AN EVALUATION OF THE BOOKKEEPER

MASS DEACIDIFICATION PROCESS

Technical Evaluation Team Report
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Section I. SUMMARY

Introduction

The Technical Evaluation Team established by the Library of Congress has evaluated the Bookkeeper deacidification process and unanimously concludes that it demonstrates the potential to meet the requirements for mass deacidification as defined in the RFP issued in 1993 by the Library of Congress (Library). The Team also recommends that Preservation Technologies, Inc., (PTI) of Glenshaw, PA, be supported for further research and development by the Library.

Bookkeeper has already met many of the Library's specifications. The process deacidifies books, leaving an alkaline reserve, without decreasing paper strength. There is potential for scaling up for mass treatment, and the costs of doing so are not excessive. Neither human health nor environmental safety is compromised. The minor physical damage caused will be acceptable for most research collections. As was expected, there were problems and concerns identified as a result of the test procedures, conducted in August 1993, that suggested the advisability of additional research and testing.

Team members have written individual reports following this summary which are the body of the evaluation and report to the Library. It is important to note that research and development have continued over the past year since the initial test at the PTI facility. PTI has worked to refine and develop both its process and its technology, and observers would find in September 1994 a different environment than that described by the Team members in their reports. PTI's report is included as Appendix E.

Technical Evaluation Team

The Pittsburgh-based Technical Evaluation Team was appointed in 1993 to work with the Library and PTI to assess Bookkeeper and its potential to meet the Library's specifications. The Team had the responsibility to establish a testing protocol based on the guidelines in the RFP. The charge to the Team was to evaluate Bookkeeper's effects on test materials at a specified period of time and to report on those results to the Library of Congress and the library and archive communities at large.

Sally Buchanan was asked to chair the Technical Evaluation Team. The remaining members of the Team, selected in recognition of the multi- faceted nature of the evaluation process, included Wendy Bennett, Michael Domach, Ph.D., Susan Melnick, Charlotte Tancin, and Paul Whitmore, Ph.D. Because of the range of expertise represented by the Team, the consideration of Bookkeeper was able to proceed on a number of levels.

The work of the Team was to culminate with a fully documented report on the efficacy of the Bookkeeper process. This report is the result. It will be published by the Library for public information and education. Kenneth E. Harris, Preservation Projects Officer for the Library of Congress, represented the Library in the endeavor. Chandru Shahani, Ph.D., Preservation Research Officer for the Library, worked with the team during the evaluation process. PTI has made all relevant proprietary information available to the Team as well as the time and expertise of its research staff. The cooperation of the staff of the Library of Congress, Preservation Technologies, Inc., and the Technical Evaluation Team members made this report possible.

The Library also contracted with the Institute of Paper Science and Technology, Inc. (IPST), in Atlanta, GA, to run independent tests on books treated by the Bookkeeper process. The detailed report from IPST is found in Appendix A.

History of Mass Deacidification

Mass deacidification is a tool that many librarians and archivists had anticipated could be used to help combat the serious problem of the acidic collections in the nation's libraries and archives. While brittle materials were being identified and reformatted for preservation, there was also the troubling question of what to do about the millions of acidic but not yet brittle books and records inexorably deteriorating in the retrospective collections.

The Library of Congress responded over a decade ago by developing the DEZ process. Its potential seemed highly promising. Testing and experience, however, taught that it had drawbacks which required further research. Other deacidification technologies also showed potential, but none met all the needs or the expectations of the library and archival communities. Many had hoped that any process marketed would be totally effective, safe for users and environment, universally acceptable for collection materials, and cost-effective. Despite these expectations, it is unlikely that one process will ever be appropriate for all library or archival materials. Selection may depend upon process parameters, specific collection needs, and types of materials to be deacidified.

Further, different kinds of decisions related to acidic collections may have to be made by collection experts. For instance, is mass deacidification, which significantly slows the degradation of paper, the best solution even though it may result in some physical changes to the book or paper? Is controlled environmental storage, which causes no visible physical change in paper or books but is less aggressive in slowing deterioration, a better choice? The likely event is that librarians and archivists will make use of all possible options to ensure the preservation of the national collections.

Over the past five years there have been useful and reliable tests conducted on most available mass deacidification processes by conservators and scientists from several countries. Gradually, the growing body of knowledge has made it possible for librarians and others to begin to make the informed decisions necessary to protect as well as preserve collection materials. The Library mass deacidification program has been pursuing two initiatives over the past 1993-94 year. One was to continue to work with the Akzo Chemical Company in Texas on refinement of the DEZ deacidification process. This came to an end when Akzo made a decision in December 1993 to withdraw from the deacidification business.

The second initiative sought to encourage and evaluate the development of other technologies. In keeping with its congressionally approved plan to assist the development of emerging processes that have the potential to preserve its collections, the Library published the RFP in 1993. PTI, the sole respondent to the Library's advertisement of the availability of its evaluation and testing program, submitted Bookkeeper, originally developed by the Koppers Company, Inc., and patented in 1985.

Evaluation Project

The Technical Evaluation Team began work in May 1993 to create a schedule, to define the testing protocol, and to decide upon appropriate test materials. The schedule established by the Team acknowledged both the requirements of the Library and the needs of PTI which, during the summer of 1993, was installing the new technology that was to be used for the test run. As first planned, the work of the committee was to be finished by the end of 1993, with the report available for distribution in early 1994. Due to the time required for contract procurements, the independent testing by IPST of the deacidified books, and other responsibilities of the Team members, publication of the report was delayed.

Team members, according to their respective expertise, assumed responsibility for separate aspects of the review process. The Team defined the testing protocol in terms of three screens, as explained below, through which Bookkeeper would have to pass.

1. First, and most important, the mass deacidification process had to meet the Library of Congress specifications for efficacy, alkaline reserve, and completeness of treatment. Paul Whitmore had responsibility for definition of tests to be done, in addition to those required by the Library, as well as for the interpretation and discussion of the data resulting from those tests.

2. Second, the process had to meet specifications applicable to process engineering criteria, its ability to be scaled up, and its environmental impact, toxicity, and health effects. In his report, Michael Domach reviewed the Bookkeeper process technology as it existed at the time of testing. The EPA report is included in Appendix B.

3. Third, in order to be considered safe for library materials, the process could not result in any harmful or unacceptable side effects. The evaluations of this third screen were designed to detect odor, discoloration, distortion of paper and textblocks, as well as any other unwanted reactions caused by the process. Charlotte Tancin and Wendy Bennett addressed these issues in their reports. The Team wanted to identify those properties of library materials which might be adversely affected by deacidification. In the development of this set of parameters for consideration, the Team polled the preservation and conservation communities via the Conservation DistList, an online forum in which members can communicate through the Internet. Respondents suggested areas of concern related to mass deacidification.

Selecting Materials for Testing

The Library has focused its testing of mass deacidification processes on bound materials and has created the LC blue test book as a standard unit for evaluation. Unlike ordinary books, these volumes consist of bound blank sheets of a variety of paper types.

Because other deacidification methods have caused a variety of undesirable side effects[1], and in response to concerns raised through the Internet inquiry, the Team expanded the original test batch beyond the mandated LC blue test books. Members decided to consider the effects of Bookkeeper treatment on a collection of books which represented a "typical" library collection. The Team selected twenty-five used books, collected from various libraries, to be added to the test batch. These books presented a range of publication dates, countries of origin, paper types, ink colors, binding methods, plate types, and other physical components. A list of these books can be found in Appendix C. These materials were not sent to IPST for testing after treatment.

Processing Test Materials

On August 30, 1993, the entire set of test materials, both the LC blue test books and the twenty-five additional books, were processed by PTI in the presence of the Technical Evaluation Team. Each of the twenty-five used library books had been cut in half, perpendicular to the spine. One half of each volume was to be processed, and the untreated half was retained as a control.

The LC blue test books and both halves of the library books were transported to PTI where they were unpacked in the Bookkeeper plant. The half of each library book to be treated was labeled with the Bookkeeper label. The Team had, for testing purposes, placed a variety of items in the books. The Team also marked some of the books with a variety of markers, pens, and pencils, in order to observe any effect of the Bookkeeper process on these markings.

After the materials had been deacidified, the treated and untreated halves of the bisected volumes were placed together for comparison. They were also photographed for documentation.

[1] Anne Lienardy, "Evaluation of Seven Mass Deacidification Treatments," Restaurator 15:1-25, 1994.

Evaluating Processed Materials

The LC blue test books were sent to the Library of Congress for limited testing and aging and were then forwarded for independent testing to the Institute of Paper Science and Technology, Inc., Atlanta, GA. A list of tests is provided in Appendix D.

The twenty-five bisected library books were scrutinized by committee members. The treated halves were compared with their untreated halves in an effort to detect side effects of the Bookkeeper process. After this initial examination, the twenty-five books were subjected to further testing by Paul Whitmore. In December, several books were also taken to the Graphic Arts Technical Foundation, Pittsburgh, PA, for abrasion testing of printed plates on coated paper on the Gavarti Comprehensive Abrasion Tester, according to ASTM D518191.

While waiting for test results, the Team served as a liaison between the Library and PTI. The members worked with PTI, explicating areas appropriate for research and development which had become apparent during the evaluation process. Issues of importance to the preservation and conservation communities were also communicated to PTI. Then, as the testing and evaluation data became available, each member of the Team addressed the relevant data in a section of the report related to that individual's area of expertise.

Library of Congress Specifications

The charge from the Library to the Technical Evaluation Team was to evaluate the Bookkeeper deacidification process to determine if it had the potential for meeting the technical requirements for deacidification set by the Library of Congress. Among these requirements are the following:[2]

1. Efficacy

Through neutralization of acidic paper and incorporation of a suitable permanent alkaline reserve, the rate at which paper loses strength upon accelerated aging at 90 C/50% RH for up to 30 days, shall be decreased by at least a factor of 3.0, when the logarithm of the folding endurance is plotted against time in days. [RFP80-21 Requirement - C.2.1.4.] The permanence of the treated paper shall be increased by a factor of 300%.

Findings

a) Treated papers showed less degradation of mechanical properties than did untreated during accelerated aging. Treated papers from the test books generally retained their desirable performance properties for 2-4 times longer in oven-aging, comparable to the factor of 3 required in the Library specifications. Overall performance in the oven tests show benefits of the treatment.

b) The treatment did not measurably affect the physical appearance of the papers in the Library test books.

