ISSN 0034-5806

RESTAURATOR

International Journal for the Preservation of Library and Archival Material

Volume 7 · Number 3 · 1986

MUNKSGAARD · COPENHAGEN

RESTAURATOR, *International Journal for the Preservation of Library and Archival Material* is published quarterly. Subscription price 1985–86: D.kr. 456.00 including postage (US$ 55.00, £ 38.00, DM 132.50). Payable in advance. Prices are subject to exchange-rate fluctuations.

Subscription orders should be sent to MUNKSGAARD International Publishers, 35 Nörre Sögade, DK-1370 Copenhagen K, Denmark, or to any bookseller.

Printed in Denmark by AiO Print Ltd., Odense 1986.

Paper Deacidification: A Bibliographic Survey
Part II

by DANIELLE MIHRAM

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5. SURVEY STUDIES OF METHODS

Deacidification of Paper (Conservation of Library Materials, Bulldog Clip no. 7). APLA Bulletin, 42(4): 4–5 (Jan. 1979).

A description of the several methods in use and under study: W. J. Barrow one-bath and two-bath methods; D. Baynes-Cope; G. Kelly (Library of Congress); W. H. Langwell; R. D. Smith (Wei T'o®).

Banks, Paul N.: *The Preservation of Library Materials.* Chicago: The Newberry Library, 1978. (Reprint of Banks (1978), below).

Banks, Paul N.: *The Preservation of Library Materials.* pp. 180–222, Vol. 23 (1978) of the Encyclopedia of Library and Information Science (Kent A. et al. (eds.), N.Y.: Marcel Dekker, 1978). Reprinted in 1978: see Banks, above.

A short note, in the section "Paper Treatment" (see pp. 201–02), on the three main deacidification processes: aqueous, non-aqueous, and vapor.

Banks, Paul N.: *Some Problems in Book Conservation.* Library Resources & Technical Services, 12(3): 330–38 (Summer 1968).

Suggestions are made for less destructive methods of binding (in addition, criteria are listed for the selection of binders for rare books). Several methods of deacidification of bound books are noted (British Museum Research Laboratory, W. H. Langwell, R. D. Smith, and Washington State University). The paper concludes with the note that book conservation should be elevated from the level of housekeeping to a specialized profession.

Belov, Gennadyj: *New Techniques, New Materials and New Experiences Concerning Restoration of Documents and Seals and Preservation of Maps and Plans and Photography Since 1950.* Archivum, 10: 72–80 (1960).

A survey of the preservation techniques used in several Eastern European countries (Bulgaria, Hungary, Poland, Roumania, East Germany, Czechoslovakia, and the USSR). Only one short paragraph deals with the subject of deacidification of paper: in the USSR records are placed in an air-tight cupboard and unfolded over a slightly concentrated solution of ammonia (see p. 75).

Recommendations for Repair and Allied Processes for the Conservation of Documents. Part 1: Treatment of Sheets, Membranes, and Seals. London: British Standards Institution, BS 4971, Part 1 (Dec. 1973).

Section 7 (p. 7) of this booklet deals with aqueous and non-aqueous deacidification, descriptions of which are given (immersion in aqueous solutions; aqueous sprays; immersion in non-aqueous solutions). Appendix B (p. 12) describes methods used to determine the pH value of paper. Appendix C (pp. 13–14) is a set of "recipes" for the preparation of deacidifying solutions, as well as a description of tests to be conducted so as to determine the degree of deterioration over time of the prepared solutions.

Brock, J. A.: *A Program for the Conservation and Preservation of Library Materials in the General Library.* Berkeley, CA: Univ. of California Press, 1975.

A comprehensive program for the conservation and preservation of library material is outlined. The section dealing with deacidification (pp. 14–19) is a survey of the various methods of deacidification.

Browning, B. L.: *Deacidification.* pp. 323–24 of Analysis of Paper. N.Y./Basel: Marcel Dekker, 1977 (2nd ed., rev., expanded). For book review of first edition (1969), see Dupuis (1970), below.

The aqueous (Barrow) and non-aqueous deacidification methods are briefly noted with the recommendation that a desirable deacidification process should leave a residue of base (e.g. calcium carbonate or magnesium carbonate) in the paper as neutralizing protection against future oxidation by organic compounds and acidic atmospheric contaminants.

Bruce, James: *Deacidification.* pp. 11–13 and 35 of Notes on Paper Conservation. Queensland: The State Library, 1981.

Detailed algorithms for aqueous and non-aqueous processes are given, and the advantages and disadvantages of the two methods are tabulated.

Clapp, Anne F.: *Acidity.* pp. 17–28 of "Fac[illegible] Harmful to Paper", in: Curatorial Care of Works of Art on Paper. Oberlin, Oh[illegible] Conservation Association, 1978 (3rd rev. ed.).

Introduces the reader to the causes of acidity in book papers and notes the various methods of deacidification (aqueous, non-aqueous, vapor). Footnote 28 (p. 19) constitutes a short bibliography on deacidification (10 items). Cautionary notes are included regarding the indiscriminate use of deacidification procedures; the deacidifying of papers of value is not recommended. The various commercially available acid-base indicators are also discussed.

Cunha, George Martin & Norman Paul Tucker (eds.): *Deacidification.* pp. 175–80 of Library and Archives Conservation. Boston: Library of the Boston Athenaeum, 1972 (Boston Athenaeum Seminar 1971).

Chemical factors causing acidification in paper are discussed. An evaluation of the advantages and disadvantages of various deacidification methods (British Museum Laboratory, Langwell) constitutes the main part of the discussion.

Cunha, George & Dorothy Cunha: *Conservation of Library Materials. A Manual and Bibliography on the Care, Repair, and Restoration of Library Materials.* Metuchen, N. J.: Scarecrow, 1971 (2nd ed.) 2 vols. (First ed.: 1967).

Appendix 5 of Vol. 1 is a short note on the methods devised by W. J. Barrow, A. D. Baynes- Cope, W. H. Langwell, O. J. Schierholtz, and R. D. Smith. In Vol. 2 (Bibliography) a section on deacidification (26 items) appears on pp. 279–81.

Darling, Pamela W. & Sherelyn Ogden: *From Problems Perceived to Programs in Practice: The Preservation of Library Resources in the U.S.A., 1956–1980.* Library Resources and Technical Services, 25: 9–29 (1981).

A historical review of the major events, activities, and publications which have contributed to the emergence of preservation as an important specialty within the field of librarianship. Pages 17–18 deal with the topic of published research on deacidification.

Edwards, Christopher John: *Some Aspects of the Sorption of Sulphur Dioxide on Paper.* Unpublished Ph. D. Dissertation. Victoria Univ. of Manchester, May 1967.

Aspects studied are: the long-term rate of sorption: effects of furnish, rozin size, metalic compounds, sunlight, and humidity (including sweat derived from fingerprints) on the sorption. Experimental results and tables are given. A brief notation on the subject of deacidification appears on pages 25–26.

Harris, Carolyn: *Mass Deacidification – Science to the Rescue?* Library Journal, 104(13): 1423–27 (1979).

A survey of the various methods of deacidification (early attempts: aqueous (Barrow), non-aqueous, vapor; current developments: mass deacidification, liquefied gas, morpholine process) leads to the conclusion that mass deacidification is only a limited solution to book preservation: While useful for books that are important to preserve yet are little used, the method should be combined with other approaches dealing with preservation.

Kathpalia, Yash Pal: *Deacidification.* pp. 104–20 of Conservation of Archive Materials. Paris: UNESCO, 1973. (Documentation, Libraries and Archives: Studies and Research Series, no. 3).

The various processes developed for deacidification of paper are discussed (aqueous, non-aqueous, gaseous or vapor). For each method a description (including diagrams) of the technique, as well as an evaluation of the results of each method used, are provided.

Kathpalia, Yash Pal: *Deterioration and Conservation of Paper IV: Neutralization.* Indian Pulp and Paper, 17(4): 245–51 (1962).

Wet and dry processes of deacidification (termed "neutralization" by Kathpalia) are discussed, and "recipes" for the various solutions are given.

Kelly, Jr., George B. & Stanley Fowler: *Penetration and Placement of Alkaline Compounds in Solution-Deacidified Paper.* Journal of the American Institute for Conservation, 17(2): 33–34, 1978.

A series of brief studies led to the following 3 results: 1. in deacidification with magnesium bicarbonate solutions, papers from an old book took twice as long (80 min) to achieve the equilibrium alkali content in 2.13g/l solutions as in 8.5g/l solutions. Methanol (10%) in the solution greatly shortened the time required; 2. During the drying period, migration concentrated the alkali at the surface of the paper (3.1 ratio, surface to interior). High humidity heat treatments increased the ratio, but freeze-drying lowered it to 1.5:1.3. In non-aqueous deacidification, solvents cause the alkali to lag behind the solvent front as it penetrates the paper. The authors warn that those studies are not exhaustive and serve as explanatory guides to our understanding of such problems.

Kelly, Jr., George B.: *Practical Aspects of Deacidification.* pp. 91–105 of Archives et Bibliothèques de Belgique Special Issue 12, 1974. Appeared earlier in Bulletin of the American Group – International Institute for Conservation 13(1): 16–28 (1972).

Tests were devised to evaluate the various deacidification processes: Barrow two-step method, Barrow single-step method, Baynes-Cope, Smith, Ruff, Langwell, Kathpalia. Conclusion: each method has something to recommend it and each suffers from certain disadvantages (some more than others).

Kelly Jr., George B.: *Practical Aspects of Deacidification.* Bulletin, American Institute for Conservation of Historic and Artistic Works, 13(1): 16–28 (1972).

An almost identical version of the paper appearing in Archives et Bibliothèques de Belgique Special Issue 12, 1974 (see above).

Langwell, W. Herbert: *Causes of Damage to Paper.* Chapter 3 of The Conservation of Books and Documents. Westport, Conn.: Greenwood Press, 1974 (1957).

For deacidification see in that chapter: pp. 21–25.

Langwell, W. Herbert: *Methods of Deacidifying Paper.* Journal of the Society of Archivists, 3: 491–94 (Apr. 1969).

A short critical review of the available deacidification processes: 1. methods using solid neutralizing agents; 2. aqueous and non-aqueous solutions; 3. gaseous media.

Lariviere, Jean: *Comments on Paper and Deacidification, Presented to the Graduating Students, Library Sciences.* McGill University, March 15, 1976 (typescript, 12 pp.).

Ancient and modern methods of paper-making are compared, and the gain in acidity present in the paper produced by modern manufacturing procedures is explained. pH test procedures are explained, and the more popular deacidification solutions are reviewed and compared.

Plenderleith, H. J. & A. E. A. Werner: *Acidity in Paper – Deacidification of Paper.* pp. 56–58 of The Conservation of Antiquities and Works of Art – Treatment Repair and Restoration. London: Oxford Univ. Press 1976 (1956).

A short note on the deacidification processes developed by W. J. Barrow, A. D. Baynes-Cope, R. D. Smith, and W. H. Langwell.

Robertson, D. D.: *Permanence/Durability and Preservation Research at the Barrow Laboratory.* pp. 45–55 of Advances in Chemistry Series no. 193 (Preservation of Paper and Textiles of Historic and Artistic Value II; John C. Williams (ed.); Washington, D.C.: American Chemical Society, 1981).

A biographical survey of W. J. Barrow's research in, and contributions to, the field of paper deacidification and conservation.

Smith, Richard D.: *Preserving our Books: a Chemical Problem.* Chemtech, 11(7): 414–17 (July 1981).

A succinct discussion of the sources of acidity in paper and the various methods of deacidification which are divided into four categories: aqueous, non-aqueous, gaseous, and mass deacidification. The paper is a condensation of a longer version appearing in Library Scene, Dec. 1979 and March 1980.

