable research. A basic problem is that these treatments are addressed only to the silver constituent of a print, and their effect on other constituents, such as gelatin or paper, is frequently extremely destructive. More recent articles and books on preserving photographs tend to append caveats to such formulas (which are nevertheless included), and they frequently recommend that the curator or archivist contact "an experienced technician or conservator" for such treatments.³ Still more recently, conservators have begun applying paper conservation techniques to photographs, and while some of these treatments are excellent and all are chemically less radical than the silver treatments, they address only the paper constituent of the print, neglecting the silver and albumen or gelatin constituents, and frequently damaging them.

Concerning the silver treatments, Swartzburg writes: "well-intentioned but incompetent people practicing restoration can cause irreparable damage. Weinstein and Booth point out that even in the hands of an experienced technician, a photograph can be destroyed during the complex restoration process, as uneven results and a high mortality factor are real possibilities."⁴ As far as it goes, this assessment of the situation is correct. But surely it is obvious that, whether in the hands of "incompetent people" or "experienced technicians," restoration processes which show "uneven results" and "a high mortality factor" are themselves inherently unacceptable. Their use would not be tolerated in the longer-established areas of paper or painting conserva-
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tion. Why, then, is the use of such treatments considered feasible for photographs, which are usually much more fragile, both structurally and chemically, than most paintings or ink and paper prints?

One unavoidable answer and, indeed, a reason for much of our difficulty in thinking about preserving photographs is that we are still in the early stages of a transition from a time when photographs were assigned little "value"; their archival value was unknown since historians and other serious researchers hardly used them, and their market value among art collectors was insignificant. Some of that, of course, has changed. Recently a rare, multiple print panorama from the 1870s, previously owned by a public library, was sold at auction for $37,000—despite the fact that it had been dry mounted to poster board and perforated for hanging by the library. The price made headlines—we are surprised that photographs should bring so much. We are also disappointed that the library did not recognize the "value" of this rare piece enough to mat and frame it properly. The inconsistency of these reactions points to the basic problem: when we are not totally convinced of the value of an object, however we may like it, we expend less of our attention and budget on its care, and we are less critical of treatments done to it.

We have had a hard time convincing ourselves of the intrinsic value of photographs; and it is primarily the marketplace prices that have begun to change our thinking. Photographs are apt to be perceived as a single group—as members of a process class rather than as individual objects; and "photos" is clearly a group dominated numerically by entirely disposable, throw-away pictures. It has been considerably more difficult for archivists and curators to establish and apply archival criteria for value in their photographic collections than in their manuscript or book collections. A major reason is that very few photo collections have yet seen even the beginnings of proper utilization, which would have done much to establish agreed-upon archival "value." While it is obvious that these collections hold important information, few researchers have had well-developed ideas about how to extract or use it. Recent history publications, for example, are much more often decorated than informed by the photographs they reproduce; pictorial information is infrequently translated into words and integrated with other verbal information; and photographs are almost never treated as primary sources of historical information or cited as evidence for theories or ideas.

This, then, is the situation: many collections include very large numbers of photographs which have come from a large variety of
sources and which have a large range of possible uses and archival values. They are generally perceived and treated as members of the generic class "photos," and are all stored and handled alike, usually poorly. If collections of photographs remain in fine condition, it is usually because they have had little use. Though the existence of their information value has scarcely been acknowledged by serious researchers and they are an almost completely unused information resource, their actual physical use and handling are increasing rapidly, frequently for frivolous, repetitious purposes. Very few photographic collections are adequately prepared for handling by the public. Additionally, as physical objects, photographs are unusually fragile and complex, both structurally and chemically, and few successful restoration treatments have yet been developed to repair or strengthen them. It is a real possibility that many preservation/restoration problems for photographs will never be really successfully solved, and that, to some extent, the inherent fragility and incompatibility of their materials will defeat all efforts to preserve them.

There are several lines of action archivists and curators can take to improve this critical situation in their own collections. First, reassessment of one's own judgments about the value of the collection may be needed: to what extent is the information in the collection unduplicated elsewhere? To what extent is its research value to many different areas of study known? The entire class of photographic material is often undervalued because the negative-positive generation system implies replaceability; but to what extent is the collection actually replaceable—that is, to what extent are high-quality, archivally processed and stored negatives of the collection available, and to what extent would replacement prints function as well as the originals?

Second, the most essential physical action one can undertake is to control the environment of the collection: silver photographs are considerably less stable chemically than most other paper items. The American National Standard for the storage of microfilm (the area of photography where requirements for "permanence" have been taken most seriously) best describes the particular requirements of silver photographic materials for increased dryness, environmental cleanliness and air purity. The highest priority requirement of any institution serious about preserving a photographic collection is environmental control. Institutions on very small budgets possibly need such control more than anyone else, since they are less able to acquire similar objects to replace deteriorated pieces, are less likely to have adequate archival negatives from which copy prints can be made, and will be less able to
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purchase restoration services in the future. To some extent, low-cost environmental controls are feasible, and are far better than no controls: inexpensive refrigeration dehumidifiers and room airconditioners can be extremely effective in a closed photographic collection room, for instance.

Third, collections need to be properly prepared so that damage is avoided in handling and use. The handling of unprotected pieces should not be allowed. In general, protective packaging should provide a rigid, nonbending support (usually of two- or four-ply nonacid museum board), secure attachment to that support (by hinges of long-fibered Japanese tissue adhered with starch paste, or by folded paper corners), and surface protection (usually a mylar sleeve or encapsulation, or a mylar or tissue interleaving sheet). The package should allow a print to be easily moved and examined without touching the photographic surface. Indeed, the package should obstruct touching, since people have an inexplicable tendency to touch print surfaces unnecessarily, and since skin oils are acidic, attract and hold dirt and affect emulsion deterioration. Requiring researchers to wear white cotton gloves, a practice many photographic collections follow, has some excellent results (primarily avoiding the finger-marking of mats and housings), but it increases rather than decreases the need for adequate protective packaging of prints, since the gloves reduce manual dexterity, making handling more awkward and dangerous. Handling thin, unmounted prints while wearing gloves is particularly dangerous.

In the current absence of many satisfactory conservation treatments, the role of archivists and curators in providing intelligent preventive care assumes an even larger importance in photographic collections. In order to provide such intelligent care, very specific information is needed about the varying materials and processes of photography. Because of space limitations, I will cover only the major types of silver prints on paper—salt, albumen, collodion, and gelatin prints.

Preservation Problems Relating to Structure

All of the types of prints included consist of an image of finely divided silver metal contained in or on an organic colloid layer (albumen, collodion, gelatin, or starch), present as a discrete coating or as sizing, on a paper support. All share the problem of the chemical instability of finely divided silver, which oxidizes and tarnishes, as well as the problem of cellulose deterioration, and the problem of colloid deterioration, which is presently entirely unstudied. The physical prob-
lems caused by the delicate laminate structure of the materials are less familiar, though they have probably caused at least as much damage as silver image fading.

**Salt Prints**

These prints, so named because table salt was used in their preparation, were commonly made in the early years of photography—from the early 1840s through the 1860s—and to a lesser extent, became popular for a second time about the turn of the century as part of a return to handmade materials. To make a salt print, one chose an appropriate paper: a rag fiber paper, smooth-surfaced, well sized and without metallic impurities—generally a machine-made letter paper. The paper was treated with a solution of sodium chloride, dried, and treated with a silver nitrate solution, forming silver chloride in and on the surface of the paper. Silver chloride is a light-sensitive, insoluble silver salt still used as a major component of many modern photographic printing materials. The paper had to be used within a short time of sensitizing in the silver solution; consequently, salt papers were prepared by photographers rather than manufactured commercially. After drying, the paper was exposed to light under a negative to form the image, almost always by "printing out" (i.e., the entire image was produced by light reduction of silver chloride to silver metal, rather than by chemical reduction, termed "development"). Unexposed silver chloride was removed by treatment in a solution of sodium thiosulfate (modern "fixer" or "hypo"). The print was sometimes toned with sulfur or gold, altering the color. Finally, it was washed and dried.

Salt prints have the simplest physical structure of all silver prints: the image of tiny silver particles lies on and within the surface paper fibers and sizing. The depth to which the image penetrates the paper surface varies somewhat from print to print, but is always confined to the top fibers. Salt prints are the only silver prints where the texture and surface of the paper are obvious and unobstructed. The color of their images ranges from yellow-brown to red-brown, brown, and purplish-black, but is never neutral gray. The edges of a salt print almost always show some fading (loss of image density), a shift in image color toward yellow, and sometimes a slight silvery surface deposit, visible in shadow areas—these are the typical appearances of deterioration in silver images. Examined under a microscope, the superficial fibers of the paper are clearly visible in great detail without a coating covering them.

Salt prints have many fewer structural problems than albumen or gelatin prints; the major problems are their vulnerability to abrasion...
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damage and the ease with which dirt is embedded in their surfaces. Both problems are related to the poor storage and handling photography collections frequently receive. Under the microscope, salt prints commonly show roughed-up, protruding surface fibers, as well as local areas, most visible in shadows and midtones, covered by a network of white lines: these are losses where individual surface fibers carrying image density have been abraded off the surface.

Because of the special vulnerability of their surfaces, it is important that salt prints be given adequate surface protection in storage and use. Matted salt prints should be provided with a smooth interleaving sheet, preferably of mylar, between the window layer of the mat and the print; and unmatted prints should be stored in a mylar sleeve with a generously sized rigid backing of museum board to provide support. It is extremely difficult to clean the fragile surfaces of dirty salt prints without causing damage, and many salt prints simply cannot be cleaned. All such cleaning should be left to conservators experienced in treating salt prints.