2. Completeness of Deacidification

After treatment, the average pH value will be between 6.8 and 10.4. Deacidification shall be demonstrated within each page, each book and throughout all books in a treated batch. [RFP9021 Requirement - C.2.1.7]

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[2] Library of Congress, Test and Evaluation of the Bookkeeper Deacidification Process in Support of the Library of Congress' Research and Development Efforts for a Mass Deacidification Process. Contracts and Logistic Service, 1993.

Findings

a) Treatment of all the paper types in the Library test books raised the pH of the sheets from a moderately acidic pH of 5.7-6.5 to alkaline levels ranging from 9-10. Subsequent oven-aging of the treated sheets caused the pH to fall slightly to 8.0-9.5.

b) Treatment which neutralized LC blue test books did not completely deacidify several of the old library books that originally may have been very acidic. Limited testing of the twenty-five library books selected by the Team revealed that Bookkeeper deacidification of highly acidic, older collections may require additional research into the process technology and some stricter bench marks for treatment.

3. Alkaline Reserve

Uniformity for a given paper type shall vary from specified optimal concentrations by no more than 20% between books and by no more than 20% between and within individual pages. [RFP90-21 Requirement - C.2.1.8] Alkaline reserve amount is not decreased by more than 0.5% calcium carbonate equivalent after aging for 30 days at 90° C/50% RH. The minimum amount of alkaline reserve shall be 30 milliequivalents per 100g (1.5% calcium carbonate equivalent.) [RFP90-21 Requirement - C.2.1.8] The process will result in an alkaline reserve of not less than 1.5% with stable and uniform distribution.

Findings

a) Alkaline reserves were somewhat lower than the Library's specifications (1.5%), but the initial value of the reserve did not fall during 30 days of oven aging. On some papers, alkaline reserves must be improved.

b) It would appear that the most immediate shortcoming of the Bookkeeper process involves the nonuniformity (as demonstrated August 30, 1993) of the treatment chemical to book materials rather than in the technology itself. Test results indicate that the Library test book papers contain an overall uniform deposit of magnesium oxide across the entire sheet with the exception of the gutter areas where only 30-50% of the average loading took place.

4. No Damage to Processed Materials and Media

No process-related damage to books. [RFP90-21 Requirement - C.2.1.10, C.2.1.11, C.2.7.12] The processed books will be evaluated for damage to the dyes, inks, or adhesives, for any process-induced odors, for loss of strength, or for significant change of color or degree of photosensitivity to the book paper as a result of treatment.

Findings

a) The treated books had no odor. Those demonstrating a pretest musty odor lost that odor during the treatment process.

b) There was no observable adhesive loss or damage on book spines or to shelf labels, security strips, book pockets, or plates.

c) There was no damage to book cloth or other covering material. A typical plastic book jacket acquired a light dusting of magnesium oxide. There was no softening of plastic or change of color. There was no damage to pamphlet binders. There appeared to be no damage to the leather on the two leather bound books.

d) There was no change of dye color in book cloth or in printing ink, internally or externally. There was no damage to gold tooling or gilded edges. Marker ink used for underlining text did not change color or bleed, with the exception of a pH sensitive marking pen. The Team noted there was some rub-off of colored inks from printed plates on coated stock. The inks did not transfer to hands or to adjoining pages but was discovered as result of abrasion tests.

e) There was no cockling of paper or distortion of boards, pamphlet binders, or textblocks.

f) There was some observable change in the untreated papers from the LC blue test books aged in a humid oven, causing some to darken and become less translucent. The Bookkeeper-treated book paper, aged in a humid oven, did not differ significantly. Color and translucency were neither better nor worse.

g) Slight chalking or white residues could be seen and felt on coated stock and detected by Team members on some other papers. This was not found instrumentally on the unprinted white papers of the Library test books.

h) The physical and mechanical actions involved in the Bookkeeper deacidification process did no harm to books, documents, or fragile bindings except for clamp marks that were detected on some covers.

i) Some books from the Team's set of twenty-five were 'cleaned' during the deacidification process. Surface dirt and debris such as dead insects floated to the surface of the treatment tank. There was no effect from rubber bands and paper clips placed in the books before treatment.

j) Pretreatment drying or other conditioning of materials is not necessary.

5. Potential to Treat Books on a Mass Scale

The deacidification process and production facilities demonstrate potential for scale-up to a mass deacidification process. [RFP90-21 Requirement - C.3] In addition, there were to be no health hazards or any serious environmental impact from the process.
Findings

a) The treatment technology observed in August 1993 was not designed as a mass process. A detailed description of the process and equipment can be found in the Domach report. There is reason to believe that scaling up should not be a mechanical problem. New equipment has been designed and is being tested.

b) A distinct advantage of the Bookkeeper process as compared to others is the modest estimated start-up costs for a new treatment facility.

c) Because the treatment process is not hazardous, a facility could be located in a local institution, a business, or a regional center, or it could be portable and delivered on site to treat collections.

d) The issues of shipping, receiving, handling, and packing collections must still be addressed.

e) The selection of appropriate materials for mass deacidification of research collections must be considered by librarians and archivists. Education is in order so a common understanding of needs, costs, and ability to support mass deacidification is reached. That mass deacidification is not an appropriate process for brittle, rare, or special collections must also be understood by librarians. Archivists will have different selection criteria as most of their collections are unique.

f) The EPA evaluations of the process find no serious health hazards or negative environmental impact. (Appendix B)

The Team agreed, based on their findings, that Bookkeeper has potential to meet the Library's specifications. At the same time, however, Team members identified areas which may be appropriate for further research and development by PTI, such as those mentioned by Bennett, Domach, and Whitmore. Those specified by Tancin will be of particular interest to librarians who are considering mass deacidification for their collections.

Domach discussed the factors which may contribute to nonuniform distribution of MgO particles throughout the text during treatment. Whitmore agreed that problems of controlled application had not been solved in August 1993. Because older library books which may have been very acidic before treatment were not satisfactorily neutralized, he also suggests that older and acidic papers, rather than the less acidic papers of the LC blue test books, be used to set bench marks for developing conservative process parameters.

As a conservator, Bennett remarked on the palpable residue that she found on some treated papers. Her observations that, following treatment, colored inks on coated stock showed a slightly increased tendency to rub off were supported by further testing on the Gavatri Comprehensive Abrasion Tester.

Librarians, if they are to exploit fully the potential benefits of mass deacidification, according to Tancin, must be prepared to structure guidelines for pretreatment selection and for care and handling of materials during treatment. She also emphasized need for the establishment of protocols for pretreatment testing and posttreatment monitoring of collections. These contributions, among the others found in the individual reports, should provide PTI, the Library, and the library and archival communities with direction for improvement and use of mass deacidification in general and Bookkeeper in particular.

Conclusions

The PTI Bookkeeper deacidification technology meets the criteria set by the Library of Congress for a process which shows potential for meeting their specifications. Problems identified as a result of IPST testing or the Team's observations can be addressed as part of the ongoing research and collaboration. The process is a clean one causing harm neither to the environment nor to materials tested. Questions which arose during the testing procedures remain to be answered. The library and archival communities may find that a choice has to be made between a less aggressive mass deacidification process that results in little or no physical damage or other undesirable side effects and one that is chemically more aggressive, causing some observable physical damage. Preservation and collection experts may take advantage of both, based upon condition assessment, the importance of physical appearance, and tolerance for specific technological strengths and weaknesses.

The chemistry of mass deacidification, its scientific value, and the solution of problems resulting from treatment are critical topics in the quest to find an answer for the dilemma posed by the millions of acidic books and records in this nation's libraries and archives. The significant part that acidity plays in the rapid deterioration of paper has long been recognized. Deacidification as a potential solution has been scientifically investigated over the last fifty to sixty years in several countries. Indicative of the effort made to understand and resolve the challenges raised by acidic paper and to exploit the potential of deacidification as an answer is the existence of the large body of literature on the subject.

Section II. REPORTS

Reporting on the process technology and the ability of PTI to scale up in response to the Library specification for a mass treatment facility required the expertise of a chemical engineer. He also commented on the process chemistry; and his questions related to health effects, toxicity, and environmental safety were forwarded to the Environmental Protection Agency.

The charge, made by the Library to the Team, to assess Bookkeeper at the time of the August 1993 test run, had to be balanced with the Team's realization that new developments would make some of their comments obsolete. The Team found itself playing two roles. While preparing and writing a report for the Library, the Team was, at the same time, serving as a communications link among PTI, the Library, and the outside library and archival communities. As PTI continued research and development, incorporating feedback and ideas from the Team and the Library, it was essential that progress be monitored and described to the other Team members by the chemical engineer. His interactions with the PTI staff enhanced the Team's understanding of increasingly complex technology and process changes.

Technical Evaluation of PTI Mass Deacidification Technology

Michael M. Domach, Ph.D.

This report is based on the status of process development at the time (August 1993) the test books were subjected to treatment by the Bookkeeper Process. At that time, some issues were identified that were thought to be of interest to the library and technical communities. These issues were pursued by requesting that a number of tests be performed on treated test books. The main driving force behind these requests was anticipating potential users' questions and bench-marking efficacy. Finally, the reader should note that PTI is actively engaged in continually assessing and improving the Bookkeeper process. Thus, this section should be viewed as a review of the process' principles and a "snapshot" of its capabilities at the time the test was conducted on August 30, 1993.

This review begins by providing a technical overview of the process. Thereafter, the processing aspects that generated some of the analytical requests are noted to provide the reader with a broader context for reaching conclusions from the results presented elsewhere in this report. This review concludes with comments on process capacity and control and outlines the directions PTI was pursuing at the time of evaluation. The appendices contain a statement written by PTI that describes recent process modifications in more detail.

Overview of the PTI Process

In this overview, what a typical hard cover book experiences in the Bookkeeper process is described. Overall, the aim of the process is to impregnate the text's pages with alkaline, submicron MgO particles. The MgO particles are dispersed in a perfluorocarbon carrier fluid by using a surfactant. The carrier now in use replaces the CFC compound originally used; the new carrier was adopted to minimize environmental impact. The surfactant is used to prevent the aggregation of particles. If aggregation occurred, particle penetration into the paper's fibrous structure would be reduced. The surfactant contains a perfluorocarbon-functionality which endows it with solubility in the carrier fluid.