Smith, Richard D.: *Response to 'Letter to the Editor' Alleging Special Hazards from Non-aqueous Deacidification Treatments Using Magnesium Alkoxides*. Paper Conservation News, 8: 3–4 (Sept. 1978).

A lengthy and documented response to Paul Mucci's letter in Paper Conservation News (no. 6, March 1978). Smith discusses Wei T'o® solutions, associated environmental hazards, and notes that aqueous and non-aqueous deacidification techniques are complementary. Both techniques should be used, albeit with calculated caution, rather than not at all as suggested by Mucci.

Smith, Richard D.: *The Deacidification of Paper and Books*. American Libraries, 6: 108–10 (Feb. 1975).

The presence of acid in paper is explained and a test is described for the detection of the acidity level in paper. Three methods of deacidification (aqueous, non-aqueous, and vapor) are briefly discussed and described.

Smith, Richard D.: *Maps: Their Deterioration and Preservation*. Special Libraries, 63(2): 59–68 (Feb. 1972).

Smith's experimental findings suggested that U.S. geological survey maps have a probable useful life of 100 years, and that the rate of their aging is similar to the deterioration rates of most 20th century book papers. Both aqueous and non-aqueous deacidification treatments increase the potential life of most maps, yet non-aqueous treatments (rather than aqueous) can produce more protection against the future development of harmful acidity.

Smith, Richard D.: *The Extension of Book Life*. The Library Binder, 18: 36–40 (Dec. 1970).

The useful life of books would be significantly prolonged if: (a) bookbinding cloth, cord, end papers, tape, thread, etc., were stabilized by aqueous and non-aqueous deacidification treatments, (b) if photocopying machines were modified and equipped with specially designed dowels, and (c) if book return boxes were designed so as to reduce the damage that they cause to books.

Smith, Richard D.: *New Approaches to Preservation*. Library Quarterly, 40: 139–71 (1970).

A brief outline of the various methods of paper preservation is given, while the main part of the paper deals with the non-aqueous deacidification process ("Chicago Process") devised by Smith. The results presented represent a summary of the author's doctoral research. See, for discussion of this paper: W. K. Wilson, below.

Smith, Richard D.: *Paper Deacidification: a Preliminary Report*. Library Quarterly, 36(4): 273–92 (1966).

A preliminary report of the research done by Smith for his doctoral dissertation at the Graduate Library School, University of Chicago. A short literary survey is effected, and is followed by, a brief review of aqueous deacidification procedures. Several new approaches, preliminary experiments in deacidification, and an outline of problems still unsolved constitute the main body of the report.

Turner, Malcolm: *Conservation in Music Libraries*. Fontes Artis Musicae, 27(3/4): 183–201 (July/Dec. 1980).

A short section (pp. 189–90) notes various deacidification methods: aqueous, non-aqueous, gaseous diffusion (exposure of complete volumes to a gaseous deacidifying agent in a sealed cabinet) and vapor phase.

Wei T'o® Solutions – Application Techniques. Wei T'o® Technical Note TN-102 (1 Mar. 1977).

Several techniques are discussed: brushing and roller coating, dipping and immersing, and spraying.

Wessel, Carl J.: *Deterioration of Library Materials*. pp. 93–144 of Library Conservation. Preservation in Perspective (Baker, J. P. and M. C. Soroka (eds.), Stroudsburg, PA: Dowden, Hutchinson & Ross) 1978. Reprinted from: Encyclopedia of Library and Information Science (Kent, Allen and Harold Lancour (eds.); N.Y.: Marcel Dekker) Vol. 7: 69–120 (1972).

A survey study on the deterioration of library materials which includes brief notations regarding the contributions of W. J. Barrow, F. L. Hudson, W. H. Langwell, and R. D. Smith on the subject of deacidification.

Williams, John C.: *A Review of Paper Quality and Paper Chemistry*. Library Trends, 30: 203–24 (Fall 1981).

The elements which constitute a sheet of paper are discussed, and the author reviews the changes in the chemistry of paper dating from the 17th century. The poor quality of modern paper is explained and the steps taken to remedy the situation are indicated. A section on the various deacidification treatments (aqueous, non-aqueous, vapor) constitutes an annotated listing of all the better-known deacidification processes.

Williams, John C.: *Chemistry of the Deacidification of Paper*. Bulletin of the American Group – International Institute for Conservation, 12(1): 16–32 (Oct. 1971).

A detailed review of the various deacidification processes. A helpful checklist (p. 22) tabulates each process with its respective chemical, and the name of its originator.

Wilson, William K.: *Discussion of 'New Approaches to Preservation' by Richard Daniel Smith.* Library Quarterly, 40: 171–75 (1970).

The conclusion of this analysis of Smith's paper is that the study is timely, yet Smith would have made his point more dramatic if he had used papers that were more acidic. Experimental research on the aging of materials should continue so that we may learn more about paper deterioration: the evaluation of materials in use should be carried out on a continuing basis and with the cooperation of manufacturers, research laboratories, libraries, and publishers.

Winger, Howard W. (ed.): *Deterioration and Preservation of Library Materials.* Library Quarterly, 40: entire issue (Jan. 1970).

A collection of papers on the subject of preservation of library materials. For contributions dealing with deacidification, see: Smith, R. D. (1970), and Wessel, C. J. (1970), above.

Zappala, Mariagrazia: *Some Aspects of the Chemical Research in the Istituto di Patologia del Libri.* pp. 995–1,000 of Conservation of Paintings and Graphic Arts (Preprints, Fifth International IIC Congress, Lisbon, Portugal, 9–14 Oct. 1972). London: International Institute for Conservation, 1972. Reprinted in Conservation and Restoration of Pictorial Art (Brommele & Smith, eds.). London: Butterworths, 1976, pp. 223–27.

A report on the problems recently (1972) studied by the chemical laboratory at the Istituto di Patologia del Libro (Rome) (to wit: chemical degradation of cellulose; improvements in deacidification; effects of rozin size on paper; effects of fungicides on paper). On the topic of deacidification the author notes that experiments led to refinements of the Barrow procedure (calcium or magnesium bicarbonate). Other methods examined and modified were those of W. J. Barrow (magnesium acetate), A. D. Baynes-Cope(barium hydroxide/methanol), and R. D. Smith (magnesium methoxide).

6. Patents and Tests

Barrow, W. J.: *Hot vs Cold Extraction Methods for Making a pH Determination.* TAPPI, 46(8): 468–72 (Aug. 1963).

Test data of heat aged paper (excluding coated printing papers, writing grades, and card stock) was plotted for five or more test points (e.g. cold extraction, hot extraction, their difference, percentage of retention folds, percentage of cotton content, fiber analysis) on semi-logarithmic paper to form a regression line. This procedure is more accurate than the method using the two-point plotting (control and heated) and shows that the cold extraction methods for determining a pH gives a better result when estimation of a paper's rate of deterioration is needed.

Kelly, Jr., George B.: *Composition for Use in Deacidification of Paper.* U.S. Patent no. 3,939,091. Washington D.C.: U.S. Patent Office, Feb. 17, 1976.

A patent granted for a composition comprising 0.1 to 20% by weight of methyl magnesium carbonate in an organic solvent. Three examples of experiments undertaken to test the solution are given (3 Tables are included).

Kusterer, Jr., James E. & Reavis C. Sproull: *Gaseous Diffusion Paper Deacidification-Morpholine.* U.S. Patent no. 3,771,958. Washington, D.C.: U.S. Patent Office, Nov. 13, 1973.

Description of a safe and relatively inexpensive deacidification process by which paper is impregnated with gaseous morpholine. Two sets of experiments testing the method are described.

Kusterer, Jr., James E. & John D. Hind: *Gaseous Diffusion Paper Deacidification-Hexamethylenetetramine.* U.S.Patent no. 3,703,353. Washington, D.C.: U.S. Patent Office, April 15, 1971.

Description of a deacidification process by which paper is impregnated with gaseous hexamethylenetetramine. An advantage of this method is that the gas penetrates tightly closed books extremely thoroughly and very rapidly. The results of 4 experiments are included, as are 7 figures depicting the equipment to be used during the deacidification process.

Improvements in Processes for the Chemical Stabilization of Paper and Product. Great Britain Patent Specification no. 443,534. (Complete Specification Accepted March 2, 1936). London: His Majesty's Stationery Office, 1936.

A process for the stabilizing of sized, acid paper (newspaper, wall paper, wrapping paper, etc.) which renders it non-tarnishing when impregnated with an aqueous solution containing an alkaline earth metal bicarbonate (barium, calcium, or strontium bicarbonates, e.g.) presented by the Ontario Research Foundation. This body describes itself as the "assignees" of Otto Jansen Schierholz (see below), the inventor of the process.

Process for Treating Paper. Great Britain Patent no. 1,422,385 (1/28/76).

The content of this patent is essentially identical to U.S. patent 3,771,958: see Kusterer & Sproull (1973) above.

Schierholtz, Otto J.: *Process for the Chemical Stabilization of Paper and Product.* U.S. Patent no. 2,033,452. Washington, D.C.: U.S. Patent Office, March 10, 1936.

Describes the stabilization of paper which is effected by introducing into the paper an alkaline earth metal bicarbonate, such as barium, calcium or strontium bicarbonates, after the paper web has been formed and preferably after it is sized (various methods are discussed). The process is designed for paper made from chemical pulp and mechanical pulp which contain acid or acid- forming bodies.

Smith, Richard D.: *Preserving Cellulosic Materials Through Treatment with Alkylene Oxides*. U.S. Patent no. 3,676,055. Washington, D.C.: U.S. Patent Office, July 11, 1972.

An improvement in non-aqueous deacidification processes whereby the deacidified cellulosic material is reacted with an alkylene oxide such as ethylene oxide. A particularly effective method is the contacting of cellulosic materials such as books, which are deacidified by a non-aqueous deacidification process, with ethylene oxide for 15 min, or less, at ambient temperature and atmospheric pressure, and equivalent reaction conditions at other pressures and temperatures.

Smith, Richard D.: *Non-Aqueous Process for Deacidifying and Preserving Cellulosic Materials*. U.S. Patent no. 3,676,182. Washington, D.C.: U.S. Patent Office July 11, 1972.

A non-aqueous process for deacidifying and preserving cellulosic materials by means of a solution of an alkali or alkaline earth alkoxide, or mixture thereof (e.g. sodium or potassium methoxide), in an organic solvent. Also reported are non-aqueous deacidification processes employing other alkali and alkaline earth compounds, and processes which employ a liquefied gas and/or halogenated hydrocarbon solvent. For a discussion of this process, see L. F. Jonson, (p. 91, Vol. 7, No. 2).

Suchoff, L. A.: *Method of Forming an Adherent Film of Magnesium Oxide*. U.S. Patent no. 2,796,364. Washington, D.C.: U.S. Patent Office, June 18, 1957.

Detailed description of the method developed to provide an extremely thin, adherent coating of magnesium oxide to surfaces such as metals, glass, and plastics: a solution of magnesium methylate in methyl alcohol is obtained and is applied to a surface by conventional methods such as dipping or spraying.

Standard Test Method for Hydrogen Ion Concentration (pH) of Buffered Paper Extracts. American Society for Testing & Materials. (ASTM) D778–50. Reapproved 1971: TAPPI: Tentative Standard Method T435m-52.

The original date of this standard test was 1950 (ASTM D778-50) and it was revised initially in 1965. A step-by-step description of the method used for the preparation of materials, and the testing procedures used to determine the pH of buffered paper. The method is suitable for commercial industrial papers, but not for unbuffered and neutral paper such as insulating papers.

Standard Test Method for Water-Soluble Acidity or Alkilinity of Paper. American Society for Testing & Materials. (ASTM) D548-41. Reapproved 1971: TAPPI Standard Method T428m-45.

A step-by-step description of the method used for the preparation of materials, and testing procedures used to determine the water-soluble acidity or alkilinity of paper. This method is not applicable to highly alkaline papers (such as those containing casein or calcium carbonate) or to electrical insulating papers.