Because they are among the earliest photographs, products of a time when photography was on the leading edge of scientific, technological and artistic culture, and because they were made for only a short period and were never a medium of massive portraiture, early salt prints have an intrinsic interest and rarity not found in other classes of prints. They are frequently more fragile and difficult to care for as well: since they were made in a period when photography was far more experimental than it was even a decade later, one cannot have the certainty about their processing methods that one has for other types of prints. The fading caused by exhausted fixing baths, which were frequently used for toning in the 1840s and 1850s, is common among salt prints. It is wise to be particularly conservative in caring for salt prints; they should not be exposed to unnecessary light, low-humidity storage is particularly important, and they should be inspected frequently.

Albumen Prints

Albumen prints were first made in the early 1850s, became the dominant printing material from 1860 until the turn of the century, and did not disappear from use until the late 1920s. This is the major printing process of the nineteenth century; prime examples of its use include the classic, large, Western landscape views, such as those of Muybridge, Watkins, Jackson, and O'Sullivan. Prints with glossy surfaces made before 1890 are almost certain to be albumen prints.
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Paper stocks similar to those for salt prints were used. A sodium chloride solution was mixed with egg whites, beaten and filtered. The paper was floated on the surface of this solution and dried, forming a thin, even, shiny albumen coating on the surface. From the 1870s on, as a surface of higher gloss became fashionable, papers were frequently floated twice, forming a thicker, shinier layer. Most such papers were commercially prepared; from the late 1850s, papers albumenized in factories were available; by the late 1860s, it was unusual for a photographer to albumenize his own paper. Evidence of hand-coating, such as drips and slight unevenness of gloss, can frequently be found on early prints. Shortly before printing, the paper was floated on a silver nitrate solution, forming light-sensitive silver chloride within the albumen layer. After drying, the paper was exposed to light in contact with the negative until the image was fully printed. Then it was toned with gold, fixed, washed and dried.

In addition to problems with the chemical stability of the silver image, albumen prints show severe structural problems. As albumen coatings age, a network of tiny fissures develops, dividing the layer into very small, unevenly shaped segments. A microscope must be used to see the fissures easily. In a well-preserved, unmounted albumen print, the fissures will usually not have opened and will be difficult to see. Examining a midtone area with raking light and about 20X magnification will show it most easily; internal reflections at the fissure surfaces make the fissures apparent. In poorly preserved, mounted prints, especially prints which have been thickly albumenized, the fissures will be somewhat visible, without magnification, and the microscope will reveal open cleavages, through which white paper fibers are visible around the edges of the segments of albumen, which frequently show "cupping" (i.e., the albumen coating pulls up at the edges forming a concave segment). Such a surface, showing cleavage and cupping, is seen in figure 1. The tough, protruding edges of the albumen segments easily catch against other surfaces and are sometimes scraped or pulled away, leaving behind a patch of rough, broken paper fibers. The effects of the fissuring and cleavage are an initial loss of the surface fineness and gloss of the print, a serious weakening of the print (the albumen layer provides much of the physical strength of the laminate), and eventual loss of segments of the image.

Albumen prints can be best identified by the presence of this network of fissures in the thin, shiny surface coating. These prints show the characteristic colors of gold-toned, printed-out silver images, ranging from yellow-browns and red-browns to purple-blacks. The highlights
Fig. 1. Secondary electron micrograph of the surface of an albumen print, showing fissuring, cleavage and cupping.

typically have a yellow cast, though later albumen prints usually have a pink tint, which is frequently the result of a pink dye added to the albumen coating to intensify the appearance of gold-toning.

The severity of the fissuring and cleavage appears most directly related to the thickness of the albumen layer. The only albumen prints I have seen completely without fissuring are prints from the 1850s and 1860s, so thinly coated that they have almost no gloss and are sometimes mistaken for salt prints. Yet a more thickly coated spot on such a print will show the usual fissuring and cleavage, and the amount and severity will depend on the thickness of the spot.

The severity of fissuring and cleavage also seems to be affected by the paper stock of the print—particularly the extent to which it expands and contracts upon wetting and drying. Indeed, for most albumen prints, the fissures are oriented in the predominant fiber direction of the
paper (i.e., in the machine direction). This dimensional orientation is frequently pronounced in mounted prints, which were attached in a wet state with water-based starch or gelatin adhesives to dry, rigid boards, and dried under weight, causing much tension in the dried prints. Such prints show cleavages oriented in parallel lines along the machine direction of the print paper, as though the dimension of greatest contraction opened the most fissures. The surface of such a print is shown in figure 2.

Another group of albumen prints shows just as decided a dimensional orientation ninety degrees to the machine direction (i.e., in the cross direction). These prints show an even more precise and regular arrangement of parallel, straight fissures than do the prints with machine-direction orientation. These prints are thickly albumenized, and date from about the late 1870s through the turn of the century. They have an unusually high gloss to their surfaces, and one suspects that the fracturing and fissuring of the albumen was caused in the original finishing of the prints by the use of rolling presses and burnishers. These presses, some of which were heated, consisted of two parallel rollers between which the prints were passed, rather like the wringer on an old-fashioned washing machine. Such treatment would have exerted a moving line of great pressure and tension in the print, capable of creating the fracture pattern one sees now.

There is much variability in the extent of fissuring and cleavage in mounted prints—it seems reasonable that the degree to which the albumen layer had aged before mounting would affect the extent of cleavage. Albumen prints which have been heated and desiccated badly, or which have been exposed to years of severely cycling humidities seem to show more severe fissuring and cleavage. The condition is not aided by rehumidifying, as is some brittleness of gelatin emulsions. It seems rather to be an aging process specific to albumen.

When an albumen print is wetted, the fissured layer swells along with the paper support, the cleavages fill in, and their cupped edges relax. As the print dries, the albumen and the support contract again, forming cleavages usually considerably wider than before. Their severity is very much affected by the drying method: the more even the drying and the more freely the print can move and contract as it dries, the less severe the cleavage, though it always seems worse than before the print was wetted. The largest increases in cleavage occur when wetted prints are dried under tension, such as occurs when a print is backed with a pasted support paper and dried on a drying board or other rigid support, or when a print is pasted to a rigid mount board and dried under weight.
Fig. 2. Light micrograph of the surface of an albumen print, showing typical, severe fissuring.
A second structural problem, connected to the fissuring/cleavage problem, is the strong tendency of albumen prints to curl. Unless restrained, unmounted albumen prints tend to curl into tightly rolled cylinders with the emulsion on the inside of the curve and the axis of the curve parallel to the machine direction of the paper. The thicker the albumen coating and the thinner the paper stock, the tighter the curl. After wetting and drying, prints tend to curl more and are harder to restrain. It seems likely that water treatment of aged albumen prints may cause or promote contraction or shrinkage of the albumen.

These two physical problems—the opening of fissures and increased curling with wetting and drying, and the strong curling tendency of unmounted prints—combine to obstruct most of the treatments one would like to do for these prints. Many albumen prints, for instance, are mounted on brittle, acidic, ground-wood-core boards which are frequently badly warped, torn or foxed; the prints need to be removed from such boards. Yet most albumen prints require mounting, especially the larger ones—the thin, weak paper provides very inadequate support for the tough, curling, brittle albumen layer—and presently one cannot safely remount most albumen prints on new boards. The traditional starch or gelatin adhesives require wet mounting, producing serious cleavages as the print dries. The only presently available alternative seems to be some type of heat-set adhesive—and the heat required for this is damaging to the albumen coating as well. This is an area that will require some inventiveness and much work. It may be that we shall have to abandon the historical mounting format altogether. In the meantime, small prints can be hinged into mats with mylar interleaving sheets tacked in position over them to restrain curling and movement when the mat is opened; or they can be placed in museum board/mylar packages quite successfully. Large prints are simply not safe hinged into mats, however; their tendency to curl and move is too great, and becomes less manageable with increased size. Museum board/mylar packages are safe (specifically, the print is hinged or attached with corner supports to a generously sized four-ply backing, which is then sleeved or encapsulated with mylar), but they do not lend themselves to framed display and interfere with direct visual access to the print surface, and for these reasons many institutions and collectors find them unacceptable.

A third, related structural problem is the difference in stiffness and strength between the albumen coating and paper support, which causes much functional brittleness. Most unmounted albumen prints show small, crescent-shaped "pinch" creases, caused when a print is picked
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up or handled without support. Such creases frequently form a new pattern of fissures in the albumen layer, with open fractures along stress lines; consequently, such creases cause permanent damage. Prints are very frequently creased in the machine direction of the paper, and when the albumen fissures are oriented identically, and with few paper fibers lying in the cross direction, such creases quickly become tears. Albumen prints need secure attachment to a rigid support—a mount, a hinged window mat, or a museum board backing in a sleeve—if creases, folds and tears are to be avoided. Sleeves without backings provide inadequate support for unmounted prints, which typically fall partially out of the sleeve at one end, ruffling and tearing the protruding edge.

Extremely gentle surface cleaning, using soft erasers and working under a microscope, is very useful for albumen prints in which the system of fissures has not yet opened. Once cleavages have opened, surface treatments may not be possible.

Collodion Prints

Collodion prints were in common use from the early 1890s to about 1910. They consist of a collodion (cellulose nitrate) layer containing the silver image, a gelatin-barium sulfate layer underlying the emulsion, and the paper base, which is usually similar to that used for albumen prints. Collodion paper was commercially prepared and did not require sensitization before use, as did albumen paper. Collodion prints usually have a very high gloss and a perfectly smooth surface; though matte-surfaced collodion papers were manufactured, they are much less common. The surface has a distinctly "plastic" look and feel. Collodion images were formed by printing out, and their image colors are similar to those of albumen prints.