The texts to be processed in the batch are first attached to a horizontal, V-shaped platform. Attachment is accomplished by clamping the binding's corners to the platform surface. Thereafter, the platform bearing its load of texts is immersed into the MgO suspension. Immediately after the load is immersed, the air from between the pages and binding exits. The high specific gravity of the carrier fluid (1.7) fosters flotation resulting in the opening of the text's pages. At this point, a text appears to be half open with the fanned out pages supported by the dense carrier fluid. Often, dirt and debris from the books floats to the top of the bath thereby providing some cleaning.

Apart from the materials used, another key component of the Bookkeeper process is the agitation a text experiences following immersion. MgO particle penetration is aided by establishing convective mass transfer. This meansthat the carrier fluid flows over the opened pages. Such motion is intended to increase the rate and extent of contact between the pages and MgO suspension. Carrier fluid motion is induced by moving the platform back and forth in the horizontal plane; motion occurs parallel to the text's spine. This motion establishes mild fluid circulation in the immersion bath. Adjusting the range of platform motion is possible prior to operation. This adjustment regulates the period and phasing of the circulation. The motion combined with the high specific gravity of the carrier fluid causes the pages to fan as the platform moves. The motion of branched kelp in a gentle tidal flow is reminiscent of what is observed. As the flow passes by and recedes, the kelp's branches move laterally back and forth.

Following impregnation for ca. 12-15 minutes in a bath containing 2.5 g MgO/l, the platform is raised above the immersion bath and excess carrier is allowed to drain. Thereafter, the platform and attached books are transported to an evaporator chamber. There, the carrier fluid is evaporated at approximately room temperature conditions. The evaporated carrier is collected and condensed so that it can be recycled. The normal boiling point of the carrier is 80¡ C; hence, the evaporation process for a ca. 200 page text is complete in less than ca. 16 h based on gravimetric criterion. Carrier recovery observed in the August 1993 process is less than 100 percent.

Main Process: Issues Relevant to Efficacy

Penetration & Uniformity of MgO Distribution. Apart from the type of paper, the operation of the equipment (e.g. duration of immersion), and size of the text, the shadowing effect of neighboring texts could conceivably affect the treatment a book experiences in a batch. If these effects occur, then the MgO particles could prove to be not uniformly distributed on a page or throughout the text.

PTI has considered the MgO distribution issue. At the time of Library-sponsored study, PTI staff utilized alkaline pH indicators to determine if treatment confers alkalinity to all areas of a given page as well as to all pages in a text. Supplemental information in the form of scanning electron micrographs was also provided to the Technical Evaluation Team. The micrographs indicated that particles are adsorbed on cellulose fibers. Elemental analysis via energy dispersive x-ray analysis is also claimed by PTI to confirm that the particles observed in micrographs are indeed MgO. Overall, the operational parameters (e.g. immersion time, platform motion range) used in this study were based on PTI's prior videotaped motion studies and analyses (e.g. pH indicator studies) of their own test books. The results of fold endurance and other tests which bench-mark efficacy are discussed by Paul Whitmore.

Process Control & Quality Assurance. The treatment is a batch process. Thus, as time elapses, MgO concentration in the bath may potentially change due to uptake by texts or carrier fluid evaporation. The former would reduce MgO concentration while the latter effect would increase concentration. At the time of the test, once the range of platform motion was set, the main method of controlling the process entailed periodically withdrawing a bath sample for analysis. The control strategy involved maintaining the MgO concentration at the level anticipated to yield the desired alkaline reserve for the treatment times used.

Assessing the extent of treatment for actual circulating books is not straightforward. Using pH indicators is obviously undesirable due to the staining; hence, selected surface pH electrode measurements would have to be performed. Alternately, representative samples of low value books could be inserted in a batch and subjected to destructive testing. Relying on historical data and limited analyses is an omnipresent challenge in the majority of deacidification processes.

Process Capability and Availability

Process Capacity and Scale-Up Potential. At the time the tests were conducted, PTI had one immersion bath and one drying chamber. Both units can be regarded to be pilot or semi-works scale. The bath was capable of processing 3-5 books per cycle. The drying chamber was multi-tiered and could handle the product from numerous batches.

We observed that the process has two labor-requiring steps that contribute significantly to cycle time. First, the attachment of the books to the platform consumed 10-30 minutes. The loading of conventional sized hard cover books with reasonably intact bindings was fairly straight forward. Books with weakened bindings required special handling and the use of additional supports. The second labor-intensive step entailed transferring the books from the bath to the drying chamber (ca. 15 minutes). For one treatment bath of the scale demonstrated, we estimate that 125-175 books can be treated per 24 hour day.

Adding more treatment baths and increasing bath and drier capacity would raise throughput and transform the operation to semicontinuous. If the scale- up of the treatment tanks was considerable, then the relationship between range of platform motion, inter-book distance, and treatment efficacy would have to be assessed to ensure that the relationships established from pilot studies hold. PTI has acquired some experience with this optimization problem. Drying at a larger scale would require a shift in how treated product is inventoried as well as an increase in carrier recovery capacity (e.g. chilled condenser) beyond that currently available.

Availability of Process Materials

One key component of the PTI process is the surfactant obtained from an off-shore, Italian vendor. Because this source is presently unique, the process may be vulnerable to vendor stability or whims unless substitutes or other sources can be identified. Alternately, an inventory strategy must be developed.

To address this concern, PTI has obtained a letter of commitment from the vendor that states that the likelihood is very low that the product line will be discontinued in the foreseeable future. Additionally, PTI has been in communication with 3M Company on manufacturing a perfluorocarbon surfactant. Such a development would represent increased vertical integration of product lines for 3M because they also vend the carrier used in the Bookkeeper process.

Agenda for Process Refinements

At the time of testing, PTI was considering different means for increasing treatment capacity. Additionally, implementing additional process control strategies was under discussion. One potential control strategy entails installing an optical sensor in the bath to monitor continuously the MgO concentration.

Conclusions

From the processing standpoint, the Bookkeeper process has the advantage of simplicity. Essentially, two components are required: a controlled solid-liquid contacting system and a volatile liquid recovery/recycle system. Many aspects are amenable to optimization which, in turn, would lower costs and increase throughput. Increasing the utilization of bath volume and the recovery of carrier, for example, would conceivably reduce the cost per batch.

A statement provided by PTI on current work can be found in Appendix E. Overall, the materials and requirement of fluid motion relative to the text will be fixed characteristics. The statement, however, will allow the reader to gauge how capacity and other features may change over the next year.

Many of us think that science can resolve almost any problem if given enough time and funding. Our expectations are high, and we demand perfection. Several deacidification processes have been developed over the past decade. Over and over again, librarians were assured that the newest process was the ideal solution they had been waiting for. Further testing and research inevitably revealed otherwise. All processes have had drawbacks; some were totally unacceptable; others showed potential. Clearly, however, compromises will have to be made. It is important for those involved to understand treatment chemistry, to educate themselves about collection conditions, and to make informed decisions.

This report, written by a paper chemist, contributes to the continuing discussion and analysis of Bookkeeper. Using the data generated through extensive testing in his own lab, by the Library, and by IPST, he has provided insight into the potential of this process to meet the Library's specifications and to serve the needs of the library and archival communities.

Evaluation of the Bookkeeper Process Chemistry

Paul M. Whitmore, Ph.D.

This section of the report summarizes technical data which should be useful criteria by which to judge the performance of the Bookkeeper process and its prospects to meet the needs of the Library of Congress. Because of the very limited set of sample materials, it is premature to consider the results of these evaluations to be typical or to represent the fullest capability of the technology. Instead, these examinations should be taken as a screening, to highlight successful performance or failures for these particular materials and to target important process performance tests that should be considered in future, comprehensive evaluations.

This section of the report addresses four key issues:

1. *Process technology.* What is the Bookkeeper process designed to do? This includes an overview of the treatment process and the deacidification chemistry as it is designed to work. Experimental evidence to verify the intended process chemistry is summarized and assessed, and particular benefits or risks associated with this process chemistry are explored.

2. *Process performance.* What actually results from the application of the treatment? The results of the technical evaluations of the treated test books are examined. Was the application process successful in depositing the alkaline agent uniformly and in the desired quantity into these materials?

3. *Process efficacy.* Is the treatment effective? This section compares the performance of treated and untreated pages from the LC blue test books during humid oven aging. Did the deacidification succeed in slowing the deterioration of the papers in the aging test?

4. *Process side effects.* What does the treatment do besides the intended deacidification? Alterations in appearance and inks in the twenty-five book test lot are addressed in other sections of the report. This section will address changes in the LC blue test book pages.

Process Technology

According to the vendor, the Bookkeeper process is based on the application of fine magnesium oxide particles into the paper sheet. These particles are applied by immersion of the book into a suspension of the magnesium oxide in an inert fluid carrier, chosen to minimize possible interactions with the book materials. Mechanical agitation of the text allows the slurry to penetrate the book structure and deposit MgO on the surfaces of and within the pages. Removal of the book from the reactor followed by evaporation of the carrier fluid completes the treatment, and only then is the neutralization of the paper acidity thought to begin. The magnesium oxide particles rapidly absorb water and form magnesium hydroxide, which is claimed to be the active alkaline agent in this treatment. This alkaline salt being sparingly soluble in water, the paper acidity must migrate to the solid particles and react to form the neutralization products.

The Bookkeeper process is exceptional in two respects. It is by its nature "clean," introducing only very pure magnesium oxide into the paper and exposing the book to relatively unreactive fluids and surfactants. It also does not subject the books to "preconditioning" treatments which may risk incidental changes to the book materials or structure. The process as it exists today (in August 1993) also has the advantage of using materials which are not likely to become subject to environmental regulation. A second key feature of the process is the inherent simplicity of the treatment. No chemical reactions are necessary to produce the desired combination of ingredients in the paper, and consequently the treatment is unlikely to create an unexpected outcome due to poor process control. This treatment puts magnesium oxide into paper, and the only apparent variability in the treatment application is the quantity and distribution of the magnesium oxide deposited in the book.

At the same time that the process enjoys advantages of simplicity and safety, it also has two intrinsic problems. The first is the application of the particles to the paper by transfer from a fluid suspension. This procedure relies both on the fluid transport through the book structure and on the sticking efficiency of the particles on a sheet to determine the amount, distribution, and rate of particle deposition. Both of these factors depend on characteristics of the individual books and remain poorly understood; more research is needed before the treatment process will be able to guarantee that a particular specification can be met for every treated volume. The operation as it exists (in August 1993) has almost no control over the outcome of the process (i.e., the deposition in each book), but only over the external variables such as the suspension formulation and processing conditions. While this may be typical for "mass" treatment services in general, only after more experience with the current technology will the vendor be able to identify useful bench marks, such as difficult-to-treat materials, which should be used to develop conservative processing parameters.