Hydrogen Ion Concentration(pH) of Paper Extracts – Cold Extraction Method. TAPPI Standard Test T509 os-77. New York: Technical Association of the Pulp & Paper Industry, 1977.

This method measures the hydrogen ion concentration of a cold aqueous extract (unfiltered) paper, expressed in terms of the pH value. The method avoids change of acidity or alkalinity resulting from heat-induced hydrolysis. It is suitable for writing, printing, and sized industrial papers, but it is not intended for unbuffered types such as insulating and condenser papers. The determined values may not be exact in a fundamental sense.

Hydrogen Ion Concentration(pH) of Paper Extracts – Hot Extraction Method. TAPPI Standard Test T435 os-77. New York: Technical Association of the Pulp & Paper Industry, 1977.

This method measures the hydrogen ion concentration (pH) of an aqueous extract of paper obtained by hot extraction (unfiltered and extracted by boiling water for 1 h). It may be applied to writing, printing, and sized industrial paper, but it is not intended for unbuffered types such as electrical insulating and condenser papers.

Hot Water Extractable Acidity of Alkalinity of Paper. TAPPI Standard Test T 428 pm-77. New York: Technical Association of the Pulp & Paper Industry, 1977.

This method (based on the work of S. Kohler and G. Hall) measures the titrable acidity or alkalinity (end point at pH 7.0) of an aqueous extract of paper (filtered and extracted by boiling water for 1 h). It specifies one extraction, and so does not measure the total acidity or alkalinity of the paper, for which exhaustive extraction is required (it may be applied to writing, printing, and sized industrial papers, but is not intended for testing electrical insulating papers, nor for those containing alkaline fillers or coatings).

Walker, Bernard F. & James E. Kusterer, Jr.: *Process for Deacidifying a Book which has a Pyroxylin-Containing Cover*. U.S. Patent no. 3,837,804. Washington, D.C.: U.S. Patent Office, Sept. 24, 1974.

Books having pyroxyline containing covers can be deacidified by impregnation with morpholine vapor without substantially damaging the covers, if the impregnation is conducted for about 5 to 15 min with a gaseous atmosphere consisting essentially of about 30 to 55 weight percent morpholine and a balance of water vapor at a temperature of about 90°F to 115°F.

Williams, John C. & George B. Kelly, Jr.: *Method of Deacidifying Paper*. U.S. Patent no. 3,969,549. Washington, D.C.: U.S. Patent Office, July 13, 1976.

A method of deacidifying paper, wherein the paper has a substantial cellulose fiber base or substrate, by exposing the paper to the vapors of a volatile organometallic compound (most preferred compound being diethyl zinc), and subsequently decomposing that compound to a base or alkaline material in situ. Large quantities of materials can be thus treated at any one time.

Williams, John C., George B. Kelly, Jr. & Richard L. Rest. *Method of Deacidifying Paper*. U.S. Patent no. 3,898,356. Washington, D.C.: U.S. Patent Office, Aug. 5, 1975.

In serial order, paper is contacted with a saturated aqueous solution of group II metal salt (preferred solution: calcium chloride) and another aqueous solution (preferred solution: ammonium carbonate) capable of forming a substantially insoluble buffer material in situ with the group II metal; then, subsequently, the soluble reaction products are removed by means of a controlled wash in deionized water. Seven examples of tests are included.

Wilson, W. K.: *Test Methods for Determining the Effect of Various Treatments on Paper*. pp. 985–94 of Conservation of Paintings and the Graphic Arts (Preprints of the Fifth International IIC Congress, Lisbon, Portugal 9–14 Oct. 1972). London: International Institute for Conservation, 1972.

Various methods are considered: chemical, physical and optical analyses; moisture calibration; and accelerated aging of paper (2 tables and 1 figure are included).

III RELATED TOPICS

1. Acidity

Acid Fallout & Buffering. Abbey Newsletter, 4(3): 41 (July 1980).

A summary (with excerpts) of letters written by James R. Druzik (Norton Simon Museum of Art, Pasadena, California) to the Abbey Newsletter on the subject of airborne acids and the process (developed at the museum) for the measurement of alkaline reserve (or buffering capacity) of commercially available buffered papers as opposed to laboratory buffered papers.

Surface pH Determinations of Paper. American Achivist, 37: 475–77 (1974). In "Technical Notes", Clark W. Nelson, ed.

James E. Kusterer, Jr.'s method for the non-destructive pH determination of cellulose materials (present in the paper of books and documents) is described.

A Summary and Review of the Art of pH Measurement and Control. Paper Trade Journal, 135: 19–27 (Sept. 1952).

As the title indicates, the paper is a technical summary and review of the art of pH measurement and control given by the American Cyanamid Co. (Stanford, Conn.). The two general methods for the measurement of pH (chemical and electrochemical) are described and information on pneumatic and electric controllers is given. Ten figures are included.

Arney, J. S. & A. H. Chapdelaine: *A Kinetic Study of the Influence of Acidity on the Accelerated Aging of Paper*. pp. 189–204 of Advances in Chemistry Series no. 193 (Preservation of Paper and Textiles of Historic and Artistic Value II; John C. Williams (ed.); Washington, D.C.: American Chemical Society, 1981).

The influence of acidity on the rates of yellowing and of tensile strength loss of a newsprint and a 100% cotton rag paper were examined at 90°C and 100% R.H., under both an atmosphere of air and an atmosphere of nitrogen. The results suggest that the influence of acidity on the rate of degradation of natural paper would be the same regardless of which degradation process predominates at room temperature.

Barrow, W. J.: *Test Data of Naturally Aged Paper*. Vol. 2 of Permanence and Durability of the Book (7 vols). Richmond, VA: W. J. Barrow Research Laboratory, 1964.

Describes the principal characteristics of book papers; reports on the results of a study based upon measurements of the folding endurance and tearing resistance of papers in 60 old books (dating from 1425 to 1900 A.D.); and discusses the strength of naturally aged writing papers. Concludes that, unless manuscripts of the 19th century are deacidified, their longevity can be expected to be significantly curtailed.

Barrow, W. J.: *An Accelerated Aging Study of Several Writing Papers*. TAPPI 47(2): 60–2 (Feb. 1964).

A re-evaluation of the results obtained by H. P. Dixson and J. C. Nelson ("An Accelerated Aging Study of Several Writing Papers", TAPPI 45(10): 753–60 (1962)) points to some defects in the original analysis of the data, yet such defects do not lessen the basic value of such results. One of the results given in Barrow's study shows that the correlation of total acidity with loss of fold and tear was very poor.

Barrow, W. J.: *Migration of Impurities in Paper*. Archivum 3: 105–08 (1953).

Test data assembled in this study show that many compounds migrate from one paper to another if they remain in contact with each other for a period of time. Examples: migrating compounds in ground wood fibers are acidic in nature; sulphuric acid present in many iron gall inks will migrate through the contaminated paper and will acidify adjoining sheets; low grade manufactured paper contains chlorine and alum, and those migrate also. Laboratory tests should be made on such materials as file folders, sheets in books, interleaving sheets, sheets used for mounting, or any other similar materials stored in contact with documents of value.

Belen'Kaya, N. G., T. V. Istrubtsina & V. A. Smirnova: *The Aging of Paper*. pp. 10–31 of Preservation of Documents and Papers ed. by D. M. Flyate. Transl. from the Russian, by J. Schmorak, of Problema Dolgovechnosti Dokumentov i Bumagi (Akademiya Nauk SSSR: Laboratoriya Konservatsii i Restovratsii Dokumentov, Moscow-Leningrad, 1964). Jerusalem: Israel Program for Scientific Translations, 1968.

Artificial aging was carried out on twenty-nine samples of paper prepared from four different kinds of fibres (100% bleached sulphite pulp, 100% bleached sulphate pulp, 100% bleached flax half stuff, and 100% bleached cotton halfstuff). The results are tabulated and the concluding summary notes that sizing with dark rosin and aluminum sulphate increases acidity while the aging of the material is accelerated regardless of the fiber content. Fillers, especially chalk, reduce the acidity of the paper.

Browning, B. L. and R. W. K. Ulm: *The Nature and Measurement of Paper Acidity*. Paper Trade Journal, 102: 89–98 (Feb. 1936).

A technical study on the nature of acidity of paper using the TAPPI Standard T 428m (slightly modified). Problems involved in the determination of acidity are considered. Eight figures and fourteen tables of results are included.

Chakravorti, S.: *Effect of 'Gammexane' on the Durability of Paper*. Nature 163(4146): 607–8 (1949).

The use of "Gamexane" (insecticide) is conclusively injurious to paper records of all kinds and affects their durability as badly as acidic gases. Further research on "Gamexane" is announced, to appear in "a subsequent issue of the Indian Archives".

Clapp, Verner W.: *The Story of Permanent Durable Book Paper, 1115–1970*. Scholarly Publishing Jan. 1971: 107–24 (Part I), Apr. 1971: 229–45 (Part II), July 1971: 353–67 (Final Part).

A historical survey of papermaking in the period 1115–1970. Pages 111–14 (Part I) and 355–62 (Part III) constitute a short biographical note on the contribution of W. J. Barrow. Parts II and III deal specifically with the problem of acidity present in book paper dating from the second half of the nineteenth century to the present and constitutes a historical survey of the attempts, by many, to correct the situation and to enforce a set of specifications for paper permanence. See also: Restaurator (supplement no 3) (1972).

DuPuis, Robert N.: *Book review of Analysis of Paper by B. L. Browning (New York: Marcel Dekker, 1969)*. Library Quarterly, 40(2): 278–79 (1970).

A reference tool for scientists in the field of papermaking and paper analysis, yet the book provides insights on the preservation and durability of paper. Of pertinence to the subject of deacidification is the section on acidity and alkalinity.

Edwards, Christopher John, F. Lyth Hudson & J. A. Hockey: *Sorption of Sulphur Dioxide by Paper*. Journal of Applied Chemistry, 18: 146–48 (May 1968).

Sulphur dioxide is sorbed ('picked up') by paper and is slowly converted to sulphuric acid. When a representative range of papers was tested over a period of many months, and at concentration of sulphur-35 dioxide approaching atmospheric concentrations, it was found that the relative humidity does not significantly affect the long-term sorption rate. The effect of paper additives, with some exceptions, is not significant in the long-term sorption rate.

Hansen, Fred S.: *Resistance of Paper to Natural Aging*. Paper Industry and Paper World, 20: 1157–63 (Feb. 1939).

Exploratory tests were carried out to learn what are the favourable characteristics of a sheet of paper which will not deteriorate with age. Among the several findings listed in the conclusion, those pertinent to the subject of deacidification are as follows: a small amount of calcium carbonate increases resistance to natural aging; some inks will accelerate paper deterioration; a pH level of 7.5 is satisfactory while a pH of 4.9 is too low.

Higham, Robert R. A.: *A Handbook of Papermaking*. London: Oxford Univ. Press, 1963.

As the title suggests this is primarily a handbook on papermaking. A short description of acidity/alkalinity tests (pp. 85–86) and a note on acid-free paper (p. 205) are included in the handbook.

Hoffman, W. F.: *Effect of Residual Acid on Rate of Deterioration of Paper*. Paper Trade Journal, 86: 58–60 (1928).

A report (including graphs and a Table) on experimental results which demonstrate that the higher the pH number, and the higher the hydrogen ion concentration, the greater is the decrease of the bursting strength of various kinds of alum-sized paper (bursting strength being used as the measurement for the deterioration of paper).

Hudson, F. Lyth & W. D. Milner: *Atmospheric Sulphur and the Durability of Paper*. Journal of the Society of Archivists, 2: 166–67 (Oct. 1961).