Collodion prints were made during the period of transition from albumen to gelatin papers, and following the same turn-of-the-century aesthetic, they resemble both. Under the microscope they are easily differentiated, however, since they show no network of fissures, unlike albumen prints; and their surfaces, unlike gelatin prints, are relatively impermeable to water. If a small droplet of water is placed on the surface and watched, a gelatin print will be seen to absorb the droplet and swell, while a collodion print will neither absorb it nor swell—although the droplet may seep away through breaks in the collodion surface if a scratch, abrasion or other damage is present. In this case, one will see a darkening in immediately adjacent highlight areas as the baryta under-layer wets. The diphenyl-benzidine spot test, while destructive, is an extremely sensitive chemical test for nitrates, and is very useful as a
learning exercise in identification; the reaction of a tiny fragment of material will identify collodion prints and nitrate film bases as well. Less is known about the care of collodion prints than other types of silver prints. Fortunately, they show none of the radical instability of cellulose nitrate film bases. Many solvents soften, deform or dissolve collodion emulsions; any solvents being considered for treatments need to be thoroughly tested before use. Water-based treatments are problematic, since water has uneven, limited access to the emulsion. Abrasion, surface dirt and functional brittleness caused by differences in stiffness between the layers of the laminate are the major problems of collodion prints. They require rigid support and surface protection, which can be provided by museum board and mylar mats and packages.

**Gelatin Prints**

Gelatin printing materials were first introduced in the 1870s, became popular at the turn of the century, and have been the dominant printing material ever since. Their use spans enough time, with changing photographic fashions and technological developments, that many different types are commonly seen: gelatin emulsions designed for printing out or development have been coated on thin or thick paper stocks; gelatin print surfaces may be smooth or textured, and glossy or matte, in any combination or permutation; image colors range from yellow-browns, red-browns and purples (for printing out papers) to warm, cold or neutral blacks (for developing papers), and many other colors are possible with toning. Gelatin papers have frequently been designed to resemble other printing materials, especially albumen, collodion and platinum papers. They are not difficult to differentiate, however: under a microscope they show none of the fissuring found on albumen prints, and their swelling behavior with water separates them from collodion prints. They usually show some signs of silver image deterioration (fading, yellowing, surface “silvering”) which separates them from platinum prints. A miniaturized hydroxyproline test for gelatin can be used for confirmation of visual identifications while one is learning, but is unnecessary in practice.

Gelatin papers were commercially prepared, allowing their structure to be far more uniform and complex than the earlier, handmade materials. Most consist of four layers: the paper base, a gelatin-barium sulfate layer, the “emulsion” containing the image, and a protective gelatin supercoat. The paper bases of earlier gelatin prints were thin rag papers similar to those used for albumen papers; then thicker paper stocks were adopted to better support the thicker gelatin layers. Modern
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paper bases are high α-cellulose, wood-fiber papers containing additives to provide wet strength and water and chemical resistance. The first coating over the paper base is a layer of gelatin containing the white pigment, barium sulfate ("baryta"), along with gelatin hardeners, and sometimes optical brighteners or dyes; its function is to provide a smooth, opaque, white base over which a uniformly thick image layer can be coated. The light-sensitive layer, termed the "emulsion," is coated next. This is the functional layer of the paper and contains crystals of silver chloride and/or silver bromide of given sizes, forms and light sensitivities in a gelatin medium, along with gelatin hardeners and various additives to control sensitivity and developability under varying conditions. When the paper has been exposed, developed, fixed, washed, and dried, this layer contains tiny particles or tiny masses of filaments of metallic silver forming the image, contained in a gelatin matrix. The last layer is a protective coating of gelatin and hardeners, called the supercoat. A matte-surftaced paper is usually obtained by adding a "matting agent"—starch or colloidal silica—to this layer. There have been many variations on this four-layer structure: some papers have omitted the baryta layer, others have omitted the supercoat.9 A common modern variant is resin-coated paper; here the paper base is coated on both sides with polyethylene, and the emulsion and supercoat are coated over the polyethylene layer. Although this material washes more thoroughly in less time, providing better image stability against sulfiding from intrinsic contaminants, its use in archives should probably be avoided since "RC" paper is not a time-tested material. It has already shown emulsion oxidation problems, and should be expected to suffer worse emulsion bonding difficulties and structural problems than conventional papers.

Several major conservation problems are closely related to the laminate structure of gelatin papers. First, the expansion and contraction of the different layers with changes in humidity varies, with the emulsion and supercoat expanding the most, and the paper base the least. As a result, humidity changes cause curling and local plane deformations in unmounted prints. Most archivists are probably familiar with the sight of curled gelatin prints set out on a table, with the image on the inside of the curve in the winter when the heat is on and the humidity low; but when humidity is high, the same prints curl with the image on the outside of the curve. The amount of curl is primarily controlled by the ambient humidity and the thickness of the various layers.
Many gelatin prints are seriously damaged by fluctuating humidity. I sometimes see framed prints which have warped or deformed to the extent that they have contacted the framing glass and adhered to it. Local deformations in unframed prints are even more common. If the warps are recent, such deformations can be removed from unmounted prints by humidifying the print to relax it (or by wetting it completely if the warping is severe—but wetting involves several problems) and pressing it between photographic-grade blotters under a plate-glass weight. The print must afterward be stored flat in an environment of even humidity and restrained from curling, or deformations will recur. It is obviously essential that humidity be controlled in storage and use areas of photographic collections.

The problems of curling and deformation have traditionally been dealt with for gelatin prints by "dry mounting," that is, adhering the print to a rigid mount with a heat-set adhesive in a heated press. In an environment of uncontrolled humidity, however, dry mounting sometimes makes the problem worse—in effect, it adds a still less humidity-reactive layer on the less humidity-reactive side of the laminate, increasing the tension on the more reactive side, the emulsion. I have sometimes seen an emulsion under such tension, because of low humidity, that it had split its paper base in two layers, curling up with the baryta layer and the top half of its paper base, and separating from the lower half of the paper, which remained firmly dry mounted to the rigid mounting board. Much more common are dry-mounted prints stored at high humidity which have separated locally from their mounts in "bubbles" and patches. The emulsion must expand in response to elevated humidity, and the weakest bond between expanding and non-expanding layers will fail, usually at the dry mount tissue/mount interface. I should also mention that dry mounting has several other serious problems, including the difficulty, damage and expense of removing damaged mounts which have been attached by this method, and the damage to emulsion and image caused by the initial heat and pressure of the mount press, seen as color shifts in the image and probably as a factor contributing to eventual brittleness of the gelatin. In the 1960s, dry mounting was considered to be a wonderful archival mounting method for photographs generally, since it formed a barrier between the back of the photograph and the mount, isolating the photograph from "impurities" which might be migrating from the mount. Consequently, many prints of permanent value were dry mounted, including albumen and even salt prints. Today, we can see the irreparable damage caused by such treatment, especially the very severe
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fissuring and cleavages in albumen layers, and the darkening, embrittlement and scorching of salt prints—all effects of the heat required for dry mounting.

Dry mounting should be avoided for prints of permanent value, though it is an acceptable and useful mounting method for copy prints (i.e., institution-generated prints intended to be replaced, made from available archival negatives). If prints of value have been dry mounted to archival mount boards, it is important to treat the board as an integral part of the valuable object—it should be protected from handling damage and dirt, for instance.

A second problem caused by structure is the prints’ extreme vulnerability to damage from flexing and bending: even slight bending places the exterior layers under strong tensile and compressive stresses, cracking emulsions and creasing and breaking paper bases. Cracks in emulsions are irreparable and occur frequently; one sees them particularly often at the corners of prints and at the center of the right margin, where the thumbs of generations of right-handed researchers have picked up unsupported prints. The emulsion is usually the most brittle layer in the laminate; one frequently sees severely damaged emulsions, with multiple parallel straight, curved or branching lines of cracking, demonstrating the positions and directions of stresses and shocks. The housings devised for gelatin prints must provide rigid support to prevent bending; prints showing signs of emulsion brittleness such as cracking require particular protection.

Little is known about the optimal hardening of gelatin layers for maximum useful life; the effects of various hardeners over long periods of time is completely unstudied. Yet it seems likely that the embrittlement and cracking of emulsions is as frequent and serious a factor in prints’ longevity as image fading. Certainly “underhardened” emulsions stick to other surfaces and swell excessively when wetted; while “overhardenened” emulsions probably show increased brittleness. Though I know of no experimental work linking hardening and brittleness, it is reasonable that a relation exists. Formaldehyde, the hardener commonly called for in the restoration literature, has been shown to cause “afterhardening”—that is, the hardness of the treated emulsion continues to increase long after the treatment. Until more is known about the long-term effects of hardeners, their use (particularly the irreversible aldehydes) on irreplaceable prints seems foolish.

In the meantime, lack of a safe hardening system creates an obstacle to the treatment of some gelatin prints, since anytime a thick gelatin emulsion is wetted there is a chance that a swelling problem will result.
Uncontrolled swelling, which results in separation of the emulsion from the support around edges and excessive surface softness, can be predicted only partially by droplet tests. Prints should be wetted gradually with careful inspection, and only cold water treatments should be used. In general, wetting any silver print is a serious treatment with wide-ranging effects and should not be undertaken without specific need. Drying wetted gelatin prints poses its own difficulties since foreign matter—loose paper fibers, dirt particles and so forth—easily adheres to and embeds in the soft, sticky, swollen emulsion, deforming the surface. Gelatin prints must be dried almost completely before any drying/flattening method involving contact or weight can be used. The commonly recommended method of drying prints face down on fiberglass screens causes frequent surface damage; prints should dry face up after water droplets have been carefully wiped from their surfaces. Drying or flattening with heat should be avoided.