The second inherent problem facing this process (although not necessarily peculiar to this process) is the fact that the chemistries leading to acid neutralization are poorly understood and occur over some indefinite time period following the treatment itself. The formation of active alkaline agents and their reaction with the resident paper acidity are left to the forces of thermodynamics to carry out; there is no control over, and very little current evidence to indicate, when the proximity of alkaline particles and diffusing acidity will achieve the desired neutralization. The vendor’s claims that such reactions will occur are plausible, but at issue is whether, for a variety of papers in ambient environments, acids will be neutralized faster than they will degrade the papers. The uncertainty surrounding this issue is no different than the uncertainty, that some paper chemists raise, that alkaline reserves will actually provide substantial benefits. However, unlike some processes which promise some neutralization chemistry during the treatment, the Bookkeeper process is utterly dependent on these slow, uncontrolled chemistries.

There are two separate chemistries which must be established to have a needed understanding of the process capabilities and risks. The first is the formation of the various alkaline salts which will react with the paper acidity; the second is the neutralization reaction itself. The first type of chemistry is relatively well established, and the oxide will probably react with ambient water and carbon dioxide to form the basic hydroxides and carbonates which will be the active alkaline agents. The eventual formation of the carbonate salts may be likely. It should be noted that the higher solubility of these carbonate salts may greatly affect the rate and efficiency of the neutralization chemistry. To date it is unknown how quickly these transformations will take place. Evidence is needed to support the vendor's claims of what magnesium species are finally formed in the paper.

Similarly, evidence is so far lacking to support PTI's claims that acid neutralization is a rapid process in treated paper. In ordinary paper at ambient conditions, the transport of acidity to the insoluble magnesium salts, or the migration of solution phase acidity and alkalinity, will control the rate of neutralization. Conventional "proof" of acid neutralization, such as pH or alkaline reserve measurements, requires adding copious amounts of water to the sheets, and this will greatly facilitate the progress of the acid-base chemistries. In fact, these measures can only serve to demonstrate that the ingredients necessary to achieve neutralization are present in the paper. To date, there is no direct evidence to demonstrate the rate of neutralization in a treated sheet at normal conditions. Furthermore, for a process which can probably only deposit alkaline agents on the surfaces of heavily sized or calendered paper fibers, the effectiveness of this treatment in rapidly neutralizing acidity present in the interior of the paper fibers is unknown.

Without the detailed information about the species formed in treated papers, it is not possible to make definite claims about other issues relevant to this process. For example, the risk of damage to the paper or other book materials from excessively high pH (above pH = 9 or so) is difficult to assess without knowledge of the salts present. The hydroxide, which is probably formed rapidly (at least on the surfaces of the oxide particles), has a relatively high pH in a saturated solution (10.4) which may be cause for concern. Conversely, if the carbonate species are the major alkaline agents eventually formed, the pH of their solutions will tend to be lower and the risk of alkaline reactions less.

Another concern for this process which cannot be resolved with current information is the nature and fate of the reaction products formed from the neutralization. Since neutralization only takes place following the completion of the treatment, there is no opportunity to remove the magnesium salt neutralization products from the paper, and the consequences of their incorporation into the papers must be addressed. Unfortunately, very little is known at present about such salt additions on paper properties or aging. One would expect that the reactions of hydroxide and carbonate salts have an intrinsic advantage in the release of some of the neutralization products (water and carbon dioxide) which will tend to encourage the reactions to proceed to completion rather than stop at some equilibrium mixture which remains acidic. The use of magnesium salts for the alkaline agents will create neutralization products such as magnesium sulfate or nitrate which tend to be soluble (so they may not inactivate the salt by forming a barrier crust on the particle surfaces), pH neutral, and have no known adverse reactions on paper strength properties.

Until more materials have been tested, the possibility of any adverse interactions with inks, sizes, glues, or other book materials can not be eliminated. The fluid carrier used has a low solvent power for most of the commonly encountered book materials, and it may be the lowest risk of the available alternatives. However, the solvent power of the surfactant/carrier mixture is not documented, and as a result there could be a risk for solubility of some book materials. Similarly, while the chemical stability of the fluid carrier is great enough that the risk of interactions of the residual fluid in the book may be low, the immediate consequences of the surfactant absorption into the book materials and its long-term aging behavior are unknown.

Process Performance

The focus of this evaluation is to assess whether the current process parameters are appropriate to achieve the immediate objective of the treatment: to deposit adequate alkalinity uniformly across the pages of all the books included in the study. All the books were surveyed using a pH indicator (0.04% chlorophenol red) to test for the presence of enough alkalinity to produce an alkaline reaction of the indicator. For the LC blue test books, individual pages were also examined by scanning electron microscopy, to estimate the concentration of magnesium salt particles across the page and within the paper web, and by ICP/mass spectrometry, to quantitatively measure the local salt concentration deposited across the sheets. Cold extraction pH and alkaline reserve measurements were also done to compare the page-average particle loading to the Library specification. These measurements were also performed on those books in the test batch which seemed to contain an inadequate alkaline deposit as measured by the pH indicator, so that it could be determined whether the particle loading was insufficient, or whether the loading was typical but overwhelmed by abnormally high paper acidity.

Because of the large number of materials to be tested, application of pH indicator solution was chosen to provide a rapid qualitative screening for "alkalinity" of the book pages. This test serves two functions: 1) where the color reaction differs after treatment, as a measure of the completeness of the deposition over the sheet area; and 2) where the solution reflects alkalinity, as an indication that the local area now contains enough MgO to render the pH alkaline. An acid indication on a treated page can result from either no particle deposition or a deposit so small as to leave the pH acid after the neutralization reaction has progressed as far as possible. This indicator test alone cannot determine whether there are any particles deposited on apparently incompletely treated areas. For some materials, particularly newsprint or coated papers, the indicator color was often not easily determinable because of rapid color shifts between acidic and alkaline response as the indicator solution dried. For papers containing an alkaline coating over an acidic core, such color reactions may indicate the slow penetration of the solution and eventual neutralization reaction. For treated sheets, it is not known if this occurrence also indicates zones where the local pH varies, or if the process chemistry itself is being altered as the indicator solution carries alkaline salt into regions of poorly accessible acidity. In any event, results are reported only for those tests where the color of the indicator was definite and unchanging.

The pH indicator test was performed on all the paper types included in the LC blue test books. In addition, LC blue test books which had been humidoven aged for 1 and 2 weeks prior to treatment were also surveyed. Of the six paper types included in these books, only the Clear Spring offset, alum/rosin-sized, and newsprint pages tested definitely acidic prior to treatment. Single pages of the Clear Spring offset paper and the alum/rosin-sized paper from all three treated books (oven-aged for 0 weeks, 1 week, and 2 weeks prior to treatment) tested alkaline across the entire page, except for the gutters of the Clear Spring offset in the unaged treated book (patches comprising about half the total gutter area tested acidic); the alum/rosin-sized page from the book oven-aged 1 week (40% acidic in patches in the gutter); and the alum/rosin-sized page from the book oven-aged 2 weeks (about 5% acidic in the gutter). With the exception of these gutter areas, the treatment application over the rest of the pages was apparently complete. For the newsprint pages, the color change of the indicator was not the instant conversion to purple but rather a rapid color shift between acidic and alkaline response, which eventually indicated alkalinity. Since this color shift was not apparent in the untreated newsprint, the treatment is judged to have affected the entire page surface. However, because of the complex color indication, it could not be determined whether this resulted in an alkaline pH over the page. Based on its performance on these LC blue test books, the treatment seems to be reaching most of the page surfaces, but there seems to be some difficulty in controlling the treatment in the gutters. There does not seem to be a trend in the locations in the books where deposition in the gutters is poor. Oven-aged, more acidic materials also seemed to be treated adequately (with the exception of some gutters).

The deposition of magnesium oxide particles on the surfaces and interior of the papers in the LC blue test books was examined directly in a scanning electron microscope. The surfaces of all of the papers tested (Clear Spring Offset, alum/rosin-sized, newsprint, alkaline-sized, Sterling litho gloss, and supercalendered) showed evidence of the deposit of fine particles distributed rather uniformly on the fiber surfaces and in the interstices between the fibers. The images of the cross-sections of the sheets, however, showed no obvious signs of particle deposits in the interstices within the sheets. It could not be determined from the photomicrographs how deeply the treatment was able to penetrate into the paper web. The x-ray fluorescence spectra, which provide semi-quantitative elemental analyses for the areas pictured in the SEM images, are generally consistent with this visual observation. All the surfaces of the treated papers show evidence of the presence of magnesium, but none of the analyzed areas of the interior of the papers, with the possible exception of the newsprint interior, indicate the presence of magnesium. (It should be noted, however, that this x-ray fluorescence analysis is not well suited to detect interstitial materials in cross- sectioned samples, for it will tend to probe the fiber cross-sections which make up most of the imaged surfaces rather than the interstices where the magnesium oxide would be present. A better approach for future analyses might be to analyze the fiber surfaces revealed in the interior of split sheets rather than cross-sections of papers.)

The quantitative measure of the distribution of magnesium salts across the pages of these test papers was provided by the ICP/mass spectroscopic analysis. These data for the six paper types (Clear Spring offset, alum/rosin-sized, newsprint, alkaline-sized, Sterling litho gloss, and supercalendered) illustrate the ability of the process technology to apply the magnesium oxide uniformly and thoroughly across the pages. The results are consistent with the findings from the pH indicator tests. Most of the papers contain an overall uniform deposit of magnesium oxide across the entire sheet, with the exception of the gutter areas, which generally have less (about 30-50% of the average loading). The exception was the alkaline-sized sheet, which had slightly smaller loadings on both the gutter area and the 'top edge' of the sheet (i.e., the area of the sheet near the nominal top of the book). The other remarkable result of these analyses that was not apparent from the pH indicator testing was the variability of the loadings for the different sheets. The average loadings ranged from a high of 0.48% MgO for the newsprint, to about 0.2-0.3% for the three sized papers (Clear Spring offset, alum/rosin-sized, and alkaline-sized), down to 0.15% for the supercalendered sheet and 0.06% for the Sterling litho gloss sheet. This trend suggests that the smoother calendered and coated sheets may have a lesser tendency to adsorb the particles during the treatment, or the particles may be more easily detached from these sheets in subsequent handling. It is also possible that the observed variability in the particle loadings is related to the book structure (i.e., the position of the papers in these test books) rather than on the properties of the papers themselves. More testing is needed to determine if these types of sheets are inherently more resistant to treatment.