A short report on the authors' investigation of the deleterious effects of sulphur absorption by paper. Using radio-active sulphur as a tracer, the authors were able to detect and measure the sulphur picked up and fixed by the paper in as short a time as two hours. Results of the investigation: copper and iron, present as impurities in paper, will help to fix sulphur by catalyzing the oxidation of sulphur dioxide to sulphuric acid; high quality furnishes pick up less sulphur than impure furnishes; mechanical pulp will pick up more sulphur than rag. The rate of degradation of paper also appears to depend on temperature.

Hudson, F. Lyth & W. D. Milner: *The Use of Flat Headed Glass Electrodes for Measuring the pH of Paper*. Svensk Papperstidning, 63(3): 83–84 (1959).

The surface pH of paper can be measured by placing a calomel and a flat glass electrode in a drop of water on the surface of paper. The results of this method agree closely with those of TAPPI cold extraction (TAPPI Standard T435 m-52), and its added advantages are: it is quicker; different parts of the same sample can be tested; and samples are not destroyed by the testing method. Such advantages are important when old books and documents are examined.

Irvine, Robert & G. Sims Woodhead: *On the Presence in Paper of Residual Chemicals Used In its Preparation.* Journal of the Society of Chemical Industry, 13: 131–33 (1894).

A detailed account of the impurities and chemicals present in paper as a result of pulp production (using sulphurous acids, sulphites, caustic soda), bleaching (using chlorine, sulphuric acid), sizing (using alum, or acid aluminous compounds in conjunction with resin soap). A method for the detection of sulphur in paper is given, and some "remedies" to the problem of harmful impurities in paper are suggested.

Jarell, T. D., J. M. Hankins & F. P. Veitch: *The Effect of Inorganic Acids on the Physical Properties of Waterleaf Rag Bond Paper.* Paper Trade Journal, 95: 158–163 (Oct. 1932).

A detailed, technical study (including 3 Figures and 6 Tables) of the effect of small quantities of aluminum sulphate and sulphuric and hydrochloric acids on the folding endurance, bursting strength, tensile strength, and color of waterleaf, all-rag, bond paper which has been artificially aged by heating for 72h at 100°C.

Joel, A., N. Indictor, J. F. Hanlan & N. S. Baer: *The Measurement and Significance of pH in Paper Conservation.* Bulletin, International Institute for Conservation – American Group, 12(2): 119–25 (1972).

This paper is, essentially, a set of 3 Tables, each accompanied by a short discussion of the results obtained: Table II deals with surface vs cold extraction measurements of pH for several different papers; Table III shows the effect of making surface pH measurements after conditioning the surface electrode with buffer solutions, rinsing thoroughly in distilled water, and permitting contact with the paper sample for 4 min; Table IV presents the results of pH measurements (both surface and cold extraction) on paper-adhesive and paper-impregnating agents.

Kantrowitz, Morris S., Ernest W. Spencer & Robert H. Simmons: *Permanence and Durability of Paper. An Annotated Bibliography of the Technical Literature from 1885 A.D. to 1939 A.D.* Washington, D.C.: U.S. Govt. Printing Office, 1940 (Technical Bulletin No. 22).

Detailed, and frequently quite lengthy annotations, are provided for each entry (290 in total). Thirty-eight entries dealing with acidity are listed in the subject index. The latter does not list "Deacidification" as a subject entry.

King, A., A. Pelikan & W. E. Falconer: *The Use of the Archivist's Pen and Universal pH Solution in Estimating the Surface pH of Paper.* Studies in Conservation, 15(1): 63–64 (1970).

The Archivist's Pen (a pH sensitive marker), or the application of a drop of universal pH solution to the paper, are two easy and rapid methods which can be used to estimate the acidity or alkalinity of the surface of paper. A comparison of each method shows that the reliability of either method is quite high. One disadvantage is that permanent stains are left on the paper once a measurement has been taken. Such techniques may thus be used only when several samples are available, or for the pH assessment of items such as mat boards, or lining and hinging papers.

Launer, H. F.: *Determination of the pH Value of Papers.* Journal of Research of the National Bureau of Standards 22: 553–64 (1939).

A simple and rapid procedure (using a glass electrode) for the determination of the pH value of papers is described in detail.

Launer, H. F.: *Retention of Aluminium Ion and Hydrogen Ion in Papers.* Journal of Research of the National Bureau of Standards, 23: 663–74 (1939).

The decrease in pH, observed when paper-water mixtures are heated and then cooled, were found to be ascribable to the increased hydrolysis of the aluminum salts in the papers. Studies of fiber-alum water mixtures showed that aluminum ion is selectively retained by the fibers, and that the amount of aluminum salts in papers is thus much larger than that calculated solely from the concentrations involved in the manufacture of papers. Hydrogen ion is also strongly retained by fibers in an amount shown to be unchanged after heating and cooling. The effect of rosin upon pH relationships in papers is also discussed.

Plenderleith, H. J. & A. E. A. Werner: *Acidity, Neutrality, Alkalinity – Use of Indicators.* pp. 364–65 of The Conservation of Antiquities and Works of Art – Treatment Repair and Restoration. London: Oxford Univ. Press, 1976 (1956).

A very short note describing the origin (1909) and measurement of the hydrogen ion exponent, commonly known as pH.

Rulfs, Charles L.: *The pH of Things as They Are – Part I: The pH of Adhesives; Part II: The Surface pH of Papers.* Abbey Newsletter 2(5): 49–50 (Apr. 1979).

The acidity present in a host of materials containing adhesives and paper is recorded by means of two Tables listing the pH values of differing adhesives and surface boards and papers.

Rulfs, Charles L.: *The pH of Things As They Are – Epilogue.* Abbey Newsletter, 3(4): 42–43 (Nov. 1979).

The PVA's of the 1950's do age and their acidity levels rise. pH checks of stored adhesives as well as of those newly received should be effected on a regular basis.

Smith, Richard D.: *Paper Impermanence as a Consequence of pH and Storage Conditions.* Library Quarterly, 39: 153–195 (1969).

A review article aiming to provide basic information on the acidic nature of modern paper. Detailed discussions of a large number of publications on the subjects of acidity of paper and storage procedures constitute the major part of the paper.

Wessel, Carl J.: *Environmental Factors Affecting the Permanence of Library Materials.* Library Quarterly, 40(1): 39–84 (1970).

Factors such as humidity, pollutants, radiant energy and heat, and biological deterioration, are discussed. Ways to detect and measure acidity in paper are noted, pp. 52–60.

Williams, John C.: *Paper Permanence: A Step in Addition to Alkalization.* Restaurator, 3(3): 81–90 (1979).

Trace metal compounds, which act as oxidation catalysts in paper, speed the oxidation of sulphur dioxide to sulphuric trioxide and accelerate the drop in pH due to direct oxidation of the cellulose. A procedure is given whereby trace metals are removed or inactivated, and alkaline reserve is created in the paper.

2. Environmental Factors

Hudson, F. Lyth: *Acidity of 17th & 18th Century Books in Two Libraries.* Paper Technology, 8(3): 189–90 and 196 (June 1967).

25 books, varying in age from 150 to 300 years were taken from two different libraries: Portico Library (in the center of Manchester (England), which has a badly polluted atmosphere) and Chatsworth Library (located in open country). The surface pH value of the paper of those books was determined and the results confirmed the hypothesis that atmospheric pollution is one of the causes of low pH value, particularly at the edges of the pages.

Hudson, F. Lyth, R. L. Grant & J. A. Hockey: *The Pick-up of Sulphur Dioxide by Paper.* Journal of Applied Chemistry, 14: 444–47 (Oct. 1964).

Radio-tracer techniques, using radioactive sulphur dioxide, are tested in closely controlled conditions of temperature and relative humidity in order to examine the effects of variables such as humidity, temperature, and furnish on the affinity of sulphur dioxide for paper. Detailed descriptions of the experimental steps are given.

Kathpalia, Yash Pal: *Deterioration and Conservation of Paper III: Chemical Deterioration.* Indian Pulp and Paper, 16: 314–16 (Nov. 1961).

The deleterious effects of atmospheric contaminants, and harmful chemicals (present in paper as a result of papermaking and printing) are discussed in detail. Parts I and II "Biological Deterioration" and "Physical Deterioration" (Indian Pulp and Paper 15: 117–125 (July 1960), and 442–47 (Jan. 1961) respectively) are not relevant to the subject of deacidification.

Kimberly, Arthur E.: *Deteriorative Effect of Sulphur Dioxide Upon Paper in an Atmosphere of Constant Humidity and Temperature.* Bureau of Standards Journal of Research, 8: 159–71 (1932).

To demonstrate the need for proper ventilation in libraries, the author exposed 14 different commercial book and writing papers for 240 h to an environment containing 2 to 9 parts of sulphur dioxide per 1,000,000 parts of air, at constant conditions of temperature (30°C) and R.H. (65%). The results showed a marked loss of folding endurance (with little change in tensile breaking strength) and a considerable increase in acidity and copper number. Initial quality of paper was no criterion of resistance to sulphur dioxide.

Knightbridge, A. A. H.: *Sulphur Dioxide Test Papers.* Journal of the Society of Archivists, 4: 64–65 (Apr. 1970).

Small sulphur dioxide test papers have been devised, by W. H. Langwell, for the determination of the degree of sulphur dioxide pollution in rooms. The papers, initially a mottled dark brown, will bleach at varying degrees of rapidity, or completely, according to the amount of sulphur dioxide in the air. Such papers can be used as danger signals, and are inexpensive to purchase (ordering information is given).

Langwell, W. Herbert: *Sulphur Dioxide Pollution of the Atmosphere.* Society of Archivists, 1: 291–93 (Oct. 1959).

Sulphur dioxide is not in itself harmful to paper but it combines readily with metallic impurities in papers to form sulphuric acid. To detect levels of sulphur dioxide in the air, test papers 1 cm × 5 cm (with the active ingredient being higher oxide of cobalt) were prepared by W. H. Langwell. Two test studies were carried out (in the summer, then in the winter) to determine the atmospheric conditions of several repositories. Results showed that complete protection from sulphur dioxide in the air may be obtained from air-conditioning, even when the apparatus in use is not specifically designed for that purpose. When air-conditioning is not possible, boxing will allow virtually complete safety, provided the boxes have loose-fitting lids and the documents within them are left unwrapped.

Lewis, Harry F.: *The Deterioration of Book Paper in Library Use.* American Archivist, 22: 309–22 (Jul. 1959).

A report which describes an experiment begun in 1934 in order to (a) compare the resistance to wear of a book printed on paper made from highly purified wood pulp and another printed on paper of same weight made of 100% rag stock; (b) determine the extent of deterioration in such books when exposed to non-identical variables such as geographic location, degree of use, and atmospheric conditions. James L. Gear, in his comments on Lewis's report (pp. 321–22), notes that two elements, lacking in the original experiment would need to be added in similar future experiments: the testing of calcium carbonate-filled papers (because calcium carbonate permits the absorption and neutralization of acid gases from the atmosphere) and the use of control samples.

Richardson, Marie S.: *Bibliography on Air and Water*. Special Libraries, 57: 385–90 (Jul./Aug. 1966).

The bibliography (with occasional short annotations) is divided into 4 parts: 1. a listing of sources of information (including associations and organizations), 2. books and book reports, 3. serial titles and 4. selected current (1966) articles.

Smith, Richard D.: *The Relative Hazards of Vapors from Solvents Used by Conservators*. Journal of the Guild of Book Workers, 11: 3–9 (Winter 1972/73).

Article written (a) to introduce conservators to information (including bibliographic information) on ways to evaluate the relative toxicity of solvent vapors: and (b) to discuss briefly some methods whereby conservators can safely expose themselves to hazardous quantities of solvent vapors. Table I is a handy checklist of 52 chemicals and their threshold limit values (TLV): see pp. 6–7.