Dry gelatin emulsions are soft and easily scratched, and their vulnerability to abrasion varies widely depending on the particular gloss and smoothness of the surface, extent of hardening, and presence of matting agents. Some surface cleaning with erasers is possible on some gelatin prints, but it is very delicate work and should only be done under a microscope with raking light. Some solvent cleaning of the surface is useful, but the solvent must be used so sparingly as not to penetrate, or dissolved material previously confined to the surface will spread through the emulsion. The use of water-based solutions (especially containing ammonia, as has sometimes been recommended) should be avoided for surface cleaning, since emulsions swell and soften so easily with water that dissolved material is more likely to be absorbed into the emulsion than removed.

Gelatin prints need the same rigid support, restraint from curling and surface protection that albumen prints need, but providing it is quite a bit more difficult because of the softening and swelling gelatin emulsions undergo at elevated humidities, and because of their moldability in that state. The use of mylar sleeves and interleavings, ideal for other print types, may cause problems if used over gelatin prints in an environment without humidity control—glossy contact spots, called “ferreotyping,” and adhesion to the smooth, water-impermeable plastic surface can occur with the combined conditions of a soft or thick emulsion, elevated humidity and pressure. A variety of packaging modifications, with the mylar window lifted up away from the print surface, can be worked out. Interleaving sheets for matted prints of a smooth, nontamishing, nonacid tissue paper can be used. When humidity can
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be controlled at about 40 percent relative humidity, these difficulties with mylar sleeves disappear.

As proteins, gelatin and albumen coatings are vulnerable to mold attack. A storage environment with humidity above 65 percent invites mold growth; because of the possibility of locally trapping excessive moisture in impermeable packages, such as mylar sleeves and encapsulations, their use should be avoided when excessive humidities are possible.

Preservation Problems Relating to the Silver Image

Silver undergoes two major chemical reactions in normal, indoor environments: it oxidizes and it forms silver sulfide, the familiar tarnish layer one removes from silverware. The silver of photographic images occurs in very small particles and bundles of fine filaments, and has an extremely large surface area in relation to its mass, giving it much greater chemical reactivity than bulk silver. While the colloid matrix holding it in position protects the image silver somewhat from materials which oxidize and sulfide it, photographs have a long, consistent history of "fading." Their impermanence has been an enduring worry to photographers since the earliest days of the medium. In 1855 the Photographic Society of London established a committee to study the fading of photographs, which duly reported back to the membership much of what one is told today: that photographs should be very well washed after fixing in thiosulfate, that gold should be used for toning, and that prints should be stored in dry environments if fading is to be avoided. Until rather recently, an invariable claim of each new photographic printing process has been that it was "absolutely permanent." The products of all of these processes have faded, of course, to widely varying degrees; the degree of fading or other deterioration appears to depend on a very large number of individual and process-related variables, most of which cannot be determined, today, by archivists and conservators looking at the aged, faded prints in collections.

The deterioration of the silver image has been seriously studied, using modern techniques, for only one type of photographic material—microfilm. In the early 1960s it was discovered that a large proportion of microfilms (which had then been in archival use for only about thirty years) had formed spots of several distinct types in the outer layers of the reeled film. The problem was studied in the research laboratories of the film manufacturers and at the National Bureau of Standards, and the published results of these studies offer almost the only reliable information on the deterioration mechanisms of silver in photographic images.
After the spots had been carefully examined and characterized and had been reproduced under a wide variety of conditions, it was decided that they had been caused by the oxidation and reduction of image silver at preferred sites, and that the oxidizing and reducing agent had probably been a peroxide formed by the cardboard containers the films had been stored in, under conditions of elevated humidity. Migration of image silver while in an oxidized state was an important factor in spot formation: the distribution of silver in the spots showed either that silver had migrated from positions in the normal grain structure through the gelatin matrix, to form a changed, thickened grain structure with different optical properties (recrystallization), or to form new, colloidal-sized silver particles giving orange and red color effects; or that silver had migrated to the surface of the gelatin, where it formed a reflective surface "mirror." Silver sulfide formation did not appear to be an important causative factor. The spots were reproduced under laboratory conditions by exposing film to peroxides generated by a wide variety of common materials such as deteriorating paper (including the original microfilm cartons), rosin, turpentine, some oils, and hydrogen peroxide itself, as well as by storage in an oxygen atmosphere, and incubation in normal air at raised humidities and temperatures. Hydrogen sulfide, ammonia and sulfur dioxide, common in polluted air, promoted the attack of atmospheric oxygen on silver images; and ozone and its derivatives, including the nitric oxides it generates in smog, paint fumes, some plastics, and bleached wood, were all cited as oxidants and sources of oxidants commonly present in archive storage areas and likely causes of spot formation.

Oxidation of silver photographic images has a distinct appearance: when test strips of silver print papers are exposed to hydrogen peroxide vapors in a closed jar, the first effect observed is a shift in the hue of the image toward yellow, seen in areas of minimum silver density (highlights). As the image oxidizes further, spots form in middle silver density areas (midtones) where the reaction occurs unevenly, and the highlights fade to pale yellow tones. Then midtones fade evenly and shadow areas show color changes toward red tones, spot formation and finally uniform fading, leaving the image in pale gradations of yellow and brown. This is true of albumen and salt prints as well as gelatin prints. Using similarly prepared sets of prints, gelatin prints show early hue shifts first, salt prints complete fading first, gelatin prints complete fading last, and albumen prints are intermediate. Heavily gold-toned prints gain a pink hue in highlight areas and fade much less than lightly gold-toned or untoned prints. When removed from the test atmosphere,
the oxidized prints show very noticeable light sensitivity, darkening considerably with light exposure.

Outside the controlled atmosphere of the dessicator jar, oxidation rarely occurs without some sulfiding, and takes place much more slowly, less uniformly and less completely. One sees the characteristic shift in image hue toward yellow in the highlight areas first, as well as density losses. In badly oxidized prints, the highlights will have faded to pale yellow tones and the midtones will have a grainy, mottled appearance, giving a two-color effect—gray or brown grains against a light yellow background, or vice versa. This pattern is typical of salt, albumen, collodion, and gelatin prints. A further, very conspicuous symptom is the formation of a surface layer of silver, a silver mirror, which is most obvious in the deepest shadow areas where the largest amount of silver is located. Mirror formation is most pronounced in gelatin prints where the conditions of elevated humidity which commonly promote oxidation also swell the gelatin matrix, aiding silver migration. It occurs in albumen prints also, but only to a small extent in salt prints, and only if the print paper is heavily sized. Oxidation damages typically occur much more strongly at the edges of prints, which are exposed to increased flow of moist, polluted air by most storage systems. Strong fading, yellowing and mirror formation, which are sharply limited to edges, are frequently seen in tightly closing albums of albumen prints; if the pages of such an album are warped, forming a gap of air along one edge, the prints will be found to have increased oxidation damage in the gap area.

To minimize oxidation of silver in photographic collections, the conditions specified in the American National Standard PH5.4-1970 for the storage of archival microfilm should be duplicated as closely as possible. The relative humidity should not exceed 40 percent—this is the most important single condition. For general photographic collections, a small range just under 40 percent is desirable, since the brittleness of the colloid layers and paper bases of prints increases with lowered humidity; the importance of providing rigid support for prints becomes correspondingly greater. The temperature should not exceed 70°F and should be even. The air should be filtered against oxidants and pollutants. Wooden cabinets and frames should be replaced with metal ones. Deteriorating paper and cardboard storage materials should be replaced with clean, buffered, “archival” papers. Sometimes the most deteriorated papers in a collection will be the mounts of albumen prints, for which a satisfactory remounting method has yet to be developed; these mounts should never be stacked on top of other prints—a barrier of

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mylar or some other material should always be present as an interleaving.

The transformation of the silver image to silver sulfide is the second major deterioration process. Silver sulfide is one of the most insoluble and stable of the silver salts, forming readily whenever oxidized silver contacts a source of sulfide. It is therefore closely connected with silver oxidation in photographic images. Silver sulfide concentration typically increases along edges of prints where oxidation has occurred, and surface mirrors are usually composed of mixed silver and silver sulfide. Because of its ease of formation and stability, as well as the widespread availability of sulfides in polluted air, silver sulfide is the natural end product of a variety of image deterioration processes.

To minimize sulfiding in photographic collections, oxidation must be minimized and the availability of sources of active sulfur must be reduced. Storage and matting materials containing active sulfur must be rigorously avoided. This requirement is more difficult than it appears, since, in general, the manufacturers of archival storage materials have not concerned themselves with the requirements of photographic materials. It should be understood that the word archival as applied to storage materials means only "nonacid"—it does not imply freedom from peroxide sources or active sulfur sources, though these are probably more critical requirements for the storage of photographic materials than is neutral pH. Peroxide-forming materials may perhaps be avoided by using paper from an adequately clean pulp—most archival papers should satisfy that requirement. But the presence of active sulfur must be tested for, using a silver tarnishing test such as that described by Collings and Young.16 Surprising number of archival materials contain active sulfur, including some art papers, interleaving sheets, polyvinyl acetate emulsion adhesives, and Japanese hinging and repair papers. In my own tests, Permalife bond paper, unmodified cooked starch paste, Elvace 1874 PVA adhesive, the heavy, gray buffered Hollinger paper used for negative envelopes, and most nonacid rag museum boards have given negative results; but such a small amount of sulfur causes such large visual effects that its presence as a contaminant rather than a constituent must be considered. Probably each lot of material ordered should be tested before use.