Evaluation of the twenty-five book test batch provided a better opportunity to assess the process performance on a wider variety of paper types, sizes, and book structures. As with several papers in the LC blue test books, five of the books in the test batch contained alkaline papers which could not be used to measure the process performance by a pH change from acidic to alkaline. As judged by the pH indicator color, in twelve of the remaining twenty books (60%) the pages were treated completely, and in four of the twenty (20%) the pages were treated completely except for about 1" in the gutter. In another four of the twenty (20%) larger areas of the pages (up to 95% of the page area) were left incompletely treated, and these page areas also tended to be toward the gutter. The ICP/mass spectroscopic analyses of pages from these last four books were performed to determine the magnesium particle distributions on the pages. They generally indicate the low particle loadings in the gutters of the books. More significantly, though, these analyses show that the edge areas of each of the tested pages had sizable particle loadings comparable to those obtained for the pages of the LC blue test books, about 0.3-0.75% MgO. Because the pH indicates acid conditions even in the presence of this particle loading, it suggests that these book papers may have been very acidic originally and that the treatment process parameters that were able to satisfactorily neutralize the LC blue test books papers may have been insufficient to deacidify these very acidic papers. This possibility suggests that such old, acidic papers may be more realistic bench marks for developing conservative process parameters than the less acidic papers of the LC blue test books. More experience should be gained with such old book materials in order to judge the likely outcome on more typical library holdings.

Process Efficacy

The focus of this evaluation is to attempt to answer the broad question of whether application of this treatment is effective in prolonging the useful service life for books. This seemingly simple objective is not so straightforward, however, for it requires both the specification of the quantifiable desired properties which denote "useful service life," and the choice of how to predict the future performance of the treated books. No attempt has been made to resolve these issues, which continue to elicit debate. Instead, the test protocols which the Library of Congress has chosen to perform in evaluating other deacidification processes have been followed here, with some minor additions, for these probably represent the current state of understanding of how to test for future paper performance. The three acidic papers in the LC blue test books (Clear Spring offset, alum/rosin- sized, and newsprint) were examined, and their physical properties (MIT fold endurance, zero-span tensile strength and finite-span tensile strength/stretch/stiffness/energy absorption, and internal tear resistance, each measured in the machine and cross directions of the paper), appearance (brightness, opacity, L/a/b color), and indicators of cellulose chemistry (extraction pH, alkaline reserve, hot-alkali solubility, viscosity DP) were monitored as the papers were aged in a humid oven. Since the changes in the measured properties did not usually occur linearly with time, linear rates calculated for the data are not particularly relevant. Instead, the oven-aging times required for the treated and untreated papers to reach equivalent values were used as approximate measures of the relative degradation rates for that particular property.

With the exception of the tensile stiffness which remained essentially constant, all of the other physical properties measured for the untreated papers declined during the thirty day humid oven treatment.

Treated papers generally tended to show less degradation of mechanical properties than untreated. The most pronounced differences were observed in the fold endurance, which declined about 2-3 times more slowly for the treated sheets of all three paper types. Finite-span and zero-span tensile strengths also declined 3-4 times more slowly for the treated alum/rosin-sized and Clear Spring offset papers, and the other tensile properties (stretch and tensile energy absorption) also showed comparable factors of 2 differences between treated and untreated sheets. For the newsprint, the changes in tensile properties tended to be smaller and less precise, and determining significant differences between treated and untreated sheets was more difficult. However, the overall trend seems to be a slight (factor of 1.5-2) decrease in the rate of decline of these properties for the treated newsprint. For all three paper types, tear strengths for all the treated sheets showed small decreases in degradation rate (factor of 1.5-2) compared to untreated pages.

Aging of these papers in a humid oven changed their appearance, causing them to darken (decrease in measured brightness and lightness parameters) and become less translucent (increase in opacity). The Bookkeeper treatment had no significant effect on these appearance changes, with the possible exception of the Clear Spring offset paper, which seemed to darken slightly less rapidly (by a factor of about 1.5) following treatment.

These measures of mechanical properties and appearance are the quantities which describe the desirable characteristics of the paper, and slowing the rate of their decline is an indicator of the long-term benefits resulting from the treatment. However, addition of the treatment process chemicals can potentially alter not only the rates of reactions but the overall degradation chemistry itself. Should this occur, the premise of these oven-aging comparisons--that treated and untreated sheets are degrading by the same process, so relationships observed at oven temperatures will also apply to room temperature aging-- would be rendered invalid. Unfortunately, there are no probes which allow precise characterization of the degradation chemistries in aging paper. The chemical measures employed here, viscosity and alkali solubility, are very crude monitors of the cellulose component of the paper. Viscosity monitors the molecular weight of the cellulose, or the average length of the cellulose chains. Alkali solubility is also a measure of molecular weight, increasing as the number of chain ends increases (i.e., as the molecular weight decreases), but it is also a measure of oxidation of the cellulose polymer, increasing dramatically as the cellulose chains become oxidized. Taken alone, alkali solubility cannot confirm or disprove cellulose oxidation, so this quantity for now is merely compared during the aging of untreated and treated papers.

The changes in viscosity and alkali solubility have been measured during the humid oven aging of the papers in order to confirm that the changes in these chemical properties are also slowed by the application of the deacidification treatment. The measured cellulose viscosity decreased and the alkali solubility increased for both treated and untreated sheets of all three paper types, which indicates that the molecular weight of the cellulose was decreasing during the aging. This is to be expected, for it is this chemical change in the cellulose that is thought to result in the loss of strength and elasticity of the paper. Unfortunately, with the amount of paper required for each of these measurements, statistics are poor. The alkali solubility measurements appear very scattered and show no significant differences between treated and untreated pages, except for the Clear Spring offset paper whose alkali solubility may have increased slightly less rapidly for the treated than untreated sheet. However, the general trend for the viscosity data seems to be a viscosity loss which occurs about twice as slowly for the treated papers as for the untreated. It is worth noting that this difference in the rate for the cellulose degradation following treatment is approximately the same as that observed for the deterioration in physical properties.

The other two chemical measurements performed during the oven aging of these papers were sheet-averaged extraction pH and alkaline reserve. These quantities were monitored because they are believed to be measures of the protection afforded against future acidity, either formed in the paper or incorporated from external sources. For all the paper types, the untreated sheets were moderately acidic (pH of 5.7-6.5) and became slightly more acidic during the oven aging (pH of 4.1-5.6). Treatment of all the paper types raised the pH of the sheets to alkaline levels, about 9-9.5 for the alum/rosin-sized and Clear Spring offset papers, and about 10 for the newsprint. Subsequent oven aging of the treated sheets caused the pH to fall slightly to about 8 for the alum/rosin-sized and Clear Spring offset papers, and about 9.5 for the newsprint. It is not known whether the slight pH decreases occurring during the aging of the treated sheets are a result of further neutralization of paper acidity or merely the conversion of the magnesium salts from more alkaline to less alkaline ones.

The alkaline reserve measurements indicate this treatment process introduces excess alkalinity which persists essentially unchanged throughout the oven aging. The magnitude of the sheet-averaged alkaline reserve is somewhat low, with the alum/rosin-sized paper and the newsprint showing an alkaline reserve of about 1% (CaCO3 equivalent), the Clear Spring offset paper about 0.7% after treatment. There are reasons to view these data with some caution, however. There is considerable scatter in the data, and the acidic (by pH determination) alum/rosin- sized and Clear Spring offset papers produced measurable alkaline reserves. Alkaline reserve measurements were repeated on a separate set of unaged papers that were taken from another LC blue test book that had been treated with the same process equipment. These results were very similar to the original data (with the exception that the acidic papers had no measured alkaline reserves), and they showed the newsprint with an average alkaline reserve of 1.5%, the alum/rosin-sized about 1.2%, and the Clear Spring offset paper 0.5%.

While the overall performance in the oven tests show benefits of the treatment, it is noteworthy that for decreases in average acidity by factors of 100-10000 (increases of 2-4 pH units), the measured degradation in the oven slowed by factors of 2-4. While this could be evidence that other processes are participating in the degradation that are not slowed by, or may even be aggravated by, alkalinity, it is more likely that this behavior is a reflection of the damage done by local acidity within the fibers before those acids can migrate out to the magnesium salt particles where they can be neutralized. This technology is similar to others in the apparently slight effect it has on paper aging. This effect deserves closer scrutiny, for it calls into question two central issues in this field--the efficacy of such externally situated alkalinity in alleviating internal acid attack, and the reliability of these humid oven tests in accelerating the migration processes as well as the chemical degradation processes.

Process Side Effects

Comparison of all the physical and appearance properties measured before oven aging for the untreated and treated sheets in the LC blue test books indicates that none of the quantities were affected significantly as a result of the treatment. That is, no detectable changes in the papers' mechanical properties or appearance were produced by this treatment, which is consistent with the general lack of side effects and interactions found in the qualitative and visual evaluations described elsewhere in this report. Even the slight chalking or white residues noticed on some treated books in the twenty-five book test batch were not detected instrumentally, probably because sensing of such appearance changes on the unprinted white papers was more difficult than observations of such alterations on glossy, darkcolored materials.

While this process appeared to be free of side effects immediately following treatment, it is likely that the full effects will not be observable until the process chemistry has had the chance to progress, at least as far as the conversion of the magnesium oxide to the active alkaline agents. Since the time when this conversion occurs is not known, it is also unknown whether the evaluation for treatment side effects reported here, occurring several months after the treatment, is adequate to assess the full extent of risks. As a first effort to probe the long-term changes which might accompany this treatment, samples of papers from the treated LC blue test books were exposed to high humidity by suspending them over a water bath in a closed container for 24 hours. A slight but noticeable darkening of the treated newsprint occurred, darkening which seemed more severe for the newsprint samples which had been oven aged prior to treatment. This darkening of deacidified newsprint is a side effect frequently encountered in other treatment processes, but it only occurred following the humidification of the Bookkeeper-treated sheets. While this should not be construed as an accurate appraisal of the potential for such belated after-effects, this observation points out the need for more critical consideration in deciding when and how to assess these risks.