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An Evaluation of the Statistical Significance of Hudson's Acidity Data for 17th & 18th Century Books in Two Libraries

by NORBERT S. BAER & SIMEON M. BERMAN

Introduction

The effect of air pollution on the durability of book papers has long been recognized[1-6]. A number of authors have attempted retrospective studies of paper permanence as a function of storage conditions for identical copies of books in different libraries[1,3,4,5]. Among these studies, that of Hudson[3] is particularly suitable for statistical analysis of the significance of the experimental results. In his study, surface pH was determined for the paper of 25 books varying in age from 150–350 years. The books were in the collections of the Portico Library, subject to the polluted urban atmosphere of Manchester, England; and the Chatsworth Library, in open country, some 20 miles east at a not normally polluted site. The author concluded that atmospheric pollution was a cause of the lower pH values obtained particularly at the book edges for samples from Manchester. It is the purpose of this note to test the statistical significance of this conclusion.

Statistical Analysis

Hudson's data are reproduced in Table 1. For each book title, contact pH was measured at three positions for the same page in identical copies of books from the two libraries. There are three sources of variation in the data: library location (Chatsworth and Manchester), page position for the pH measurement (top, side, or center), and individual book title. It would be expected that different titles would be constructed of different materials and would have been exposed to their respective environments for different times. In testing for significance of the location and position factors, the effect of book identity was taken out. The particular statistical model is a three factor analysis with no interaction[7] [a].

[a] See Appendix for a discussion of the statistical model.

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Table 1. Acidity of 17th & 18th Century Books in Two libraries[a].

Ref. No.	Date of publication	pH value[b]						Author	Abbreviated title of book
		Portico copy			Chatsworth copy				
		Top[c]	Side[c]	Centre	Top[c]	Side[c]	Centre		
1	1619	3.2	3.5	5.1	4.4	4.9	5.5	A. Duchesne	Historiae Normannorum Scriptores Antiqui
2	1640	3.4	3.4	5.2	4.2	4.3	5.1	Willielmo Wats	Matthew of Paris Historia Major, etc
3	1656	3.4	3.4	4.9	4.3	4.5	5.1	Wm. Dugdale	Antiquities of Warwickshire
4	1673	4.0	4.2	4.8	4.3	4.4	5.5	Sir Peter Leycester	Historical Antiquities
5	1681	3.4	3.6	5.2	5.1	5.5	5.5	G. Burnett	History of the Reformation of the Church of England
6	1681	3.3	3.3	4.4	4.2	4.3	4.7	Sir W. Dugdale	Short View of the late troubles in England
7	1682	3.4	3.5	4.5	4.2	4.5	5.1	John Nalson	Impartial Collection...Affairs of State 1639
8	1705	5.7	6.7	8.3	4.9	4.8	5.7	Robert Plot	Natural History of Oxfordshire
9	1726	5.2	5.2	7.6	7.5	8.9	9.0	Joannis Seldeni	Opera Omnia
10	1726	6.3	6.2	7.9	4.0	3.9	4.5	Rev. J. Dart	History and Antiquities: Canterbury
11	1733	3.5	3.5	4.9	3.8	4.1	3.8	J. A. Thuani	Historiarum sui Tempori
12	1753	3.2	3.0	4.4	4.1	3.9	4.5	R. Wood	Ruins of Palmyra
13	1754	3.6	3.6	4.6	4.3	5.0	5.1	Thos. Birch	Memoirs of Reign of Queen Elizabeth
14	1757	3.1	2.8	4.2	5.2	4.4	4.9	R. Wood	Ruins of Balbec
15	1767	3.2	3.6	4.2	3.9	4.0	4.0	Clarendon Press	Clarendon State Papers from 1621, Vol. I
16	1768	3.5	3.8	4.9	4.2	4.4	5.1	Sir Robert Atkyn	Ancient and Present state of Gloucestershire
17	1771	3.7	3.8	4.2	4.4	4.4	4.7	Sir John Dalrymple	Memoirs of Great Britain & Ireland: Charles II
18	1773	3.4	3.3	4.2	4.2	4.7	4.7	J. Hawkesworth	Voyages of Discovery
19	1781	3.5	3.6	3.9	3.9	4.0	4.4	T. Nash	Collections for History of Worcestershire
20	1791	3.6	3.9	3.9	3.9	4.1	4.4	John Bridges	History & Antiquities of Northamptonshire
21	1791	3.6	3.6	3.9	4.6	4.9	4.8	Rev. John Collinson	History & Antiquities of Somerset
22	1792	3.7	3.8	4.1	3.9	4.1	4.2	Daniel Lysons	Environs of London
23	1793	3.7	3.8	5.2	4.5	4.9	4.9	J. Strutt	Regal & Ecclesiastical Antiquities
24	1793	3.4	3.4	4.0	4.6	4.6	4.5	Wm. Roy	Military Antiquities of the Romans in Britain
25	1798	3.3	3.5	4.0	4.3	4.4	4.3	H. Walpole, Earl of Orford	Works

[a] Reproduced from Hudson (reference 3).
[b] Contact pH measured with a flat glass electrode.
[c] Measurement made 8 mm from the center of the top of the page or 8 mm from the center of the outside of the same page, respectively, as noted "top" or "side".

Results

In Table 2 the results of the analysis of variance computation are presented. As noted above, the identity of the book is obviously significant. Analysis of variance demonstrated that the position, i.e. edge vs center, and the location of the library, were highly significant at the 1% F-level or at the 99% level of confidence.

An additional test (t-test) was used to evaluate the significance of differences in the averages obtained for pH measured at the tops and sides of the books. The results given in Table 3 demonstrate that the P-value for this difference is 0.22. Thus we must accept the hypothesis that there is no significant difference in the results obtained at the two positions.

Table 2. Analysis of Variance Test for Hudson's Book Acidity Data[a].

Source of Variation	Degrees of Freedom	Mean Square	F-Ratio	1% F-Level
Library Location	1	10.140	25.83	6.63
Position on Page	2	10.152	25.86	4.61
Individual Book	24	3.542	9.02	1.79
Error	122	0.3926	–	–
Total	149	–	–	–

[a] Analysis of variance by F-ratio[7] for data in Table 1. The F-ratio is the ratio of the mean square corresponding to the indicated source of variation to the mean square due to error. Large values of the ratio indicate significance of the source.

Table 3. Evaluation of Hudson's "Top-Side" Book Acidity Data[a].

Average top	4.084
Average side	4.238
Standard error of difference	0.12532
Absolute difference divided by standard error	1.23
P-value of 1.23	0.22

[a] The P-value of the t-ratio is determined from the table of the t-distribution[7]. High P-values, generally taken to be >0.05, are associated with lack of significant difference.

Table 4. Confidence Interval for Hudson's "Side-Center" Book Acidity Data[a].

Average center	4.93
Average side	4.238
Difference	0.692
95% Confidence interval	0.692±0.246

[a] The confidence interval is based on the normal curve because the degrees of freedom (122) is large.

One may set a confidence interval for the average difference between the pHs measured at the side and center (Table 4), the minimum significant differences observed. With reference to the normal curve the 95% confidence interval for this difference is 0.246 so that we may report the average difference for the books studied as 0.692±0.246.

Conclusion

It may thus be concluded that, to the degree that the variance in contact pH for the two groups of books studied by Hudson can be attributed to library location and position on the page, the low pH at the edges of the page as compared to the center of the page may be attributed with great confidence to the differing conditions of storage for the two libraries. It should be noted that environmental factors in addition to the local SO_2 concentrations, e.g., average annual temperature, frequency of use, maintenance practices, may have contributed to the observed differences.

Appendix. Technical Note on the Statistical Analysis

The analysis of variance is a statistical method for determining the influence of various factors on the measured values of an experimental variable. In this study the variable of interest is contact pH, and there are three factors of interest: library location (local environmental conditions), page position, and book title. The three factor analysis of variance with no interaction requires the following mathematical assumption:

The typical pH measurement is, on the average, given by the sum of four terms,

$$m + l_i + p_j + b_k = pH \qquad (1)$$

where

m = term common to all measurements
l_i = term due to library i, i = 1,2
p_j = term due to position j, j = 1,2,3
b_k = term due to book k, k = 1, ...,25.

A factor is considered significant if the corresponding component is not identically equal to 0. For example, the position factor is considered significant if at least one of the numbers, p_1, p_2, and p_3 is not equal to 0. It may be assumed that the terms satisfy the relationship

$$l_1 + l_2 = p_1 + p_2 + p_3 = b_1 + \ldots + b_{25} = 0. \qquad (2)$$

Indeed, the averages of the l's, p's and b's may always be subtracted from their individual values and then included in the common term m.

The numbers m, l_i, p_j and b_k are assumed to be unknown, but we decide on the basis of the sample and the analysis of variance test whether or not they are equal to 0.

Summaries

An Evaluation of the Statistical Significance of Hudson's Acidity Data for 17th & 18th Century Books in Two Libraries

pHs of papers from the 17th and 18th century that have been stored under different climatic conditions (published elsewhere) are analysed according to statistical methods.

Une évaluation de la signification statistique des données de Hudson sur l'acidité pour les livres du 17e et 18e siècles dans deux bibliothèques

Les PHs des papiers du 17e et 18e siècles conservés sous des conditions climatiques différentes (publiés à d'autres endroits) et analysés conformément aux méthodes statistiques.

Eine Auswertung der statistische Bedeutung der Säuregehaltdaten Hudsons bezüglich Bücher den 17. und 18. Jahrhunderte von zwei Bibiliotheken

Die anderweitig veröffentlichten pH-Werte von Papieren aus dem 17. und 18. Jahrhundert, die unter verschiedenen klimatischen Bedingungen aufbewahrt worden waren, werden einer statistischen Analyse unterworfen.

Acknowledgements

The authors wish to thank Paul N. Banks for advice and encouragement in connection with this study.

This project was supported in part by a grant from the National Endowment for the Arts. The work of Simeon M. Berman was sponsored by the National Science Foundation, Grant MCS 82-01119.

References

1. W. J. Barrow Research Laboratory: *Permanence/Durability of the Book. 5: Strength and other Characteristics of Book Papers 1800–1899.* Richmond, VA: W. J. Barrow Research Laboratory, 1967.
2. Church, R. W. (ed.): *Deterioration of Book Stock: Causes and Remedies. Two Studies on the Permanence of Book Paper Conducted by W. J. Barrow.* Richmond, VA: Virginia State Library, 1959.
3. Hudson, F. L.: *Acidity of 17th & 18th Century Books in Two Libraries.* Paper Technology 8 (1967): 189–90.
4. Smith, R. D.: *Paper Impermanence as a Consequence of pH and Storage Conditions.* Library Quarterly 39 (1969): 153–95.
5. Smith, R. D.: *A Comparison of Paper in Identical Copies of Books.* Restaurator Supplement Number 2 (1972).
6. Thomson, G.: *Air Pollution – A Review for Conservation Chemists.* Studies in Conservation 10 (1965): 147–167.
7. Snedecor, G. W. & Cochran, W. G.: *Statistical Methods*, 7th Edition. Ames, Iowa: The Iowa State University Press, 1980. Chapter 12.

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Limp Vellum Bindings:
Their Value as a Conservation Binding

by EILEEN FITZSIMONS

Introduction

Based on a review of the literature, this paper presents an examination of the limp vellum binding as a conservation binding.

For the purpose of this paper, the term conservation binding is used as defined by Sherelyn Ogden in her thesis *A Study of the Impact of the Florence Flood on the Development of Library Conservation in the United States: 1966–1976.*[1] The term identifies bindings of books of value as artifacts, rather than binding of books solely to preserve the information contained in them.

> The concept of conservation is central to the concept of libraries in terms of the preservation and accessibility of knowledge. A library contains materials for use by patrons. The availability of these materials for use is dependent upon their physical condition, and their condition is affected by conservation practices. The condition and even survival of materials today is the result of conservation practices of the past, and the condition and survival of materials in the future will be the result of the conservation practices of today (p. 4).

