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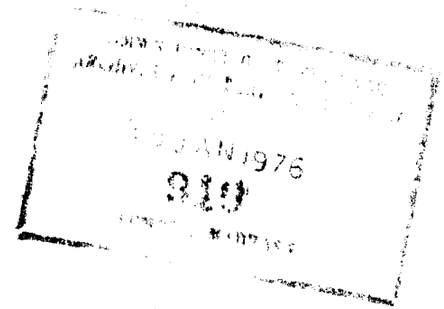

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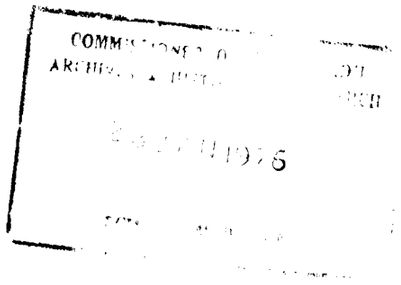

The Freeing of Papyri from Cartonnage

by ØYSTEIN WENDELBO

»Papyrus first the Mind of man did whet«.
Jean Imberdis, S. J. *Papyrus.* 1693.

The use of papyrus in Egypt goes back to an indefinite antiquity. The earliest extant specimen we have, an unused flattened roll, has been found in a First Dynasty tomb at North Saqqara *ca.* 3100 B. C. The earliest inscribed papyri come to us from Abu Sir, being temple accounts from *ca.* 2400 B. C.[3] For thousands of years, still in use in the eleventh century after Christ, papyrus was the most important writing material, and, as considered by Pliny the Elder: "Civilisation – or at the very least, human history – depends on papyrus".[4]

Technically, the making of papyrus sheets for writing remained essentially the same during the long period of its use, almost four thousand years. The *locus classicus* on the preparation of the material is found in Pliny the Elder's Natural History, *ca.* 70 A. D.[4] According to him the stem of the plant was cut into longitudinal strips. These strips were placed side by side to the required width, and a second layer likewise laid across the first, at right angles. After being soaked in the Nile water, the sheet was pressed dried in the sun, and finally trimmed and polished.

Pliny states that the muddy liquid from the Nile water served the purpose of glue, keeping the strips together. His statement has long been doubted. A more likely explanation is that the cell sap counts for the glueing effect, as the sap has been found to contain a gum; a polymer of galactose, arabinose and rhamnose.[5] As the strips were beaten, the plant juice, containing the natural gum, would extrude and cause the two layers of the sheet, the *verso* and the *recto,* to stick.

During the Ptolemaic and Roman Periods in Egypt (322 B. C.–313 A. D.) written papyri were extensively used to make cartonnage for the protection of the head, breast and feet of mummies. The cartonnage consisted of layers of papyri, glued together; sometimes with linen. The outside of the mummy cases were covered, first with gesso and then with paint and gilding.

As there exists a vast quantity of cartonnage from these periods, many attempts have been made in the past to extract the papyri. The results have not always been encouraging, as the extraction procedures have been rather crude. Known to the author are methods with plain water, boiling water, steam, acids (*e. g.* acetic acid, hydrochloric acid), etc.[6]

Perhaps the most famous text deriving from cartonnage source is Menander's play *The Sicyonian,* of which there are more or less extensive remains of 420 lines. As to how many have been destroyed during "heroic" attempts of extraction, we have no record.

The scanty collection of papyri at our university, a collection of papyri embedded in cartonnage and acquired by the late Professor Sam Eitrem in 1905, did not tempt anybody to try the hazardous procedures previously mentioned. "Par nécessité" research for developing a more efficient, less harmful method was started.

A characterization of the cartonnage material became imperative. As very little information of precise nature is found about this matter in writing, it became necessary, to some extent, to draw upon the few experts in this field. This was also so as to the botany, biology and biochemistry of the papyrus.

Alfred Lucas[7] made many chemical analyses of old Egyptian gesso, and he concluded that it consisted of whiting (calcium carbonate) containing nitrogenous organic matter. As calcium carbonate possesses very small adhesive properties, a binding substance was expected.

To determine the mineral compounds in the gesso of our collection, an x-ray diffractometric study was carried out.[8] This investigation showed, beyond doubt, that it consisted of calcium carbonate.

The adhesive binding the two layers of the papyrus sheet together, the *recto* and the *verso,* has been mentioned earlier. It is a natural gum of carbohydrate composition in the cell sap.

Left to be answered was the question what binds the *mineral compound* in the gesso. The same question obtained with regard to what keeps the different *sheets* of papyri and the layers of *linen* together.

Lucas found nitrogenous organic matter in the gesso, and this suggested to him a kind of glue of ainmal origin as the adhesive. Glue in ancient Egypt was made mainly by extracting certain animal products containing gelatine (bones, skins, cartilage and tendons *etc.).*[7] The making of casein glue from milk was also known.[9] The author has been dealing for years with the use of proteoloytic enzymes for splitting these kinds of adhesives in the work of restoration.[10] The enzyme trypsin, *e. g.*, splits casein glue

and glue of animal origin (glue from collagen). The enzyme hydrolyses peptides, amides, esters at bonds involving the carboxyl group of arginine or lysine. Glue from collagen contains lysine, as does casein. The actions of chymotrypsin and its optimum are similar to trypsin, *i. e.* a preferential attack on peptide linkages involving the carboxyl group of tyrosine and phenylalanine, merely the specificity differs. Both the last named amino acids are also found in gelatin an casein.