Unfortunately, a major source of active sulfur for sulfide formation is frequently contained in photographs themselves. Thiosulfate, the silver complexer used as "fixer" since the early days of photography, itself forms a layer of silver sulfide on the silver image particles, either during fixation or immediately thereafter. Residual thiosulfate, left
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behind in the print after washing, will continue to react with image silver, forming silver sulfide until either the thiosulfate or the silver is exhausted. This is certainly as true for albumen and salt prints as for gelatin prints, but because of the thickness and retentiveness of gelatin paper layers and the formulation of fixing solutions, thiosulfate retention is, in practical terms, a problem primarily of gelatin prints.

The problem of thiosulfate removal divides into two subproblems. The first is thiosulfate closely associated with silver: thiosulfate dissolves silver salts in the fixing bath by forming three successive complexes with silver ions. The first complex is relatively insoluble; the second and third have increased solubilities, allowing these complexes to diffuse away through the gelatin and to be removed by washing, but they can only form when plenty of excess thiosulfate is present. If a print is fixed in a less-than-fresh thiosulfate bath, much of the first insoluble complex will remain in the print, where it will eventually break down to silver sulfide. This complex is distributed throughout the image, the amount depending largely on the exhaustion of the fixing bath, and the silver it contains is unrelated to the image; when it breaks down it is seen as the yellowing of highlights and margins—areas where little or no silver should be present. This problem is easily prevented in the processing of new prints by using a succession of two or even three fixing baths and replacing them methodically. The problem can be cured in previously processed prints if they are properly fixed and washed before significant breakdown has occurred; once silver sulfide has formed, no amount of fixing and washing is useful.

The second problem is thiosulfate ion which has not been removed by washing. Thiosulfate is strongly retained by the gelatin of the emulsion and baryta layers as well as the paper base—the more so as it is usually present with an alum hardener in an acid solution—and it is extremely resistant to washing out. This thiosulfate breaks down through a series of polythionates to form silver sulfide as it contacts oxidized image silver, causing visually apparent fading and yellowing of the image. A print which retains thiosulfate will typically fade in highlights and midtones, but the clear highlights and margins will retain their whiteness. This problem, also, is not difficult to prevent in processing, if one accepts that specific procedures must be followed (wash times of at least one an hour, in a washer of efficient design, using water of 70-75°F, after proper fixing procedures—minimum-length, fresh, multiple baths with plenty of agitation—and the use of a "washing aid"—a salt solution which helps remove thiosulfate by ion exchange; Kodak Hypo-Clearing Agent is the commonest example).
The problem can also be corrected for older prints by careful rewashing procedures, though no older prints should be expected to withstand the efficient but rough washing methods used for new prints; much gentler methods must be devised. The treatment must be done before a significant amount of the image has been converted to silver sulfide.

How can prints which contain unreacted residual silver-thiosulfate complex or thiosulfate be identified so that they can be treated? There are only two possible tests applicable to prints which have not been recently processed; they are old, qualitative spot tests, one for residual silver (the silver-thiosulfate complex) and one for residual thiosulfate. These tests are recommended throughout the photographic conservation/restoration literature and in generations of Kodak guides to black-and-white processing methods, as "Kodak Residual Silver Test Solution ST-1" and "Kodak Hypo Test Solution HT-2." Unfortunately, there are major problems in their use. They can only rarely be used for prints of any value since they are stain tests—the stain each forms is unremovable silver sulfide, identical to the naturally occurring material which the tests are intended to estimate. (The residual silver test, composed of sodium sulfide, provides free sulfide to react with any silver ions present; the residual hypo test, an acidified silver nitrate solution, provides free silver to react with any thiosulfate, thionate or sulfide ions present.) One is directed to apply the test solution to a margin or highlight area of a print since a white area is needed to see and evaluate the stain adequately. Few older prints retain their margins; many do not even have clear highlight areas in the pictorial space. Moreover, the test droplet cannot be too small, since plenty of solution must be available to diffuse through the emulsion to get repeatable results. Whatever the result of the test, one is obliged to wash the print very well after testing since the test solutions introduce materials that must be completely removed if the print is to have acceptable storage stability: silver nitrate forms purple and black stains with light exposure, while sodium sulfide is one of the worst possible contaminants of silver images. There are problems with the accuracy of the test as well. For example, the residual thiosulfate test is necessarily applied to highlights, but much more thiosulfate is retained in areas of high silver concentration—shadows. Margins may be expected to be significantly better fixed and washed than the centers of prints, since most processing/washing systems pass more solution over edges than centers of prints. Moreover, nonuniform fading from local variations in residual chemicals is often seen in older prints and may be considered characteristic of very inadequate fixing and washing methods; it is impossible to
be certain that test results in one area will hold true for other areas of a
print. The effect of retention of silver and thiosulfate by the baryta layer
and paper is not assessed by the spot tests, but is known to be a large
factor in the stability of prints. Finally, though the tests are routinely
recommended in the photographic restoration literature for application
to older prints, no attempt has been made to interpret the test results for
older print materials: what, for instance, constitutes an acceptable stain
level for the residual silver test? Clearly a correlation between test results
on specific types of materials and behavior in accelerated aging tests is
needed before one can move with any certainty from test results to
treatment recommendations.

One area of exception, where the residual silver test is adequate and
needed, is the identification of prints which have been processed by
stabilization, a fast-access processing method which chemically stabi-
lizes nonimage silver salts against light reduction, instead of removing
them. A stabilized print gives a dark stain with even a very small droplet
of sodium sulfide reagent. Such a print should be refixed and thorou-
guishly washed before being added to a print collection, and any materials it
was packaged in should be discarded. Please note that both the sodium
sulfide and the silver nitrate reagent solutions are unstable and must be
mixed fresh for use; a deteriorated sodium sulfide solution will give a
false negative test result—a solution more than a week old should be
tested against a print known to have been processed by stabilization.

Can one make useful judgments about residual chemicals based on
a visual examination of prints? This is possible only to the very unsatis-
factory extent that once the residual materials break down, forming
silver sulfide, their effect becomes visible. But one cannot tell whether a
process has gone to completion or whether one which shows no symp-
toms will occur in the future. The rate at which residual chemistry
breaks down to silver sulfide, producing visible results, is largely con-
trolled by humidity, increasing greatly with increased humidity—as
one would expect; increased humidity increases the mobility of thiosul-
fate and thionates in the swollen emulsion, promotes the oxidation of
the silver image and the migration of oxidized silver, and results in
increased formation of silver sulfide. (Newly acquired gelatin prints for
which humidity conditions are likely to have increased should probably
be inspected with particular care and frequency.)

My own experience has been largely with nineteenth- and early
twentieth-century fine art photographs, where the application of stain-
ing, contaminating or destructive tests is impossible. I have come to
regard a certain amount of fading, yellowing and mirror formation as
normal among older photographs; particularly in albumen prints, such conditions seem usual and generally stable (i.e., not progressing perceptibly). With a few notable exceptions, the photographers whose prints are found in fine art collections were extremely competent workers whose toning, fixing and washing methods were excellent; indeed, many were the processing experts and manual-writers of their day. In the absence of accurate, usable tests, with the current undeveloped state of photographic conservation knowledge and practice, and given the importance of the individual prints as art and history objects and as evidence of process and technology, it has seemed absurd to undertake treatments of no proven need or benefit for a particular print, which may alter the state or distribution of image silver and obstruct the efficacy of future treatments. Refixing a print, for example, with much oxidized but not sulfided image silver (and such prints are not uncommon, their condition indicated by a slight tendency of the image to print out as the print is being examined), would have the effect of removing oxidized silver from the image, losing the possibility of reducing it back to its proper state by a treatment to be devised in the future. Present treatments are so undeveloped that it seems foolish to utilize any that would tend to obstruct future possibilities.

The situation may be different in other types of collections: local history collections, for instance, may consist primarily of recent silver-gelatin prints which have come from sources notorious for "quick-and-dirty" processing—newspaper archives, for example—and which have small individual values as original objects. In such a collection it might be reasonable to "reprocess" much of the collection, if one could know that the treatment was necessary and effective. (Again, however, the first step is control of the environment—lower humidity will decrease sulfiding of poorly processed prints as well as oxidation of all prints.) The photographic restoration literature directs one to reprocess prints by refixing, treating in a washing aid (a salt solution, usually buffered sodium sulfite—Kodak Hypo-Clearing Agent, for example), treating in a hypo-eliminating solution (a hydrogen peroxide and ammonia bath which functions by oxidizing thiosulfate to sulfate), and washing, exactly as though the prints were new prints being "archivally" processed.¹⁸

To obtain some indication of the extent of residual chemistry in a "worst possible case" collection, and the effectiveness of corrective treatments, I recently tested sixty silver-gelatin snapshots processed by photofinishers, all dated and evenly divided among the 1920s, 1930s and 1940s. They were chosen to represent a range of materials and condi-
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tions. All had clear margins on which the ST-1 and HT-2 tests were performed.