This paper will review the reasons for the appropriateness of the limp vellum binding as a conservation binding and describe a few of the innovations in limp vellum binding used in the 20th century. The procedure itself is not elaborated upon as there are quite a number of excellent sources for learning how to create a limp vellum binding. The best of these explanations is given by Barbara Guiffrida[1]. Clear descriptions are also given by Sidney M. Cockerell[1], George Daniel Martin Cunha and Arthur Johnson[1]. There is also an attempt to show that valid conservation practice is dependent upon a continuity of effort, with constant evaluation of not only recent, but also past practice.

Before discussing the development of the limp vellum binding and its "rediscovery" in the late 1960's, a quick review of the basic construction is in order. The essentials of the construction of this binding are illustrated in Figure 1: gatherings are sewn onto alum tawed thongs (a) and a parchment liner (b) placed across the spine. The head and tail bands (c) are sewn through the book and the spine liner. Then all thongs are laced back through the vellum cover (d) with the parchment liner entwining the whole together so that the text block is locked firmly, creating a "bou[illegible]" rather than a "case" binding.[2] As

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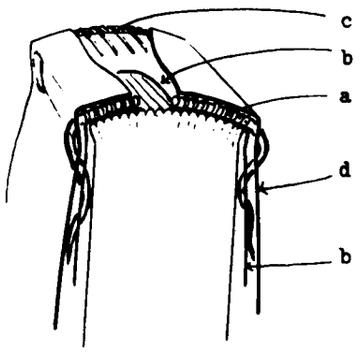


Fig. 1.

will be explained, this binding is extremely strong without damaging the book block.

The Florence Flood

The impetus for the use of this binding for conservation purposes came from an observation of its resistance to damage during the Florence flood of November 4, 1966, and conservators have been working with and refining this structure ever since the salvage operations.

The effect of the Florence flood upon conservation awareness and technique has been dealt with admirably by Sherelyn Ogden.[1] As Ogden convincingly demonstrates, although we tend to think of the flood of 1966 as a turning point in library conservation, in actuality, with the exception of the physical treatment of materials of value as cultural artifacts, the effect of the flood was an acceleration rather than a turning point. Public awareness of the necessity of conservation was raised; conservation was glamorized and popularized; and because the flood occurred during a period of generous funding, the direction already taken by library conservators moved toward realization.

The influence of the flood on the physical treatment of library materials, however, did mark a turning point, and the impact on methods of conservation was especially strong, as conservators from all over the world gathered in Florence to develop methods for the treatment of flood damaged materials.

The extent of the impact of the flood upon the work of conservators in the United States has been determined in part by the work of the Restoration Office of the Library of Congress. After the flood, three Anglo Florentines, i.e. British book conservators who assisted in the salvage operation in Florence, were hired as staff members of the Restoration Office. These three were Peter

Waters, hired first as a consultant and later as Restoration Officer, Don Etherington, and Christopher Clarkson. Techniques developed by these three, including specifications for binding and the development of the concept of a conservation binding, have had a profound effect upon the work done at the Restoration Office and therefore upon work done by other conservators in the United States. Others, such as Paul Banks, Carolyn Horton, and Richard Young, who also were active in Florence, have subsequently been very active in the United States and employed a number of Florentine techniques.

Various descriptions of the repair process and of the team work after the flood can be found in Ogden's thesis, in *The Restoration System of the Biblioteca Nazionale Centrale di Firenze*,[3] and in the film *The Restoration of Books: Florence 1968*.[1]

According to Dennis Rhodes, quoted by Ogden,[1] Florence probably has the largest number of archives and libraries of vital importance in the world, not to mention as great a variety as any place. And the libraries of Florence, according to Peter Waters, were the worst sufferers of flood damage. Although the figures vary, there may have been about two million damaged volumes.

Old Binding Techniques

In the rebinding aspect of the repair process, the conservators found themselves preferring 16th and 17th century binding techniques. Their most frequent specifications were full tanned goatskin, full limp vellum quarter goatskin, and quarter vellum.[4] The author of *The Restoration System of the Biblioteca Nationale Centrale di Firenze*[3] states:

> As in all our techniques, much thought and care has gone into the evolvement of the structures used in the binding. Our models have been, for limp vellum bindings, examples of the early 16th century, and for leather bindings, examples of the 16th and early 17th centuries. We generally specify for the binding a way that will be evocative of the period of the book, with due reference to the original binding, particularly in its colour, type of sewing, and endbanding, but we do not attempt to produce facsimile bindings. ... prime consideration is the structural needs of the book (p. 24).

Waters[1] described the observed phenomena which caused librarians working in Florence to reconsider the components of a sound conservation binding:

> ... It was a great privilege even to see these flood damaged books ... . On this occasion we had an opportunity to see hundreds and hundreds of books in certain conditions and the most noticeable feature that came over was the damage that was already done before the flood happened. It is on this basis that I think we should rethink some of the things that we do in our work (p. 13).

Current concepts of what constitutes a conservation binding are a result of observations of the books repaired after the flood. The majority of the books damaged in the flood were still in their original bindings, and, as Waters pointed out, it became apparent to those engaged in treatment of these books that some of the binding methods which were originally considered to be sound were, in fact, actually harmful to the book. For example, books rebound in 19th century Italian style, whatever the original binding structure, showed evidence of damage done *before* the flood.

> Regardless of the size, most of those have been sewn on three very thin sawn-in cords; they have tight joints and would be very difficult to open, and if they are opened they may fall to pieces. I think that's a kind of an insensitive binding which we've tried to avoid at the B. N. C. F. (p. 16).

The ideas which emerged were based upon the techniques of binding which were in practice before the flood and which proved to be non-damaging to the book block: sewing onto raised cords or on tapes; using original sewing holes; using barriers between the adhesive and the book block; and using the limp vellum structure.[5]

For indeed, a surprising number of small limp vellum bindings of the early 16th century appeared to have survived in a state of preservation which compared quite favorably with the state of other more elaborate binding structures. The significance of the limp vellum binding for conservation purposes was noted by Clarkson:[1]

> ... so called limp vellum binding structures, although often badly damaged in their covers, had seemingly not inflicted as much damage to their text blocks as had other binding structures (p. 1).

Water is, of course, extremely damaging to the bindings. Both leather and vellum lose essential tanning agents when soaked with water, and may shrink badly and become brittle when dry.[6] Vellum and water tend to form glue and, therefore, many of the limp vellums were completely destroyed; the book within, however, because of the construction, the limpness and lightness, survived quite well.[7]

Glue on the Spine

Many of the books damaged in the flood, particularly those of the 17th century, had enormous quantities of glue on the spines. These books, which can be mended at the rate of six per day, if thirty menders are at work, were damaged more by the glue than by the flood. Yet when paste had been used on the spine, the books were in very good condition. It becomes clear then, why a binding

which relies upon structure rather than glue or adhesives is an appropriate choice for a conservation binding.[8] For example, a book from about 1540 or a bit earlier was sewn onto alum-cured thongs which were so strong that even after having been through the flood it did not have to be resewn.[9] And where vellum with minimal or no adhesives was used, although it may have appeared somewhat stiff, the backs of the sections did not need to be mended.[8]

Furthermore, since very little adhesive, if any, was used in these bindings, there was less damage by insects. And unless the book had been sewn on vegetable tanned thongs, the covering material did not cause any discoloration of end papers and first leaves.[10]

Different Types and Materials

Although Waters speaks highly of the limp vellum binding as a conservation binding, it is important to remember that *there is no one perfect binding*. The individual volume must always be taken into account. Waters himself says that there is far too much talk about one structure and how it behaves in one workshop as opposed to in another.

> I would not have known, I think, before going to Florence, how difficult it was to decide on how a book should be bound. We had our own fixed ideas in our bindery, which is a very bad thing to have, perhaps, but I think by analyzing structures in this way, one might be able to arrive at a specification or a set of guidelines that one could advise libraries to follow (p. 17).

In addition to principles based on the observation of which bindings had provided the greatest flood protection, there are several cases for choice of conservation method considered valid today which had already been recognized before the flood and which the choice of a limp vellum conservation binding do not violate. The fundamental principle is a profound respect for the integrity of the artifact itself. Corollaries of this rule of respect for the integrity of the artifact are the rule of reversibility and the principle of not altering the artifact any more than necessary for the preservation.[11] Of course, the conservator must determine if the book is truly significant for its value as an artifact or only for its informational value before making a decision on extensive treatment such as rebinding. According to Paul Banks, if the value is as an artifact, "... the previous binding should be thoroughly documented photographically and verbally, and all of its parts should be retained."[12]

Another crucial principle is that the materials used in treatment or repair should be of a permanence and durability appropriate to their use. Permanence refers to the chemical stability of the materials over time and durability to the physical characteristics, such as strength and flexibility, which must demon-

strate a suitable resistance to wear. It will be demonstrated that limp vellum bindings have exhibited an appropriate permanence and durability for use as conservation bindings.

Of course, these principles represent the ideal; but although they cannot always be realized, they should nonetheless be guiding principles whenever compromises in restoration or conservation technique prove necessary.[13]

What must be kept in mind, however, is that conservation and binding are not merely crafts; they involve a code of ethics. To quote Waters, "Sometimes it's necessary to protect books from humans and certainly from disgusting techniques." (In Search ... p. 15).

Limp Vellum's Advantage

Limp vellum bindings satisfy most of these principles. They are reversible, require little or no alteration to the artifact, are durable, in general quite permanent, and when used on the smaller volumes for which they were developed, show respect for the artifact itself. They are non-adhesive structures and therefore allow for disassembly, maintenance, and reassembly with little or no damage to the text block. Furthermore, some of these techniques can be transferred to stiff board work, allowing for the development of new binding techniques. Clarkson further describes the advantage of the limp vellum technique as follows:

> ... simplicity of construction, light weight, mechanical yielding qualities, and lack of distortion in varying atmospheres, plus the durability of its component materials, showed clearly a sound conservation binding. In addition, these limp vellum structures achieve a balance between sound sewing construction and a flexible, durable, limp cover, the whole technique using little or no adhesive and having the character of a tied bundle. They also have the great advantage of supplying one with the opportunity of designing a reversible covering technique: a cover which later generations may easily and without damage to the text block remove and replace with fresh material without the need for resewing (p. 1).[14]

A complete history of this particular binding technique is beyond the scope of this paper, but a very brief summary will at least give an idea of its development. The history of the binding construction not only sheds light on its evolution, it allows one to see possibilities for refinement, and, according to Clarkson, "... reflects the history of man's ingenuity when applied to a mobile, complex subject such as the codex form" (p. 2). It cannot be emphasized too greatly that the book is a mobile form; it is not a print or a single sheet of paper. What is done to a sheet of paper in the laboratory cannot necessarily be done to a book or even to a page in a book. Furthermore, if one does not understand the development of these bindings and approach the use of them with creativity,

this perfectly sound technique of binding could easily become stereotyped and with time even structurally unsound, as did the bindings of the 17th and 18th centuries.[15]

History

Limp vellum and non-adhesive bindings were a major feature of medieval European binding techniques.[16] Although limp vellum bindings have been described as cheaper versions of the more deluxe stiff board and thonged bindings, Clarkson maintains that this is not the case at all. They may, indeed, show characteristics of the contemporary stiff board thonged bindings, but their basic structure strongly suggests two essential independent influences: Near Eastern bookbinding techniques and the vellum wrapper. The vellum wrapper is thought to have been used from early times as a means of protecting books which had been sewn but had no attached boards.

By the 13th and 14th centuries, with the growth of the universities, there was an increasingly heavy demand on the limited supply of books. A tradition of professional bookbinders grew up alongside the tradition of the monastic binders, who worked with both stiff board bindings and non-adhesive vellum bindings. In addition, amateur craftsmen, such as scholars, in doing their own copying and binding, introduced significant innovations and influences. As a result, a great variety of binding techniques appeared, both utilitarian and exotic.