None of the technical evaluations performed here showed clear indications of serious side effects from the high pH values expected for the magnesium salts applied in this process. If there is alkaline damage occurring in the treated papers, the net result of the treatment on the aging behavior still seems to be a net benefit, with the loss of desirable performance properties slowing down after treatment. It should be noted, however, that more thorough study, looking specifically for chemical changes in inks, adhesives, covers, etc., is required to assess fully the possibility of alkaline reactions in these book materials.

Summary

This mass deacidification technology has advantages of simplicity of design in the treatment process, and the results of the treatment are reasonably well-characterized. While the claims about the exact nature of the process chemistry seem plausible, they should be viewed with circumspection until further research has established the nature and rates of the salt conversions and neutralization chemistries in a variety of materials. In fairness, many of these issues--the identity of alkaline agents formed, the nature and fate of reaction products, the effectiveness of alkaline salts in neutralizing acidity which is not in proximity to the alkali--are no less well understood for this treatment than for any other. Nevertheless, the answers to these questions will provide a better basis by which to judge the viability of this process and the risk of other unexplored side effects. It remains incumbent on the vendors to continue these efforts to provide evidence in support of their claims.

Clearly the most immediate obstacle to the success of this technology is its inability to control the application of the treatment to all book materials, and only further experience with the current equipment will clarify its capability. As the treatment was applied to these test materials, the uniform application of adequate alkalinity, especially in the gutter of the book, was not assured. Particle and magnesium salt concentration surveys indicate that deposition does not occur uniformly across pages. While process parameters seem to be adequate for providing overall neutralization of pages in LC blue test books, page-averaged alkaline reserve measurements suggest that even greater particle deposition is needed for these books, for the values attained fall short of the 1.5% alkaline reserve of the Library specification. Performance on the wider variety of book materials in the twenty-five book test batch indicates that the process parameters used may not be conservative enough to deal with more difficult, but nevertheless typical, books.

It is impossible to determine whether the insufficient particle loadings in some books can be rectified with the technology used in August 1993. Some books may simply be much more acidic than the LC blue test books, and may require greater particle loadings. It is also possible that fluid flow through some book structures and/or sticking efficiency of the particles on the paper may be the limitation in particle deposition, in which case it may not be possible to assure adequate treatment by realistic adjustment of the process parameters. Further examination of such difficult book structures (e.g., small, tightly bound or oversewn books whose pages resist fanning) or paper types (smooth, coated, or highly acidic papers) should be helpful in determining whether this problem can be corrected. Only when the process parameters have been adjusted to meet the Library specifications can realistic projections be made about the potential for scaling up to address mass treatment needs.

With the exception of the low particle loading (and consequent nonuniformity of treatment and low average alkaline reserve), the overall performance of this treatment is comparable to that required in the Library specification. The treatments did not measurably affect the physical or appearance properties of the papers in the LC blue test books. The oven-aging tests generally indicated some long-term benefits to the paper as a result of the treatment. Treated papers generally retained their desirable performance properties for 2-4 times longer in the oven, which is comparable to the factor of 3 improvement required in the Library specification. As noted above, initial alkaline reserve values were somewhat lower than the Library specification, but the initial value of the alkaline reserve did not fall during the 30 days of humid oven aging.

In summary, it would appear that the most immediate shortcomings of the process involve the application of the treatment chemicals to book materials, rather than the process technology itself. These shortcomings may be remedied by changes in the process parameters or by modifications of the equipment. At this stage the Bookkeeper process should continue to be viewed as a potentially viable candidate for mass deacidification technology while its performance in treating a variety of library books is evaluated. Rather than focusing so narrowly on the performance on the LC blue test books, particular attention should be paid to developing conservative process parameters to adequately treat "difficult" book papers and structures, so that the capabilities and limitations of the process can be better defined. Further research should also be devoted to supporting the claims of the process chemistry which occurs at ambient conditions.

The physical appearance and condition of collections following mass deacidification are as important to those whose responsibility it is to ensure longevity and access as are chemistry, health and safety, and environmental impact. It was critical, therefore, to include the expertise of a paper conservator in the evaluation process.

Guided by the conservator, and the questions submitted in response to an invitation issued to the library and archival communities through the Conservation DistList, the Team decided to focus on the following potential problem areas: posttreatment color changes of paper and binding materials; instability and color changes of the inks; distortion of the textblock or the paper; residual effects such as chemical rings or blemishes; damage to adhesives; damage to labels, pockets, or security tags; distortion or damage to plastics or binders; damage to case bindings, covers, book cloth or leather; and noticeable odors.

Twenty-five books, in addition to the mandated LC blue test books, were selected to provide a range of ordinary materials similar to that found in libraries. After they were cut in half, the Team inserted rubber bands, paper clip, and staples, and marked them with a variety of inks, pencil marks, and marker pen colors. Each Team member used a form designed by the Team to record observations resulting from a comparison of the treated with the untreated half. This report is based on the conservator's expertise and the Team evaluation. The questions she poses for PTI result from this work.

A Paper Conservator's Evaluation of the Bookkeeper Deacidification Process

Wendy Bennett

The Bookkeeper deacidification process is assessed by a paper conservator. The treatment is impressive for the minimal preselection of materials, improvement in general cleanliness of the books, lack of observable color changes in all book components, lack of discernible odor, and absence of physical distortion of the book block. The presence of small clamp impressions in several of the book covers, the slight chalky feel of some of the book pages, and an increased tendency of the printing inks on coated paper to rub off slightly are the less desirable qualities of this deacidification process as it was tested in 1993. It should be noted that PTI has been continuing to develop and improve their product since the time of the test.

Introduction

This section of the report presents an evaluation of the Bookkeeper deacidification process from the point of view of a conservator. Typically, the treatment of acidic paper materials accounts for a large percentage of a paper conservator's workload. Some of this time is spent in an effort to deacidify and stabilize papers damaged by the destructive process of acid degradation. This gives the paper conservator a unique perspective from which to evaluate a mass deacidification process such as Bookkeeper.

There are two main contributors to the making of an acidic paper: one is airborne pollution and the other is "inherent vice," i.e., the original materials composing the paper (chiefly lignin and alum-rosin sizing) are inherently poor quality. In addition to acidity from atmospheric pollution and the manufacturing process, acidity in paper can be the result of proximity to poor quality secondary materials such as ground wood pulp cardboard, wooden backings and cross-linked glues or pastes. Heat and moisture tend to catalyze the degradation process, i.e., unregulated temperature and humidity, a situation common in many libraries, historical societies and archives, speed up deterioration. If the acidic process is allowed to continue unchecked, originally flexible papers will readily break apart with even the most gentle handling. If paper is acidic, because of internal or external factors, conservation procedures can never completely reverse physical deterioration but can slow it down.

Paper conservators generally counter the effects of acidity in paper by raising its pH to about 8.5-9.0 by means of a final aqueous bath or aqueous spray application. Solutions of earth metal salts of calcium or magnesium such as calcium hydroxide, calcium carbonate, or magnesium carbonate are commonly chosen for the job. The alkaline reserve helps to neutralize the acidity in the paper and counters future reacidification from the storage environment.

This process is similar to what Bookkeeper is attempting to do on a mass scale, although rather than using water, the carrier fluid for the MgO is a perfluorocarbon suspension in a surfactant. The presence of the surfactant combined with the agitation process ideally allows dispersion of the MgO to all parts of the books. Because other sections of this report feature the actual mechanics (Domach) and chemistry (Whitmore) of the Bookkeeper process, this section will focus on the look, feel and smell of the treated books and note how they compare with the control samples.

Testing

Twenty-five test books were cut in half. One half of each was labeled and dipped in the Bookkeeper solution at the PTI facility. The books ranged from pulp paper pages with newsprint covers and stapled bindings to engraved plates within a gold-tooled leather cover. A brief visual description of each book can be found in Appendix C. Additionally, marker pen was applied to several books, and post-it notes and paper clips to several others, to see how these three types of materials often found in libraries and archives would perform with Bookkeeper.

A condition evaluation checklist was drawn up. Treated and untreated book halves were compared for mechanical and cosmetic differences as well as for odor, abrasion testing, and the existence of surface deposits.

Observations and Questions from Empirical Testing

Cleansing action and odor. When the data was compiled from the empirical tests, it was noticed that items showing surface grime emerged slightly cleaner from the tank. In addition, in at least four instances, the treated book half was lacking the musty odor of the untreated half which suggests that though not water-based, the Bookkeeper solution somehow physically refreshes the books. The cleansing action of the surfactant would probably account for this situation. As a result of this occurrence, questions arose for the Team. What became of the dirt that was rinsed away from these materials? How often is the Bookkeeper solution filtered and recycled? Is the solution filtered completely enough to avoid deposition of dirt on other materials? The fact that the books emerged cleaner and free of odor is interesting and reassuring for both librarians and archivists.

Post-it notes, paper clips, and marker. None of the post-it notes or paper clips showed any change in appearance between treated and untreated book halves. None of the ordinary underliner marker inks changed colors. There was a change in the ink of a blue felt tip marker applied to the text previously (not by Bookkeeper evaluators) which turned green on the test half of book. It was discovered that this marker was pH sensitive. Consequent testing revealed that the color change was common when this ink was exposed to alkaline materials, in general, and not to the Bookkeeper product, in particular. It should not be considered a problem except, possibly, for other pH sensitive pigments or inks.

High pH. Although the deleterious effect of a low pH on paper is commonly acknowledged, aside from possible changes to inks and media at pH levels past 10, the effects of too high a pH seem less clearly agreed upon and understood. Apart from concerns about media, Some[3] believe that cellulosic materials might be damaged by high alkalinity (pH 9.5 and above) while others[4] feel that it is not paper degradation but the possibility of color change that presents the most risk at elevated pH levels. Conservators have noted color changes to pigments, dyes, and inks at pH levels higher than 10.0 as well as deterioration of the paper supports, especially those containing ligneous wood pulp. Therefore, a critical eye was turned to the test books with regard to color change. The empirical testing revealed that none of the Bookkeeper treated materials showed any observable color change whatsoever, except for the aforementioned pH sensitive marker.