Few of the prints showed the presence of residual silver: though the test solution caused varying slight stains on all prints (the solution always causes some stain—the test is called positive if the stain is darker than "a barely visible cream tint"19), after the prints had been washed (to remove colored components of the stain other than insoluble silver sulfide) and dried, no stain at all could be seen on thirty-six of the prints, a barely perceptible stain was present on seventeen, and seven showed easily visible light yellow stains. When strips of the positive-testing prints were fixed, hypo-cleared and washed, and then retested, no perceptible stain was formed. In this group of prints, aged forty to sixty years, the presence of residual silver from the silver-thiosulfate complex was slight, and could have caused significant staining in only seven prints. It is likely that the complex had already broken down fairly completely in most of the prints. Refixing was effective in reducing the response of those prints which had formed test stains.

In contrast, nearly all the prints showed significant amounts of residual thiosulfate to be present (90 percent), and some prints stained very deeply (patch #3 and higher on the Kodak Hypo Estimator20). Strips of the prints were given various treatments and retested: washing alone was very effective in reducing the response of prints to the test (bringing subsequent tests to below patch #1 on the Hypo Estimator). Hypo-clearing and washing was about as effective as washing alone. Refixing, hypo-clearing and washing was slightly more effective than washing alone for most prints, but for some prints the stain was increased (i.e., new hypo had been introduced and retained). Refixing, hypo-clearing, hypo-eliminating, and washing was consistently the most effective at reducing the stain level (though the actual difference in stains was slight), but hypo-elimination also appeared to bleach the image noticeably in highlight areas of many prints, and swelled the gelatin as well, promoting some "frilling" (separation of the emulsion from the base at the edges) and physical damage. All washes in this experiment were done by changing the water every five minutes for an hour, draining the prints completely between baths, and agitating the trays gently. The fixing solution was a plain hypo bath of 100 grams sodium thiosulfate (pentahydrate) per liter of solution, divided into two successive baths. The hypo-clearing and hypo-eliminating baths were the standard solutions.

These results may provide some indication that refixing may be less necessary than assumed, and washing more effective than hoped. But it
is only a first step—clearly some work is needed to modify the procedure for older prints, maximizing the benefits and minimizing the damages of the treatment, as well as improving the testing methods, before reprocessing—the simplest of the silver treatments—can be considered recommendable for application to collections.

Some types of treatment are presently appropriate—emergency treatments, for instance. A gelatin print which is yellowing and fading before one’s eyes probably should be refixed and thoroughly washed. (But it should also be stored at lower humidity; and salt prints and all experimental prints are another matter—here, dark, low-humidity storage, expert advice, and perhaps second opinions are in order.) An albumen print severely endangered by its mount, which is perhaps badly torn, should be removed from that mount (and given a temporary protective package or mat). There are certainly many treatments needed immediately, as well as some treatments not likely to be soon improved, such as mending tears, removing tape residues and cleaning surfaces. But it is certainly far too early for institutions to undertake massive or routine treatments of their photographic collections.

In the foregoing discussion of treatments, I have been considering treatment options per se; I have not considered who should perform them. In my own work, I see the results of much ill-conceived, damaging treatment, performed primarily by photographers (who have been the traditional “restorers” of photographs) and framers, but increasingly by paper conservators as well. Because of the chemical and structural complexity of the materials and the new and therefore experimental nature of the field (that there exists no established set of “good” treatments which one can draw on as needed), treatments should be very conservative and should be left to people who are equipped to understand the chemical and physical consequences of the treatments, as well as experienced in the treatment of photographs. Especially complete records of treatments should be kept.

Photographic materials are the products of a far more complex technology than are most types of successfully preserved art and record materials; it is only reasonable that a more complex technology is needed to study them and to develop and evaluate conservation processes for their care. It seems unlikely that the field can improve in the depth of understanding of problems and the development of appropriate treatments beyond an initial “easy” stage unless major scientific aid can be found. Therefore, an additional essential line of action for archivists and curators in the conscientious care of their collections—along with environmental control and proper preparation of the collec-
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tion for handling—might be the very strong encouragement of
conservation research facilities, such as that at the Library of Congress,
to include the problems of photographic materials in their present
programs of investigation.

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11. The current situation is not an improvement: manufacturers make no claims for
permanence any longer, even for their microfilms; and the public is so naive or unconcerned
with permanence that portrait and wedding photographers routinely use color
negative-positive materials, the least stable of all photographic materials, to produce what
were once assumed to be permanent family records. In the last few months, a color dye film
material has been introduced for making black-and-white negatives, and the author of a
magazine review concludes that "there are strong reasons for suspecting that a chromo-
genic b&w negative [the color dye negative] will probably last very nearly as long as its
silver cousins." (Bob Schwalberg. "Revolution in Black-and-White." Popular Photogra-
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phy 88(April 1981):130.) His "strong reasons" reduce to a basic confusion between the fine points of testing the comparative fading rates of various color materials, and the unavoidable fact that chromogenic dye images fade with much greater ease than comparable silver images. Someone who chooses to use such dye materials to make black-and-white negatives gives up long-term stability, and, as usual, his choice is based on less than complete information. When such materials reach archives, they will have to be copied.


17. Preservation of Photographs, pp. 16-17.


19. Preservation of Photographs, p. 16.

20. The Kodak Hypo Estimator is a set of four color patches for rough estimation of the adequacy of washing in a variety of new materials, when used with the HT-2 reagent.
Preservation and Restoration of Authenticity in Sound Recordings—To Standards

WALTER L. WELCH

The July 1972 issue of Library Trends was entitled "Trends in Archival and Reference Collections of Recorded Sound." Appropriately, the titles of the articles reflected the particular concerns of the nine authors from as many institutions, including those of the issue editor, Gordon Stevenson. The article which I contributed for that issue was "Preservation and Restoration of Authenticity in Sound Recordings,"1 to which I now add two important words: "To Standards." I will address myself to Edison's struggle to establish such standards—those used in re-recording his own discs to cylinders.

Actually, this subject has been much more trendy than the author realized in 1972. More objectives were outlined than conclusions reached. A book was written and published recently on the same subject, similarly titled,2 but omitting the work authenticity. The book covers many areas very well—so well, in fact, that I suggest it is a book all archival and reference collections should have, provided it is read critically. Why? Our first clue is in the elimination of the word authenticity. If ever there was a trend that is sorely needed, in or out of archives, it is a return toward truth in audio!

In trying to peer into the future, we may discover many major and minor trends. Melville Clark, Syracuse music merchant and inventor of the Clark Irish Harp, collaborated with me in establishing what we agreed was a necessary trend toward perserving the old acoustical

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recordings at a time when most people were replacing them with the
new Orthophonic Victor or Viva-Tonal Columbia records. Clark, a past
president of the National Association of Music Merchants, wrote arti-
cles for one or two trade papers about the urgent need to preserve some of
the old recordings. Some time later, one small record producer not only
expressed an interest, but offered to send metal molds for deposit when
they were of no further commercial use. That was in 1930, and as Edison
had only the year before left the field to his competitors, few of us really
believed that diamond styli would ever come back as the universal
medium for tracing all phonograph records produced.

It was Bell Laboratory engineers Maxfield and Harrison, who had
applied their theories of matched impedance to the successful electrifi-
cation of Eldridge R. Johnson's acoustical lateral disc Victrola only a
few years before, who were now, in a remarkable reversal, claiming that
vertical recording was superior to lateral, and that they had perfected a
new system which proved it! This process was later used for Muzak
(which now uses tape), and for producing the World Broadcasting
Company series of transcriptions. For the first time in a number of years,
diamond was again used for playback, but only for radio industry
purposes. 3

Meanwhile, acoustical Orthophonic Victrolas and Columbia Viva-
Tonal phonographs were still being made, as well as some others
designed for use with steel needles—soft, medium, loud, or extra-loud.
All of the electric pickups of the 1930s also used impermanent styli.
Tungsten styli were also available from soft to loud. There were gold-
plated steel and bronze needles, thorn and cacti needles, and dozens of
others. Automatic record players made their appearance both for homes
and as jukeboxes, and more permanent styli were desperately needed.
Also, it soon became evident that the movement toward all-electric
reproduction was more than a trend—it was inevitable!

Despite the production problems Edison had encountered in 1912
with the Diamond Discs, he and his associates had persisted. By 1915
enough of the problems had been surmounted that Edison finally
permitted what is considered to have been the first publicly conducted
tone test. Metropolitan Opera artist Anna Case sang in comparison with
her own voice as reproduced by the new Official Laboratory Model
Phonograph before guests in the library of the Edison Laboratory at
West Orange, New Jersey. The listeners, unable to distinguish any
differences, were understandably amazed. The recorded voice of Anna
Case was then transmitted by wire to San Francisco to Edison, who was
being honored at the inauguration of regular cross-country telephony
as an event of the Panama-Pacific International Exposition.
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Edison Tone-Test Publicity Photograph featuring Arthur Middleton and Karl Jorn
That was the first of many tone tests arranged by Thomas A. Edison, Inc. from 1915 to 1927, which ceased when electrification of the Edison methods began. Tone tests were conducted in music rooms and auditoriums large and small from coast to coast. In many instances the lights would go out, and the audience would wonder whether or not the singer was the one singing; when the lights would come on again, the singer would have vanished!

In retrospect, the Bell engineers, through conquering Johnson's Victor Gramophonic world empire first and ignoring Edison’s accomplishments, lost the valuable and ultimate test of direct comparison. Compton Mackenzie, founder of The Gramophone, later lamented this lack of a standard instrument with tone-testing capabilities in an editorial comment during a time when there were endless arguments over the merits of various recording methods then being employed.  

Looking back from 1981, we must concede that even the lateral disc mono LP records produced since 1951 by so many companies and in so many countries have been relegated to all but complete obsolescence by the industry and its advertising, just as surely as the so-called 78s and vertical-cut cylinders and discs are now totally out of use for either entertainment or education.