Limp vellum bindings really came into their own in the early part of the 16th century with the first printed pocket editions. These pocket editions were first produced by Venetian printers in the first decade of the 16th century, and the binder was able to achieve "a harmony of composition, structure, and technique by using a strong sewing construction and a flexible, durable limp vellum cover with little or no adhesive."[17]

A transitional period followed, in which the craftsmen were displaced by workmen. This came about in part due to the increasing pressure of work and to the demand for large quantities of identical copies. In coping with the demand, production was split into specialized sectors and techniques were standardized.

However, the bindings which were produced by the middle of the 16th century show some significant changes. Stocks of suitable, supple covering materials were exhausted, and one observes parchment and vellum of all kinds and all qualities utilized, even pages from manuscripts. Case bindings appeared which display lacings more for decoration than for structural support, and pasteboards were used with greater frequency, converting the bindings into

semi-limp bindings. The vellum skins used are noticeably thinner, and the volumes are kept intact only by their end papers, end-band cores, small size and light weight.

Toward the end of the century, these books suddenly appeared in refined circles. The covers were frequently cased off the book and decorated with gold tooled and hand painted design, as Clarkson put it "the coming of age, as it were, into the High Renaissance spirit of this binding style."[17] However, along with this refinement in decorative bindings, there also developed a

> ... general failure to retain or to recognize the fundamental harmony between composition, technique, and purpose. Perfection of form bred, as it usually does, artificial and adventitious elements which were unrelated to the needs of the binding constructions.

Unfortunately, since this later cased work tended to have surface decorations, there was a greater tendency to retain it rather than the structurally more interesting earlier and simpler bindings.

Technical Principles

Clarkson has identified the following points as significant in limp vellum technique:

1. Careful choice of alum-tawed skin for thonging, related to the expected flexibility of the bound leaves. Most commercial skins have proved quite inadequate for such an important function.

2. Firm sewing around double or single thongs, often with various types of "linked" or "packed" sewing and sometimes sewn with supported tail and head "end-of-spine" bands (Fig. 2), a development ... [Clarkson] experimented with, starting in 1967.

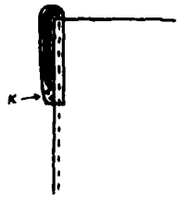


Fig. 2

3. End-band tie-downs firmly hold the head and tail of a wide, full-length spine liner.

4. Careful consideration is needed in the choice of the weight of a vellum skin in proportion to the volume's flexibility.

5. The covering process is a completely dry one, consisting of scoring,folding, cutting and interlocking.

6. Given the uncertainty of the tear-resistance of modern skins, every slot made is terminated with a punched hole. This feature can with care supply its own particular character to a binding (Fig. 3).

Fig. 3.

7. Thongs are laced through the cover and back through the cover and the liner to create a "bound" rather than a "cased" book (Fig. 1).

8. Punched holes, through which the alum-tawed thongs pass, are made smaller than the thickness of the thong. When a thong is passed through and flattened, it is firmly held by the hole (Fig. 4). No other material so far tried out achieves this sort of locking effect, which may then be dismantled and reassembled in the future if necessary.

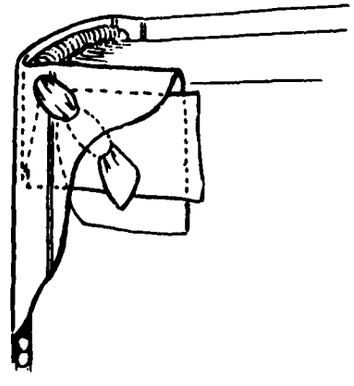


Fig. 4

9. A soft "yapp" edge gives rigidity to the fore-edge of the book and also leads the way into a book stack and remarkably protects the binding if dropped on the fore-edge.

10. Fore-edge ties help to hold the book as a bundle, but some librarians object to their awkwardness and several alternatives are being tried.

It is important, in examining appropriate binding methods for conservation binding, to understand just what the purpose of a conservation binding is. The aim, according to Clarkson, is not to make facsimile copies, but to create a new improved structure. Or to quote Waters, "I think one now needs to analyze why we do each thing to a book – why we even sew it – and if the principal intent is to conserve materials, I think one ought even to consider whether or not it is necessary to rebind a book at all." (In Search ... p. 14).

In any case, in conservation rebinding, it is extremely important to use construction and binding methods which will be readily understood by future preservation personnel in order to avoid inadvertent damage to the text block. The binder must understand that conservation binding is more than just a simple repair of the text block coupled with rebinding to allow for normal use in 20th century libraries; the book must be viewed as a three dimensional mobile object.

> ... it also implies the restoration of qualities of movement such as ease of opening, spine flexibility and leaf flow. The preservation of the actual tactile qualities of vellum, leather, board, paper, type impressions, etc., are vital ... . reliability over a long period depends to a large extent on simplicity of construction, ease of movement, and materials which are chemically, physically, and visually in harmony with one another and with the text block.[18]

If innovations show themselves to be improvements and in harmony with the text block and the integrity of the artifact itself, they should be utilized.

Modern Developments. End Paper

Clarkson has come up with some innovations of his own, based upon his study of the medieval limp vellum binding. As an example of the value of experimentation, a description of his work with end papers follows. I have relied heavily on Clarkson's own words, as he portrays well the concept of the book as a mobile object and convincingly presents integrity of the artifact as a major requirement of the conservation binding.

The end leaves play an important role in the movement of a book. "A good

growth and flow to a book starts and finishes with the end leaves. Their connection with the cover must be in sympathy with their general action" (p. 5). This is to say, the movement, and therefore the end-leaf design, of a smaller book, for which a limp vellum binding is most appropriate, will be different from the movement of a large lectern type book. The larger book is thrown open wide and must stay open at any page until the end, "and it should close firmly and squarely with that delightful air-expelling 'bloomph'." The smaller, limp vellum bound book

> is most comfortable in the hands with the structure opening easily and the covers yielding and adapting to the touch. I feel that the flow through a limp vellum book starts with the covers and not with the fly-leaves; when closing, the book expels air slowly through and around the corners.

In order to provide sufficient protection to the text block, the limp covers must be under a certain inward tension across the width. The modern method of supplying this tension to the covers is to use a "paste-down" end paper, which shrinks upon drying and thereby lends the required tension to the binding, as well as adding a certain vertical rigidity.

In the medieval period, a common method of constructing the end leaf for limp vellum bound volumes was to use a folio or two separate sheets hooked under the first and last gatherings and sewn in with the rest of the text block (Fig. 5). The end leaf or paste down of end paper was usually attached to the inner side of the cover.

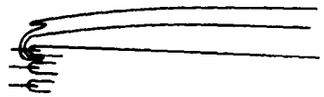
Fig. 5.

When Clarkson started experimenting with the limp vellum binding structures, this hook under gathering type of end leaf constructions was what he used. The attraction of this format was "the directness and simplicity and close connection of the end leaf with the text block" (p. 6).

In this type of limp vellum binding, the main hinging point is the spine fold, with the joint fold only adding a certain direction to the cover. Therefore, when the hooked end leaves were pasted down, opening the book created tensions. Clarkson was able to eliminate the tension by designing an expanding gusset for the end leaf (Fig. 6). However, he did not find this method completely satisfactory for several reasons. The closeness of the cover and text block at the hinging point was sacrificed; paper and vellum behave differently in varying at-

mospheres, so test results were distorted; and an even more serious disadvantage – pasting down the end papers compromised future possibilities for preservation maintenance.

Fig. 6.



It appears that in many of the limp vellum bindings of the 16th century the end papers were never pasted down; in fact, evidence shows that this was never the intention. Therefore, Clarkson began to experiment with non-paste-down end leaves. He did want to retain the shape, rigidities, and protective qualities in the cover which had been produced with the paste-down techniques which he had originally used. However, the non-pasted end leaf would have the advantage of being "reversible" (in conservation terms), that is, it could be easily removed without damage to the text block or allow for maintenance without resewing.

There are quite a few difficulties in developing a technique which will be appropriate for the wide range of text blocks and natural materials which one encounters. Furthermore, one must keep in mind the necessity of creating the opportunity for dismantling and reassembling. This last requirement demands stronger and more durable materials than modern commercial hand-made papers. And, of course, the material must be "sympathetic to the concept of limp vellum binding" (p. 7). Soft alum skin for the area from the hinge point to the joint fold, with parchment from there to the fore-edge has proved successful. Clarkson creates a significant overlap of the alum-tawed skin and the parchment, thereby supplying bulk to the cover and a non-adhesive trap to the thong when it is passed through after covering. This end leaf goes inside the vellum, supplying the necessary bulk and supporting qualities.

The parchment used for the end leaves must be tear resistant because the various fore-edge tie mechanisms create a non-adhesive inward tension to the cover. The result of the best designs is a tension between the joint fold and fore-edge, and no tension across the hinging points.

Clarkson also uses concertinas of Japanese papers in an attempt to distribute end paper connections into the text block. Apart from the end leaf, which using the techniques described becomes integral with the cover, parchment fly-leaves are also used to add more protection to the text block from the constructional features in the covers, such as whittawed lacing and tacketting anchorages.[19]

OTHER DEVELOPMENTS

There are other areas in which Clarkson has done admirable experimentation, including construction of corners, construction of fore-edge tie techniques, refinement of thongs and end-band tie downs. Another area of refinement, which he claimed that in 1975 was still in the embryonic stages of experimentation, is sewing. Although he does not describe his methods at great length, his considerations in choosing a method are enlightening. There are many types of sewing structures

> ... each one supplies to a book a particular movement, opening, or character; most have an individual role to play in the scheme of things and therefore should be recognized as such and used in solving particular book problems (p. 7).

In order to evaluate such structures one must recognize the conditions of a particular period as well as the aims or requirements of the craftsman. For example, before about 1400, books were to be housed in chests or book presses and not to be stood vertically on a shelf; obviously, this fact must be taken into consideration when evaluating the sewing structure of this earlier period. A factor to take into account with limp vellum books is that, since they are not "backed" (jointed), one aims for less swelling after sewing than is required for stiff board books.

Since the 1500's, bookbinders have placed more reliance on adhesives and less on the sewing structure. "In conservation work one needs to use minimum or no adhesive on the spine and certainly not for any structural reasons" (p. 8). Hence the experiments Clarkson has conducted with Peter Waters to see if one can develop a sewing structure which will allow one to dispense entirely with adhesives. In this regard, the limp vellum bindings of the early 16th century still show fundamentals of non-adhesive structures of earlier centuries and are worth studying.

MATERIALS. SKIN

Since Clarkson maintains that securing conservation quality binding materials is one of the greatest problems, it may be appropriate to briefly mention some of the qualities desirable in creating a limp vellum conservation binding.[20] Synthetics simply cannot provide the same characteristics as animal skins. If one chooses not to use animal skins, then the technique becomes very complicated. Skin which has been alum-tawed gives both resistance and suppleness, strength and softness, rigidity and flexibility, elasticity and toughness; it is tenacious but not harmful to the text block; and is extremely durable. Vellum and alum-

tawed skins tend to be of acceptable quality because the processing is still close to the early proven techniques; commercially prepared modern leathers, however, tend to be inferior.

The alum-tawed skin should have the following qualities: for thongs: sound supporting materials, stout, not elastic, flexible in one direction and durable; for ties: material which is more pliable and softer; for protection patches on slotted spines: a good abrasive resistant grain surface.

> There is more to the character of a covering vellum than simply the color and texture; at its best vellum is a wondrous material, delightfully variable in its tactile pleasures. It has translucent depths and if left natural thickness it imparts unique and subtle handling properties. A grain split has lost many such qualities and a binder who thinks of limp vellum as purely economic – or worse still as a 'casing' type structure – debases it ... . The ability of a vellum cover to move and flex with the text block is essential and a fundamental point of my [Clarkson's] theory of limp vellum. Also fundamental is that vellum should be rigid enough to support the volume in normal use (p. 10).