In regard to concerns about possible damage to cellulosic materials from the high pH, it was noted on visual inspection that none of the tested book papers or covers exhibited physical degradation or damage. Several questions come to mind concerning the high pH created by any deacidification process. Is pH exceeding 9.5 too high for book papers? Is the sudden change from an initial pH, possibly as low as pH 3, to one as high as pH 10 too drastic a shift? What are the long-term effects, if any, on library and archives materials from the magnesium compounds used to achieve the pH seen in the Bookkeeper process? These are questions that should be asked of any deacidification agent and that can be addressed in further studies.

Alkaline reserve. The Library of Congress requires a permanent and stable alkaline reserve meeting a minimum amount of 1.5% CaCO3 equivalent. They will also consider processes which introduce a lesser concentration of alkaline reserve provided that they offer equal protection against atmospheric pollution. However, Bookkeeper does meet the Library's minimum specifications. In sixteen out of twenty-five treated books, the physical presence of the alkaline reserve was noted by empirical testers, who characterized it as variably "gritty" or "chalky." This phenomenon was especially observed in books and book covers made of coated papers. Even though examiners did not, at any time, feel compelled to leave the testing room in order to wash hands, in retrospect, it might have been helpful to clean hands after handling a book so as to get a "fresh feel" of each subsequent book.

The presence of the alkaline reserve was subtle but nonetheless noticeable to the committee members on 64% of the books. This raises the question of whether the alkaline reserve could be adjusted slightly to retain more of the original "hand" of the paper while still meeting the Library's specifications. Aside from the aesthetic concern of how the alkaline reserve affects the feel of the paper, the Team raised issues of health and environmental safety which were referred to the EPA.

The Bookkeeper vendors stated that the MgO does not pose a health risk. PTI characterizes magnesium salts as "practically non-toxic by oral administration,"[5] though they do report that acute exposure to large amounts of MgO in a particle size exceeding the one used in Bookkeeper can cause respiratory tract irritations. Karl P. Baetcke, Chief of Toxicology Branch I, Health Effects Division, EPA, states that in "...address[ing] the use of MgO...no concerns were expressed."[6]

Rub-off and Abrasion Testing. When a soft cotton ball was rubbed gently in a circular motion on the treated book papers, a few of these materials, particularly colored plates on coated papers, showed more rub-off of some colors of ink than seen in the corresponding control group. Furthermore, the pressing of a finger to the surface of the dark-colored plates on treated, coated paper left an impression, but the inks above the surface did not smear or show softening when in contact with bare fingers. Deciding that this development required more systematic testing, the Team took a selection of books to the Graphic Arts Technical Foundation (GATF) in Pittsburgh, PA, for further evaluation.

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[3] Ann F. Clapp. Curatorial Care of Works of Art on Paper, 3rd edition. (New York: Nick Lyons Books, 1987), 25.
[4] Chandru Shahani, Ph.D., interview by author, 17 May 1994.
[5] Preservation Technologies, Inc., "Health and Environment Issues" (Unpublished report, August 1993), 2.
[6] Baetcke, Karl P. Letter to Kenneth E. Harris, September 12, 1994.

Review of toxicological data submitted in support of Preservation Technologies, Inc., proposal for a mass deacidification process. Five books were selected for abrasion testing. A variety was sought, including several printed on the coated paper stock that presented the most problems in initial rub-off tests. In one case, the color on the cover of a book showed posttreatment color transfer, but because the cover was too thick for placement on the testing apparatus, this book could not be tested. The books that were selected are as follows:

- #4 text block ink on noncoated paper
- #9 colored plates on coated paper; black and white text
- #19 color plates on coated paper; black and white text/plates on coated paper
- #21 black and white illustrations/text on coated paper
- #24 color plates on coated paper.

The Gavarti Comprehensive Abrasion Tester (ASTM D5181-91) was used to analyze the rub-off. In this test, a four-inch square sample of 20# bond paper was placed facing an identically sized sample from each of the test books. These materials were held rigidly by the machine's instrumentation while moving them rapidly up and down for twenty-five seconds. The 20# bond paper was then examined for offsetting of inks. In a few test cases, a density meter was employed to determine the relative lightness value of the abraded samples. Because the density meter was not sensitive enough, all colors registered at approximately the same value. (Black/cyan/magenta/yellow all registered approximately 1.5.) For this reason, testing of lightness values was discontinued.

In each case, the rub-off from the treated samples of coated papers was visibly darker than those of the untreated controls. Although the noncoated papers fared better, decreased rub resistance was also noted in the selected posttreatment noncoated papers. Since there is currently no way to scientifically quantify the extent of the rub-off by the Gavarti tester, it was, by visual examination alone, noted that the samples treated by the Bookkeeper process displayed approximately two to three times as much rub-off as did the controls. In addition, there was perceptible abrasion to the samples as a result of the testing that took the form of tiny striations on the surface of the paper. These interruptions to the printed surface of the paper were present in the control samples as well but were slightly more obvious in the treated samples, suggesting that the particles of magnesium oxide may have abraded the surface coating of the paper and taken some of the ink along with them. It is important to note again that no smearing of inks was observed, but rather it was the friction of the magnesium hydroxide particles against the surface coating of the paper that in all likelihood caused the rub-off. Granted, library books in general circulation will not be subjected to the strong friction of the Gavarti apparatus, but the question arose in the Team of what the long-term effects could be of more subtle actions such as page turning and photocopying? If the process seems to cause abrasion to the surface of coated book papers, is the process at all microscopically abrasive to the paper below the coating? Would there be any potential for damage to the sizings, adhesives, glues, thread, and other binding components found in library materials? It should be noted that the grittiness or chalkiness commented on previously is probably the same phenomenon causing this rub-off. Clearly, this is an area that may call for further research and testing.

Impressions from clamp. Another posttreatment phenomenon was the appearance of small indentations visible on the corner edges of the covers of seven books. This apparently occurred because the clamps used to fasten the books to a dot-perforated grid left two thumbnail-shaped impressions on either side of the cover. Though changes such as these to the original appearance of an object are unacceptable from a conservation point of view and are grounds for complaint, the problem has been addressed in the latest version of the Bookkeeper process. Because the new development falls outside the time frame of the current report, future testers should pay attention to the possibility of impressions caused by equipment.

Summary

If chemical and physical testing reveals that the Bookkeeper process successfully and safely deacidifies books, the concerns raised here do not warrant rejection of the process. The book halves in the study that were treated by the Bookkeeper solution were impressively similar to the untreated halves in almost every way. True, some of the treated halves do feel slightly chalky, but this phenomenon seems to be the baseline for materials deacidified with magnesium compounds when used in a nonaqueous suspension. Further testing will determine if the clamp impressions and decreased rub resistance seen in test books treated in August 1993 are present in materials processed using the latest Bookkeeper technology. Since the vast majority of general circulating library materials, such as those represented by our test batch of twenty- five books, does not include rare or special collections material, the Bookkeeper process does represent a viable solution to the rapid physical deterioration plaguing most library materials today.

Some of the most pressing issues to arise from the consideration of the Bookkeeper deacidification process are those related to library and archival preservation and collection management. No deacidification process will be effective or suitable for all collection materials. Those librarians who choose to make use of mass deacidification, one of many viable choices for preserving collections, must understand the process and have realistic expectations about its capabilities and its effects. In her effort to address these issues, the rare book librarian has pointed out the need to communicate, evaluate, and to work in partnership with the process vendor to ensure the best possible outcome.

Issues to be addressed include the appropriate selection of material for treatment, the logistics of shipping and receiving, the care and handling of collections during treatment, and the examination and monitoring of treated items by libraries or archives.

Additional opportunities for cooperation and dialog among vendors, librarians, and scientists are apparent. How will libraries pay for deacidification? Should there be a coordinated effort nationally to deacidify primary resources as well as those important to local collections? What scientific issues related to deacidification remain unexamined? In what venues might materials be treated to ensure cost-effectiveness, i.e., regional centers, library binding companies, individual libraries, or archives?

The following report raises and addresses many of the issues important to librarians and archivists. It is hoped that the larger conservation and preservation communities will consider them and the others which will arise.

Mass Deacidification in the Library: A Rare Book Librarian Considers Bookkeeper

Charlotte Tancin, M.L.S.

This report includes a rare book librarian's observations on the issues of handling and logistics, as well as on observed side effects which may suggest guidelines for selection of library materials for mass deacidification. As with any mass treatment process, Bookkeeper is recommended for circulating and research collections rather than for rare book and other special collections. Although only bound, published material was treated and evaluated in these tests, the Technical Evaluation Team recognized that archival collections would also benefit from the development of a reliable mass deacidification process. Twenty-five treated items were subjected to empirical testing for the presence of visual, tactile, and olfactory side effects resulting from processing by Bookkeeper. A checklist was developed and used for the evaluation. Many of the negative side effects seen with other treatments are not in evidence with the Bookkeeper process.

Empirical Evaluation

Beyond determining what the Bookkeeper process does to benefit paper--how, whether, and how well the treatment works according to Library specifications--the Technical Evaluation Team also tried to ascertain what the process does to paper (as well as to ink, adhesive, cover material, and other book components) and whether any discernible changes resulted. In particular, the Team wanted to respond to the concerns of the preservation and conservation fields related to specific undesirable side effects. Empirical tests were added so that Team members could look for potential problems in a variety of typical library materials.

In addition to the testing done by the Institute of Paper Science and Technology on the LC blue test books fabricated and supplied by the Library of Congress, empirical tests were also performed by the Team on another, supplemental test batch of twenty-five items which were collected from local libraries. Each of the items was cut in half. One half was treated and the other half retained as a control. The twenty- five treated halves were not subjected to laboratory testing, but instead were examined by Team members who compared them with the control halves for perceptible side effects such as color changes, physical deterioration, odor, and surface deposits. This small sample, which was representative rather than comprehensive, included materials typically found in circulating and research collections.

Observable Effects

In most cases, few perceptible side effects on treated material were observed. Test items sometimes emerged from treatment cleaner than the corresponding untreated halves. No odor was perceived after the treatment. In fact, in some cases, a musty smell, obvious in the control half, was removed by the treatment. The clamps used to hold test materials in the August 1993 tests left impressions on the covers of some of the books.

There was a chalky deposit, visible or, more commonly, palpable, observed in several cases. No color change resulted from treatment, except in the case of a pH sensitive marker, and no feathering of inks or pigments was observed. When illustrations on coated paper were rubbed with cotton balls, slight rub-off was observed in some cases. This ink did not come off on fingers, nor did it offset onto facing pages.