Undeniably, internecine competition in the record industry has produced great profits. However, the advertising slogan of the pioneers, "now recorded for posterity," has proven to be a vast deception in regard to access—by teachers, scholars or the public—to the greater part of the recorded voices of the past or historic performance of the great artists.

In inventing the phonograph, Edison did not have to make a choice between cylinder, disc or tape. All these forms of moving surface were already in the arts for a multitude of purposes, and therefore in 1877, as now, were not patentable features. In experiments he had used all three; an example is an experimental disc model with clock-spring motors in 1873. The reason he chose to develop the cylinder first is that it had the highly desirable attribute of uniform surface speed under both cutting and reproducing styli from beginning to end of a recording of any length. The lack of this uniform speed is a fundamental fault in present-day phono stereo systems, just as it was in Edison's disc phonograph.

In the stress of trying to catch up with Eldridge R. Johnson's great commercial success in creating a worldwide Victor Gramophone empire, Edison and his associates went along with Johnson’s constant-rpm system utilizing ten-inch and twelve-inch discs which Johnson and his foreign Gramophone allies had settled upon as most suitable. Constant-rpm, then as now, requires built-in compensatory measures.
in both recording and reproducing, whether acoustically or electrically. This is because the outer turns of a ten- or twelve-inch disc are traveling much faster than the inner turns near the label. C.S. Tainter, an associate of Alexander Graham Bell, received a patent on a constant-groove-speed cutting lathe even before Bell’s Gramophone Company entered into the disc competition, but it was never used. Also, in 1925, an English inventor made a controller for gramophones so that constant groove speed could be used on them. This had modest commercial success, failing largely from lack of artists and capital.

Although the Edison Laboratories concentrated to produce an ideal new disc, work was not neglected on improving the cylinders as well. First, Wax Amberols and the later Blue Amberols with a beautifully smooth surface were perfected and put on the market. A problem to be overcome in producing the discs was the need for a flat, hard and unyielding material for both surface and core. Without the experience of modern plastics technology to guide them—for they were truly among the earliest pioneers—the Edison men determined that the surface should remain flat and durable when bonded to a specially prepared core. (This procedure corresponded in principle with the way the Blue Amberol celluloid surface was related to the supporting plaster-of-paris cylinder cores, though celluloid was not deemed hard and unyielding enough for the discs.) Edison, himself a chemist, brought in some other experts and developed a much harder material for disc surfaces. A sophisticated process, involving the polymerization of a phenolic resin, produced a thermo-setting plastic in liquid form which he called “condensite varnish.” The core was composed of wood-flour, resins, lampblack and a bituminous binder, which under heat and pressure was formed into a quarter-inch-thick blank somewhat larger than the finished disc size, to which it was trimmed during final processing.

To receive the recording impressions from the molds, the core surfaces were coated with a suitable thickness of the condensite varnish. Unlike the way Victor records were pressed (that is, by squeezing a semimolten shellac, powdered limestone and carbon-black “biscuit” between two molds with great pressure), the Edison disc molds by comparison were gently pressed onto the condensite surface, which required heat but much less pressure. Naturally, this extended the useful life of the molds and prevented impairment of delicate overtones, so very important to the tone tests. Because of this method, the finished discs were called “prints” in the laboratory literature. Despite production difficulties, the Edison discs produced this way wore very well and did
not demodulate measurably, despite the great tracking pressures imposed for acoustical reproduction. Our current vinyl stereo discs do demodulate, although they are only partially vertical. (Some authorities recommend that vinyl discs rest twenty-four hours between playings to minimize the extent of wear somewhat.)

As if to dramatize the importance of the technical difference in materials, Edison used self-labels created by photographic means and imprinted onto the condensite varnish at the same time as the spiral groove. Photographic halftones were used at first as background, with brightly reflected lettering, Edison's signature, and lineal outlines for such decorative features as two shields—one for Edison's photograph and the other for typeset patent information. These features varied over about a decade. They were beautiful, but difficult to read!

In view of his attention to details as well as to fundamentals, it is difficult to understand why Edison did not insist that constant groove speed should be a requirement for the new system. Besides this mistake, if it may be so deemed, Edison had other problems the first few years with the new discs. They began very soon, with the peeling away of the condensite surface around the circumference due to unequal shrinkage of surface and core. Sometimes the surface would split through the grooves. Essential chemicals imported from Germany became unavailable after the Allied blockade of that country in 1914. One chemical, phenol (carbolic acid), was an essential in the production of condensite. Edison invented a synthetic equivalent and provided it to all users after the supply of phenol was shut off, but another finishing chemical proved much more difficult to duplicate, resulting in surface noise problems. The earlier records had a playing surface that was superbly smooth; unfortunately, most of them also had the problems of peeling and splitting, so relatively few are left. Meanwhile, Edison was spending much time in Washington as chairman of the Naval Research Board, dealing directly with the submarine problem.

During the war years, surface noise was a problem with all disc records, especially in the United States, for virgin shellac—imported from India and essential for producing smooth lateral disc records—also became difficult to obtain. This factor may have been partially responsible for increased sales of the smoother Blue Amberol cylinders and the Amberola phonographs. Sometimes the cylinders were smoother than the issued discs of the same performances! In researching the best ways to reduce the surface noise in re-recording from the discs, we have discovered that it is usually most troublesome in the first half-inch of stylus travel normal to the spiral. From this, it is obvious
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why none of the twelve-inch waxes made from 1910 to 1912 were ever processed by Thomas A. Edison, Inc. for commercial use as discs.

Whether or not the needed chemical was available after the war, Paul Kasakov, chemist in charge of record production for Edison, perfected in 1920 a new high-speed plating process. Moreover, the record surfaces were improved markedly. As a result, twelve-inch sample discs of new issues, with excerpts dubbed from each selection, were prepared for distribution to buyers through Edison outlets.

In late 1926, the Edison company made a great tactical mistake in the announcement of Edison Long Playing Records and Long Playing Phonographs in answer to the challenge of the Orthophonic Victrola. The process was an excellent one, except that the playback stylus, although a diamond, was shaped by an inadequate, expedient means. The result was that the boat-shaped stylus would often break through the tiny margin of land between the 450-groove-turn/inch discs, and thereafter would repeat.

Moreover, the Edison catalog did not have complete symphonies or Broadway shows (as did Victor and Columbia) for which longer-playing records would be so desirable. The Edison LP promotion was a flop. Twenty years later, the mini-groove LPs of Victor and the 45s of Columbia used sapphire styli.

Even with 80 rpm and the standard Edison record (now bearing white labels), some of the most amazingly natural records were recorded electrically for reproduction using the Edison Official Laboratory Model Phonograph as a standard. Even though a special louder reproducer called the Edisonic was made available, it is evident that Edison insisted that the 1915 standard be adhered to as far as the vertical discs were concerned.

Edison's associates later asked for, and received, permission to produce a series of ten-inch and twelve-inch needle-type records for which packets of Edison steel needles were furnished. The objective was to produce additional income by selling needle-type records, recorded at the same time as the diamond discs, to the owners of the new Victor, Columbia and Brunswick machines available prior to 1929. Unfortunately, Edison found that despite excellent quality of sound, the new records made of shellac were very prone to warp.

Edison had had all he could take, and in the fall of 1929, as chairman of the board, he ordered that all manufacture and sale of home phonographs and records cease. Thus far, the only recording system which provided a standard playback instrument over a number of years was the Edison Diamond Disc process. It is also singular in having
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passed the ultimate test of successful public comparisons of commercial discs with the live artists. It is time to combine this kind of idealism with our marvelous technology and begin again to deliver truth in audio!

Note: Mr. Welch's chief consultant on matters of physics and chemistry is Dr. Robert J. Conan, Jr., Professor of Physical Chemistry, LeMoyne College, Syracuse, New York.
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Standards for Speakers

WILLIAM D. STORM

In June 1979 I presented a paper to the International Association of Sound Archives’ Annual Conference in Salzburg, Austria. The subject was the establishment of standards for re-recording processes. This topic was again presented in May 1980 in Ottawa, Canada, to the Annual Conference of the Association for Recorded Sound Collections. The response to these presentations made it clear that concepts fundamental to sound reproduction fidelity were of interest to members. But equally clear was the fact that the technical orientation of the members was extremely diverse.

Many persons charged with the care of record collections have as primary interests the musical content, or discography. Others concentrate on re-recording processes and sound-reproducing systems. In either case, listening to recordings requires the use of a playback system. A proper sound system therefore becomes a critical consideration for all audio archivists, regardless of their personal interest in technology.

This presents us with the problem that we now have technically- and nontechnically-oriented people all trying to decide what to use for a reproducing system in an archive. It would seem in the best interest of all parties concerned to open a dialogue regarding sound reproduction fidelity.

A discussion of all the factors influencing sound fidelity would be impractical in this presentation. Therefore, this paper is limited to one of the most controversial areas of concern: speaker selection. Hardware, William D. Storm is Assistant Director, Syracuse University Audio Archives and Re-recording Laboratory, Syracuse, New York.
such as amplifiers, preamplifiers, cartridges, turntables, etc., will be assumed a constant and excluded from the scope of this paper.

Guidelines for Speaker Choice

The first goal of any archivist is preservation—i.e., to keep intact the original item. A curator who would paint a red hat on the Mona Lisa or cut off part of the painting to suit his own tastes would surely be considered criminal. Similar defacements nonetheless occur daily in the field of audio preservation, due to a lack of standards for the reproduction of the sound. Speaker systems are a main contributor to this problem. There is no agreed-upon standard for speakers in an archive; consequently, "red hats" are painted on the sound, and some parts are cut off and distorted, in a large part due to the idiosyncrasies of the speaker. If archives are to avoid this distortion of the truth, an examination of the way speakers should be selected for an audio archive seems to be in order.