At the Biblioteca Nazionale Centrale in Florence, the rebinding after the flood was done in natural goatskin vellum. Although the majority of the early Italian limp vellums were bound in sheepskin, modern goatskin was considered to be more robust and stable than sheepskin and it is easier to obtain the desired thickness.

The appropriate thickness depends upon the size and the weight of the book. The skin must be thick enough to support the book block when standing alone. According to some binders, the necessary thickness will range from 0.20 mm for a small book to 0.30–0.40 mm for a medium size book, which is not particularly heavy, to at least 0.45 mm for a large book, even though it may be thin. Clarkson uses a thickness which many binders do not consider possible to use. Incidentally, the weight of vellum varies greatly and is not dependent upon the size or the age of the animal, in contrast to leather.

Durability

An important quality of vellum which has been mentioned several times in the course of this paper is its durability. It is stronger than leather, paper, and papyrus, although sensitive to changes in humidity. Vellum can become cockled by moisture or horny by lack of it. Therefore a primary consideration in the care of vellum is a stable temperature and humidity. Cunha (p. 6) also points out that it is almost impossible to make parchment and vellum unpalatable to rodents, and therefore parchment and vellum documents should be kept in strong boxes or steel cabinets. However, it is obvious that many vellum bindings have survived quite well without benefit of a strongbox. Although vellum-

covered books do become grimy, one advantage to this covering is that it may be cleaned quite easily. As Cunha points out, "Regardless of protest from those who lament the loss of a book's old look, there is no virtue in dirt. Dirty vellum attracts vermin and dirt should not be confused with the patina of age. This vermin attracting dirt, however, can be cleaned off quite simply with the froth from castile soap. Saddle soap will also remove surface dirt from vellum bindings, and mildew stains may be brushed off and the volume then painted with benzene or fumigated in a thymol chamber."[22]

To the sensitive binder, the limp vellum structure, of all binding forms, probably shows up the faults in construction the most readily. But it must also be understood that it has quite a different flow and handle than the stiff board book; it is, after all, most satisfactory for the hand and lap, not the table top.[23]

General Use

The use of this binding, however, is not limited only to the reconstruction of vellum or alum-tawed skin bindings. The limp vellum binding, because it relies upon structural strength and minimal or no adhesive, does provide a structure for bindings which use materials other than vellum. The limp paper binding is a form of conservation rebinding for small books, using a material which has a number of advantages to the conservator seeking a standard rebinding which is quick, simple, and inexpensive. This design is simple in construction, therefore increasing the conservator's productivity without compromising conservation requirements. The use of paper of known quality can sometimes assure permanence in a way which the use of questionable modern leathers or vellums cannot. The weight of this binding is relatively light, enhancing durability and easing shelving requirements. The construction is pliant and allows for full opening, often a problem with smaller volumes. Finally, the binding form on which it is based has a proven durability and stability.[24]

This adaptation of the limp vellum binding to the limp paper binding is an excellent example of how the creative conservator can use a knowledge of the development of a historical binding form to create a binding using modern materials which will meet the needs of a fragile collection in a hostile environment within a realistic time frame and budget.

In conclusion, one can say that the limp vellum binding, which has relied on its structure and not on adhesives for strength, has proven itself to be of genuine protection to the book block. Vellum itself, although not without its flaws, is a durable material, and one which supplies both the rigidity and the flexibility required to both support and enhance the mobility of a small volume of the size to be held in the hand or the lap. The structure, sewn on thongs and completely

or almost completely adhesive free, can be removed without damage to the book block.

As our understanding of binding techniques, however, depends upon future refinements based on the study of past practices, one can agree with Clarkson that the destruction of original bindings or coverings no matter how damaged cannot be condoned, for "... future use of such original limp vellum bindings is intrinsically within the historical object itself" (p. 13). Nor should one resort to cosmetic treatments of any kind. It is better to leave well enough alone and box damaged items until better materials and/or improved scholarship can solve individual problems in conservation technique. Nor should one think that because one is binding medieval books that perhaps one must use medieval techniques rather than experiment with original methods. To quote Clarkson once again:

> The late Medieval binder came at the end of a very long period of experiment, changing techniques and awareness of a creativity and variety of codex construction, the like of which we have never seen since. To me, his thoughts and endeavors appear totally different to those of present-day bookbinders. Instead of looking backwards, my endeavor is to attempt to understand the developments and influences ... . The delight to be found in a study of pre-1550 binding structure is very much of the 20th century, for there is this genuine fascination with how tools, materials, and structures influence the character and design of objects (pp. 13–14).

Summaries

Limp Vellum Bindings: Their Value as a Conservation Binding

Based upon a review of the literature, a technical and historical description of the limp vellum binding and its appropriateness as a conservation binding is presented. This binding not only provides greater protection against water damage, but also serves as sounder protection to the bookblock under normal conditions than some other historical bindings, which have actually proven themselves to be harmful. This technique can still benefit from improvements in harmony with its basic structure and intent, for example in improvements on the end paper technique, and can be adapted for use with other materials, as in the limp paper binding. The technique is to be highly recommended in the restoration of smaller historical volumes.

Reliures souples de vélin: Sa valeur en tant que des reliures de conservation

Basée sur une revue littéraire, il a été presenté une description technique et historique de la reliure souple de vélin, aussi bien que son application en tant qu'une reliure de conservation. Cette reliure non seulement fournit une plus grande protection contre les dommages de l'eau, mais elle aussi, sous des conditions normales, sert de meilleure protection du corps du livre que quelqu'autres reliures historiques, lesquelles ont prouvé en fait être nocives. Cette technique peut encore profiter d'améliorations en accord avec sa structure de base et son but, par example, dans les améliorations de la technique des pages de garde, et pouvant être adaptée pour son utilisation à d'autres matériaux, comme dans la reliure souple de papier. Cette technique est hautement recommandée à être utilisée dans la restauration des plus petits volumes historiques.

Flexible Pergamenteinbände: ihre Bedeutung als Konservierungseinbände

Auf der Grundlage früherer Veröffentlichungen wird ein bestimmter Einbandtyp, der flexible Pergamenteinband, in historischer wie in technischer Hinsicht beschrieben, der sich bei Wasserschäden wie auch unter normalen Umständen als weniger gefährlich für den Buchblock erwiesen hat als andere historische Einbandtypen. Es können Verbesserungen innerhalb der Gesetzlichkeit dieses Einbandtyps angebracht werden, z.B. was die Vorsatztechnik betrifft. Außerdem eignet sich diese Technik auch für andere, wie den flexiblen Papiereinband. Insgesamt kann der Einband als „Normalfall" vorgeschlagen werden bei der Restaurierung von kleineren historischen Büchern.

References

1. See bibliography.
2. Clarkson, C.: p. 2. The illustrations (Fig. 1–6) are taken from this paper.
3. *Biblioteca Nationale Centrale, The Restoration System of the B.N.C. di Firenze.* 2nd edition revised. Florence, 1970.
4. Ogden, S.: p. 14.
5. Ogden, S.: p. 63. Ogden includes several references.
6. Horton, C.: (see bibliography) p. 1041.
7. Waters, P.: *Some Technical Problems*, p. 25.
8. Waters, P.: *In Search of a New Philosophy*, p. 17.
9. Waters, P.: *Some Technical Problems*, p. 24.
10. Guiffrida, B.: Part One, p. 2.
11. Ogden, S.: p. 32.
12. Quoted by Ogden, p. 33.
13. Ogden, S.: p. 34.
14. Young, L. (pp. 207–208) seems to take a very different view of limp vellum bindings: "These bindings were originally executed centuries ago as an economical type of binding. Due to the durability of vellum, a number of such bindings are around today. For the most part they are, however, rather unattractive in their present condition. The vellum is wrinkled and cockled and the high spots are rubbed and dirty; frequently, the covers have shrunk or contracted to such an extent that they no longer cover the book pages, and the board papers are invariably torn along the vellum turn-ins. For some reason, for which no one seems to have an explanation, limp vellum has regained its early popularity in the last quarter of the twentieth century. One enthusiast says they eliminate the problem of warping boards! So they do – but they create the problem of cockled covers." Young does not take into account any of the data from the Florence flood. At another point, (p. 205) she points out that vellum is very porous and expands and contracts with humidity, this being a disadvantage because it requires that the book be kept at a fairly constant temperature and humidity. This is, of course, the same environment one should provide for all paper as well. In any case, the limp vellum bindings from the 16th century which this author has examined were in remarkable condition and in no way aesthetically displeasing. According to Barbara Guiffrida, it is the structurally unsound limp vellum bindings of the 17th and 18th century which have given this technique a bad name (Part One, p. 3).
15. Giuffrida, B.: Part One, p. 3.
16. The section on the history of limp vellum bindings is based on Clarkson, pp. 2–4.
17. Clarkson, C.: p. 3.
18. Clarkson, C.: p. 4.

19. For further illustrations, see Clarkson, p. 12.
20. Clarkson, C.: p. 10. An excellent discussion of the properties of and the methods of treating parchment and vellum may be found in Herbert Fahey's *Parchment and Vellum*. (San Francisco: Herbert and Peter Fahey, 1950). If one is fortunate enough to have access to the volume itself, one can view the samples of various types of parchment and vellum, although the text, a photocopy of which is all that one can hope to get on interlibrary loan, is also extremely interesting and enlightening.
21. Giuffrida, B.: Part One, p. 7.
22. Cunha, G. M.: pp. 6–7.
23. Clarkson, C.: p. 13.
24. Frost, G.: p. 1.

Bibliography

Clarkson, Christopher: *Limp Vellum Binding and Its Potential as a Conservation Type Structure for the Rebinding of Early Printed Books: A Break with 19th and 20th Century Rebinding Attitudes and Practices*. ICOM Committee for Conservation. 4th Triennial Meeting, Venice, 1975.

Cockerell, Sydney M.: *The Repairing of Books*. London: Sheppard Press, 1958.

Cunha, George Daniel Martin: *Conservation of Library Materials: A Manual and Bibliography on the Care, Repair and Restoration of Library Materials*. Metuchen, N. J.: Scarecrow Press, 1967.

Fahey, Herbert: *Parchment and Vellum*. San Francisco: Herbert & Peter Fahey, 1950.

Frost, Gary: *Conservation Standard Paper Cased Binding*. Chicago: Newberry Library Conservation Department, s.d. (Working paper).

Guiffrida, Barbara: *Limp and Semi-limp Vellum Bindings*. Designer Bookbinders Review 4–5 (Autumn 1974).

Horton, Carolyn: *Saving the Libraries of Florence*. Wilson Library Bulletin (June, 1967): 1035–1043. Reprinted in *Guild of Bookworkers Journal* 5:2 (1966–67) with original pagination.

Johnson, Arthur: *Manual of Bookbinding*. New York: Scribners, 1978.

Ogden, Sherelyn: *A Study of the Impact of the Florence Flood on the Development of Library Conservation in the U.S., 1966–1976*. A. M. Thesis. Typewritten. University of Chicago, Graduate Library School, 1978.

The Restoration of Books: Florence 1968. Color film, 45 minutes, available on loan from the Library of Congress Restoration Office.

Waters, Peter: *In Search of a New Philosophy of Conservation and Restoration*. Guild of Bookworkers Journal 7:2 (1968–69): 12–21.

Waters, Peter: *Some Technical Problems of Book Conservation* Ibid. 22–39.

Young, Laura S.: *Bookbinding and Conservation by Hand*. New York: R. R. Bowker, 1981.

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1. Barrow, William J.: *Restoration methods*. American Archivist 6 (1943): 151–54.
2. Hunter, D.: *Paper Making*. New York 1947.

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ISSN 0034-5806