No effect on the call number labels and bar codes affixed to book covers in the selected library test batch was noted. There was no blistering, lift-off, or damage. This is good news from the point of view of posttreatment library processing. Treated books displayed no color change on their covers or damage to adhesives.

Following treatment, the test books exhibited no evidence of blocking, sticking, swelling, cockling, or any other distortion which would make the treatment less acceptable to librarians. From the empirical perspective, Bookkeeper is in many ways an attractive process because it eliminates undesirable side effects.

Selection

Once the efficacy of the Bookkeeper process and its relatively benign nature have been determined through laboratory and empirical testing, it is important to consider what type of collection materials are appropriate to select for mass deacidification. The potential effects of the mechanics of the treatment process on the material, as well as the effects and side effects of the deacidification process itself are factors in this decision-making.

As with any mass deacidification process, the items chosen for treatment should be limited to mainstream research or circulating collection materials. These collections, determined to be of long-term value, are good candidates for treatment before they become brittle. Many archival collections may also be appropriate for mass deacidification. However, archival materials were not tested as part of this project. Interested members of the archival community may wish to be involved in future testing.

Faced with difficult questions such as whether to concentrate on deacidifying new acquisitions or rather on those books already at risk, librarians will need to set priorities carefully based on local collection risk and use. The simplest and ideal solution would be to mass deacidify entire collections with no preselection, except perhaps for those items obviously too fragile or deteriorated to treat. Librarians should assume the presence of materials in every collection which are not appropriate for treatment. Few libraries, of course, except the Library of Congress, have the financial resources to contemplate treatment of entire collections. The rest of us will be faced with the need to set priorities among our collections.

The establishment of local guidelines will make possible the identification of materials appropriate for mass deacidification as well as of those items which should never be treated. Because there are a number of idiosyncratic issues relevant to preselection decision-making, some libraries will have few items to be deacidified, while others may invest significant time in establishing procedures to exclude materials from mass deacidification.

Special Collections. Special collections in general should not be treated in a mass process. Although little damage to materials was observed in these tests, special collections and rare, unique, or exceedingly valuable items should be assessed individually by a conservator who will be aware of potential effects of deacidification and handling as well as the special needs of those materials. The conservator can then make recommendations or perform treatments as appropriate. Items having artifactual value (that is, they have value as objects beyond their information content), warrant extra care in handling. The library's guidelines for preselection must reflect these issues.

Brittle Paper. Because no deacidification process can restore brittle paper, books whose paper is already embrittled are inappropriate for mass treatment. If items are fragile or deteriorated to the extent that handling would harm them, they, also, should not be sent for mass treatment.

Working with the Vendor

The librarian contemplating mass treatment will want to establish a dialogue with the vendor. Through this communication with prospective clients, the vendor can contribute to the development of selection guidelines and of a framework within which to discuss the special needs and concerns of the library. Mutual understanding will simplify procedures for both the vendor and the customer. For example, because of the necessary unpacking and repacking of books from the boxes which are used to transport the materials to and from the treatment facility, guidelines should be developed for packing and shipping. Librarians will want to ensure that there will be specifications for appropriate care and handling of the materials at the treatment facility.

PTI may wish to consider consulting with preservation experts to develop selection guidelines for treatment and for handling of materials sent for treatment once the process has been scaled up. The guidelines would address routing and handling of materials through the physical plant, the mechanical process, treatment work flow, and other issues. Such guidelines will be useful to customers who are choosing and sending collection items for treatment. They would also assist PTI staff in making decisions about items submitted for treatment which may be too fragile or damaged to treat.

Some potential issues were not addressed in the course of the testing, but could easily be explored. The physical process of immersion and mild, continuous agitation which characterizes the Bookkeeper process could dislodge or damage loose sheets or other material during treatment. However, no floating loose pages, unfolded maps, or damage to mounted plates were observed during the processing of the test batch. Only a few mounted plates and folded maps were included in the test batch. Evaluation after treatment of folded paper charts and maps in book pockets or of mounted plates and maps will indicate whether there is any damage or problem related to complete treatment.

None of the test books had pockets containing supplementary material in nonpaper formats such as microfiche, plastic overlays, or computer disks, but the growing presence of these formats presents yet another challenge. In some library collections such supplementary material is stored separately, while in others it is left in the pockets in which it was originally contained. Although not of primary importance to all collections, it will be a matter of interest for some librarians. Guidelines for treatment and handling will help highlight potentially problematic areas and create awareness for new users.

Logistics

In addition to the mechanics of the treatment process, the logistics of the Bookkeeper process are of interest to librarians. Books to be treated would be unpacked from the boxes they were shipped in, opened and individually fastened to the racks for treatment, removed from the racks after being treated and dried, and repacked for return shipment. This handling should present no problem for books in good condition from circulating and general research collections, and, in fact, would probably produce no more stress on such books than they would sustain through normal use, circulation, photocopying, and interlibrary loan.

In August 1993, the PTI personnel involved in the treatment exhibited care in the handling of the test materials. However, as the process is scaled up, training for PTI staff will become increasingly important. Training would introduce the staff to the appropriate handling of library materials, according to preservation standards. This will enable them to recognize preservation concerns which might arise in the wide range of materials that make up typical library collections. By making available staff training, seeking advice, and/or adding persons with appropriate knowledge and training to the treatment staff, PTI can minimize potential damage to the materials and alleviate any concerns of librarians.

One further matter of logistics should be mentioned. Librarians opting for mass treatment should be prepared to monitor the pH of their collections after treatment just as they monitor the results of other preservation activities. Pretreatment pH testing by the library is recommended not only to determine how much of the collection warrants treatment, but also to provide a baseline of information against which to assess and monitor treatment efficacy. After treatment, an ongoing program of random retesting is recommended to check treatment results and to monitor pH. And, as with all such collection assessments, keeping statistics is recommended to make sense of the data as well as to exploit fully its usefulness.

Conclusion

In conclusion, aside from the few effects noted in this report, little physical change in treated items was observed, making the Bookkeeper process a good potential option for deacidifying mainstream circulating and research collections. As noted above, rare books and special collections should be considered separately because the librarian must consider how treatment could affect value. The safest approach is the individual treatment of any items of artifactual value which warrant deacidification.

Books are such complex, composite objects that it would be difficult to ascertain in advance and guarantee with absolute certainty that a given book will sustain no undesirable effects from mass treatment. One can, however, get a feel for the odds, weighing positive results against potential side effects in order to make a decision. Based on examination of the limited test materials treated in August 1993, it seems likely that library materials of the type included in the test batch will sustain no damage.

APPENDICES

Most of the following Appendices are not available in the electronic version of this document:

Appendix A: Report of the Institute of Paper Science and Technology, Inc.

Appendix B: Report of the Environmental Protection Agency.

Appendix C: Description of the Twenty-Five Additional Test Books:

1. gold-tooled leather; gilt-edged; foxing on engraved plates; interleaved foxed, acidic tissue
2. Australia; fold-out, color-printed maps on hard-finish tissue; coated paper; yellow highlighting top/bottom on page 15
3. plastic book jacket; paper jacket; pyroxyline-coated publishers' binding
4. foil stamping on blue cover; typical size and publication date; marked with felt-tip marker and highlighter
5. red cloth binding; coated paper; gold tooling on spine; black and white plates; signatures
6. Eastern Europe; stapled; pulp paper; journal; rough paper cover
7. stapled; mimeographed
8. clear plastic cover; plastic spiral bound; plastic adhesive label on spine; photocopy
9. large size; black and white illustrations on text paper; color plates on coated paper; spine label; coated cloth binding
10. Gaylord pam binding; brown tinted ink; selin label; date-due pocket; book plate
11. India; journal; green paper cover; lavender-tinted paper; plates on white coated paper; sewn binding
12. sewn; plasticized cover; color illustrations; coated paper
13. China; journal; poor pulp paper; colored illustrations on coated cover paper
14. sewn; brittle; calendered; remainder of paper cover on spine; no other cover
15. South America; adhesive binding; blue-coated paper cover; good pulp paper
16. Jordan; stiff green paper plasticized cover; adhesive binding; calendered paper for text; black and white illustrations on coated paper
17. paper dust cover; cloth book tape spine; paper-covered boards; plain paper
18. bright blue cover; gold tooling on spine; colored maps on end papers
19. red paper cover, gold tooling; deteriorating tape on spine; bar code; color illustrations on coated paper; tinted pages and nontinted newsprint; thick large book; adhesive binding
20. Western Europe; mutilated; black cloth cover; gold stamping on spine; selin label; bar code; pulp paper; date-due pocket; stamped with red ink
21. typical trade paperback; thick; adhesive bound; plates on coated paper
22. badly repaired and falling apart; black cloth binding; clear adhesive tape on spine; bar code; block of plates on coated paper; maps on end papers, stamped with red ink; gold tooling on front cover is worn off
23. thick paper back; paper cover; signatures; adhesive spine
24. portfolio style; collection of color prints on coated paper mounted on one edge on calendered paper; boards exposed along spine; book cover is torn
25. plastic spiral bound; hand covered with brown paper wrapper; hand written title in black ink; bar code; call number label, date due pocket; original cover has mounted color illustrations; color plates on coated paper mounted on black paper; black and white illustrations and text on coated paper; exposed boards are faded black

Appendix D: Summary of the Tests Performed:

A. Tests of process results: amount and distribution of applied particles.

1. SEM pictures of deposited particles and uniformity of deposit on paper surfaces and interiors
2. X-ray fluorescence spectra for semi-quantitative measure of magnesium particle location
3. ICP/MS analysis to determine total particle deposit and uniformity of deposit (Also done on 4 library books which failed pH spot tests)
4. Cold extraction pH
5. Alkaline reserve
6. "Completeness of deacidification": indicator spot tests with 0.04% chlorophenol red

B. Tests of efficacy in oven aging.

1. MIT fold endurance
2. Tensile properties (tensile strength, stiffness, stretch, tensile energy absorption)
3. Internal tear resistance
4. Zero-span tensile strength
5. Opacity
6. Brightness
7. Color (L*, a*, b*)
8. Retention of alkaline reserve
9. Viscosity DP
10. Hot alkali solubility

C. Tests of side effects.

1. Measured properties above for unaged papers, treated vs. untreated
2. "Condition evaluation"

Appendix E: Report of Preservation Technologies, Inc.