The speaker is still considered the weakest link in the reproducing chain, and consequently competition in solving this problem thrives, each manufacturer making claims of superiority. A visit to any audio showroom quickly reveals the complexity of the problem. The consumer is confronted with rooms filled with different speakers. Narrowing the choice can be as frustrating for the audiophile as it is for the novice.

The consumer can—and usually does—make his decision on a subjective basis. Personal preference is the guide. After all, saving sound for posterity is not the normal concern. With so many speakers to choose from, he may like the sound of one speaker for some musical selections and yet prefer a different speaker for other music. It is not unusual to see buyers going from room to room and store to store, trying to decide what speaker to purchase. Nor is it unusual to see the same person repeat this pattern year after year for as long as money and enthusiasm hold out. This subjective approach, however, should not be used by the audio archivist.

The archivist should be objective. Personal taste in a speaker should not take precedence over the ability of the speaker to produce the full spectrum of sound on a recording in an unbiased fashion. Speaker selection for an archive should be governed by the fundamental rule that the sound emanating from the speaker (acoustic output of speaker) is equivalent to the signal fed into the speaker (electrical input to speaker), or simply, acoustic output equals electrical input.

Very few speakers approach that ideal, so the choices are actually very narrow in comparison to the variety of speakers manufactured.
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Some objective criteria can be used to make this judgment. As suggested in an earlier paper advocating the establishment of re-recording standards, a speaker's ability to meet these criteria should be decided by consensus of the International Association of Sound Archives (IASA) and Association for Recorded Sound Collections (ARSC) technical committees. Since that consensus process is not yet a reality, the following guidelines can help narrow the possibilities. Five variables will be discussed:

1. frequency response,
2. flat response,
3. intermodulation distortion,
4. arrival time, and
5. placement.

Frequency Response

Frequency response is the most commonly used measurement appearing in audio literature to describe the performance of audio equipment. Such is the case for speakers. An audio archivist should use this descriptive measurement as one of the primary guides in speaker selection. But first an understanding of frequency response measurements is in order.

For the average consumer, an explanation of frequency response by an engineer or salesman can often be more confusing than helpful, causing the person to believe that the topic is unapproachable without a degree in electrical engineering. Fortunately, this is not true. Consider the instruments in an orchestra for a moment, categorizing the instruments that produce the lowest notes (low range), highest notes (high range), and the notes in between (middle or midrange). Typical response might be the bass drum and tuba for the low range, piccolo and triangle for high range, and trumpet and clarinet for midrange. Repeating this process with a chorus, the classification of bass, tenor, alto, and soprano are obvious.

Assuming this exercise was no problem, then you already understand the reproduction of the audio spectrum in terms of lows, middles and highs. Frequency response measurement is nothing more than a mathematical expression of sound waves on a scale ordered from the lowest audible frequency to the highest. The bass drum fundamental (lowest tone) frequency would be approximately 50 cycles per second, or 50 hertz (named in honor of German physicist Heinrich R. Hertz); the tuba, 40 hertz; the piccolo, 450 hertz; the triangle, 500 hertz; the trumpet, 180 hertz; and the clarinet, 150 hertz. Approximate values for voices are:
Fig. 1. Example of poor speaker reproduction of recorded signal
bass, 98 hertz; tenor, 130 hertz; alto, 195 hertz; and soprano, 250 hertz. In addition to the fundamental frequency, each of these instruments produces a range of higher frequencies.

Fig. 2. Frequency ranges of instruments and voices (data obtained from Tremaine, Howard M. Audio Cyclopedia, 1st ed. Indianapolis: H.W. Sams, 1959, pp. 7, 14.)

The general audible range for humans is 20-20,000 hertz. It is this range of frequencies that influences our perception of sound. A speaker designed for accurate reproduction of the sound spectrum should be capable of reproducing all of these frequencies. It is logical to assume that if the specifications for a speaker included a 20-20,000 hertz response, then it is a good speaker. True, that range is a good starting point, but the frequency response must also be carefully examined with respect to its linearity.
Flatt Response

In figure 3, frequency is compared to the loudness (or amplitude) of sound. Sound level is measured in units called decibels (db). If tones of 20, 100, 500, 1000, 10,000 and 20,000 hertz were turned up to the same volume level of 70db, they would be plotted on the same horizontal axis on the scale. Likewise, if the remaining frequencies from 20 to 20,000 hertz were also plotted at 70db, the infinite series of dots would eventually form one straight horizontal line. This straight line would represent what is referred to as “flat” response.

Flat response in a speaker means that if all frequencies were fed into the speaker at the same amplitude, the speaker would reproduce them at equal amplitudes. If 1000 hertz measures 70db, then all others should measure 70db. On the other hand, if 1000 hertz measured 70db, 100 hertz 55db, and 5000 hertz 80db, then the levels of the original sound are obviously not being reproduced equally at all frequencies.

If 70db is assumed the reference level, the 55db level at 50 hertz would make the fundamental in a bass drum all but disappear, while the 80db level at 5000 hertz would make a piccolo sound inordinately shrill. Such speaker deviations from flat response would seriously alter the listener’s perception of the original sound. An archivist or other listener would therefore have a false impression of the sound on the recording. Specifications for speakers should include the ±db variance from flat response. Frequency range alone is not sufficient. If the ± deviation is not included in the specification, be wary. For example, a speaker advertisement could state a frequency response of 30-15,000 hertz. That seems good. But if the measured response deviates by a figure like ±15db, the speaker would be extremely poor. If the ± variation is listed and two speakers claim the same range, but speaker A is ±2db from flat response and speaker B is ±6db, then A would be the better choice, other things being equal. The first two criteria for speaker selection are, in short, a sufficient frequency range and flat response of that range.

Intermodulation Distortion

Range and linearity are important, but of little consequence if the reproduction is distorted. Speakers generally have the highest percentage of distortion of the components in a high-quality sound system. Unlike amplifier advertisements which proudly display distortion characteristics in hundredths of a percent or better, speaker ads rarely even include distortion figures.

Some speaker specifications will include percentage of distortion for single frequencies, but most recordings reproduce many frequencies
Fig. 3. Flat response v. uneven response
Fig. 4. Response of Speaker A v. Speaker B
Standards for Speakers

simultaneously. The influence of one frequency on another is therefore important. Unfortunately, this simultaneous reproduction of frequencies is not a simple task for a speaker. The anomalies of a speaker can cause the original frequencies to interact negatively and generate non-harmonic frequencies unrelated to the original signal. This form of distortion is called intermodulation (IM) distortion. It interferes with the definition of the sound and can cause listening fatigue. When listed, a rating of less than 0.5 percent IM distortion would be considered good for a speaker.

Arrival Time

In an effort to minimize intermodulation distortion and increase frequency response, multiple speakers are put in one cabinet with each assigned a range of frequencies to cover. A three-way system, for example, would have a low-range speaker (woofer), a midrange speaker, and a high-range speaker (tweeter). This type of combination allows the manufacturer to design specialized speakers that do a better job in their respective ranges than a single speaker forced to reproduce the entire audio spectrum.

This does not mean the more speakers the better. A well-engineered single speaker could outperform a cheaply and/or poorly designed multiple-speaker system. However, assuming that the multiple-speaker system is basically well designed, its capacity to reproduce the total sound spectrum is superior to that of a single speaker.

One design problem of multiple speakers that has been overlooked by manufacturers for years is the arrival time of the various frequencies to the listener. In a multiple-speaker system, the physical separation of each of the speakers in the system causes the fundamental frequencies and overtones to reach the listener's ears at different time intervals than existed in the original recording environment. Differences in time, as well as amplitude, of the frequencies are thereby created by the speaker system. Recreation of the original performance is distorted in these respects. Fortunately, a few speaker systems are now being designed to produce more natural arrival times, thereby increasing the authentic reproduction of the sound. Perception of arrival time distortion does vary with frequency, but a difference of one millisecond or less between speakers is a good reference point.³

Placement

The objective of this article has been to list some of the important criteria in speaker selection. Assuming the ideal speaker can be found, a
major nemesis still remains—the room in which the speaker is placed. The size, shape, surfaces, and objects within a room all have an effect on sound reproduction. The placement of the speaker within the room can also have serious repercussions on speaker fidelity.

![Diagram](image)

Fig. 5. Used by permission of McIntosh Laboratory, Inc., Binghamton, N.Y.

As shown in figure 5, the low frequency response of a speaker is substantially different in different room locations. The discussion of an ideal listening room deserves a great deal more attention that is possible here, but what must be realized is that if the speaker selected is inherently accurate, the number of variables to worry about is reduced by one. A good speaker specification should state which location is optimal for the most accurate response.

**Conclusion**

Sound archivists must recognize that in addition to discographic (audiographic would be a better term) responsibility, an obligation exists to contend with the technical problems of the audio medium. This paper has concentrated on one of those problems—the speaker system. Speakers selected to reproduce sound objectively should:

1. have a wide frequency range—approximately 25-16,000 hertz or better;
2. have a flat response—±3db or less;
3. have low intermodulation distortion—0.5 percent or less;
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4. have minimal differences in speaker arrival time—one millisecond or less; and
5. be properly placed for best response.

The guidelines are governed by the basic premise that authenticity comes from objectivity. Those who have assumed the task of sound preservation owe it to future generations not to distort the reality of that sound.

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Forthcoming numbers are as follows:

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