"Ex juvantibus" it should be possible to test the hypothesis that an adhesive consisting of protein *(e. g.* glue from collagen or casein glue) had been used. As crystalline trypsin is very expensive, a technical preparation, Pancreas Trypsin NOVO, was chosen. This contains trypsin and chymotrypsin only and is free of any foreign extenders. Apart from containing enzymatically inactive protein, a major non-enzymatic component is ammonium sulphate (50 %).

The procedure of the method has been dealt with in two previous publications.[1, 2] Shortly recapitulated it consists in dissolving the enzymatic preparation (activity 6 Anson units/gr.) in a Sørensen's phosphate buffer solution, pH 8. Pancreas Trypsin NOVO is active at pH 5–11 with maximum activity at pH 8. This enzymatic solution (1 %) is kept at + 40° C by using a water-bath. For most purposes this temperature gives the most advantageous combination of activity and stability.

The cartonnage fragment is put into the solution, and the gesso starts "dissolving" almost immediately. The text usually emerges within 5–10 minutes. When the papyri are glued together in layers, a separation occurs after a somewhat longer exposure time, from 10–15 minutes. The separation is aided by the use of a fine, blunt spatula. The enzymatic effect is stopped by washing out in ordinary tap water, and the papyrus fragment is then dried and flattened between blotters under light weight. Finally the papyrus is mounted between glass.

Some of the results obtained with the method are shown in the plates 1–5. Plate 5 demonstrates one aspect left out in this article; the application of the method to other restoration objects. As will be seen from the plate, the textile is completely freed from the gesso and the glue.

The enzymatic approach will be the answer to many problems in restoration presently regarded as insoluble. This is so because the enzymes represent a varied, omnipotent group, from which one can be chosen that deals with one definite process, and this only. It leaves the many structures in the restoration object intact, except for the one which the enzyme, by selection, is to work upon. The chemicals presently used in restoration

usually lack this specificity. Another advantage is the speed of the enzymatic process. What can be achieved by other chemicals in the course of days or weeks (with sometimes deleterious effects to the restoration object in the meantime by chemical or solvent, light, air *etc.)*, is brought about within minutes.

Of the Sam Eitrem collection, 16 fragments have been treated with the enzymatic process. During a demonstration at the XIV. International Congress of Papyrologists, Oxford, 27. July, 1974[2], a piece (ca. 18 cm. × 12 cm.) of the Oxyrhynchus cartonnage was treated in the same way. This last specimen consisted of a hard layer of gesso and four layers of glued papyri, all four carrying writing. In neither case was any fading of the writing observed.

The immediate results were good. A fundamental question to be answered is whether they could have been obtained by any of the previously mentioned methods. On theoretical grounds, those applying acids, boiling water or steam, are considered inferior to the enzymatic method as to the chances of causing destructive effects to the plant material and have not been tested. The use of plain water has been used, and with good result, in a case where the gesso layer was very thin. This is what one would expect, as the organic adhesive will more easily be broken down during the milliena in a thin layer of gesso. The thicker, more compact layers of gesso are not prone to such easy break-down.

Another important question to be answered is whether the method causes delayed detrimental effects. The papyrus sheets stem from the pithy material of Cyperus papyrus and consist of *ca.* 2–3 % of proteins (D. W.), Grant 1970[16]; the rest (*ca.* 97 %) being structual material. Such structual plant material is almost entirely of carbohydrate composition (cellulose, hemicelluloses), lignin *etc.* and inert to proteolytic enzymes. The small content of proteins i considered *une quantité néglieable* when considering papyrus as substance for writing material. An eventual enzymatic attack on the proteins will have negligible effect on the restoration object.

Amino acid determination of Cyperus papyrus lends further support to this statement.[13] Three samples from the pith of the lower stem were exposed to acid hydrolysis by 5.7 M HCl, containing 0.05 % (v/v) thioglycolic acid at + 105° C in sealed Pyrex tubes under N_2 atmosphere for 48 hours. The samples were analyzed on a Bio-Cal amino acid analyzer (type BC-200), according to the one column system of Dus et al.[14] The analysis revealed the presence of all the common amino acids, but the yield for some was too

TABLE 1: Amino acid content in Cyperus papyrus* (from the lake Tana, Abyssinia).[15]

Amino acid	Content (μ moles/g, dry weight)	Weight (mg/g, dry weight)
Aspartic acid	5.25	0.70
Threonine	2.65	0.32
Serine	3.79	0.40
Glutamic acid	4.11	0.60
Proline	3.17	0.36
Glycine	3.99	0.30
Alanine	3.00	0.27
Cysteine	Trace	
Valine	4.78	0.56
Methionine	1.61	0.24
Isoleucine	2.76	0.36
Leucine	4.77	0.63
Tyrosine	1.99	0.36
Phenylalanine	1.43	0.24
Histidine	0.89	0.14
Lysine	3.57	0.52
Arginine	2.40	0.42
Total	50.16	6.42

* Average from the determinations of three different samples.

low to be calculated, and is not listed in TABLE I. Based on the molecular weights of the amino acids listed, the amino acid content could be calculated to be 6.42 mg. pr. 1000 mg. plant tissue (w/w, dry weight), *i. e. 0.6 (6)* %.

Papyrus, subjected to the enzymatic method, was studied by light- and scanning electron microscopy to see if untoward effects could be noted. This study did not reveal microscopically visible detrimental effects to the papyrus.[12]

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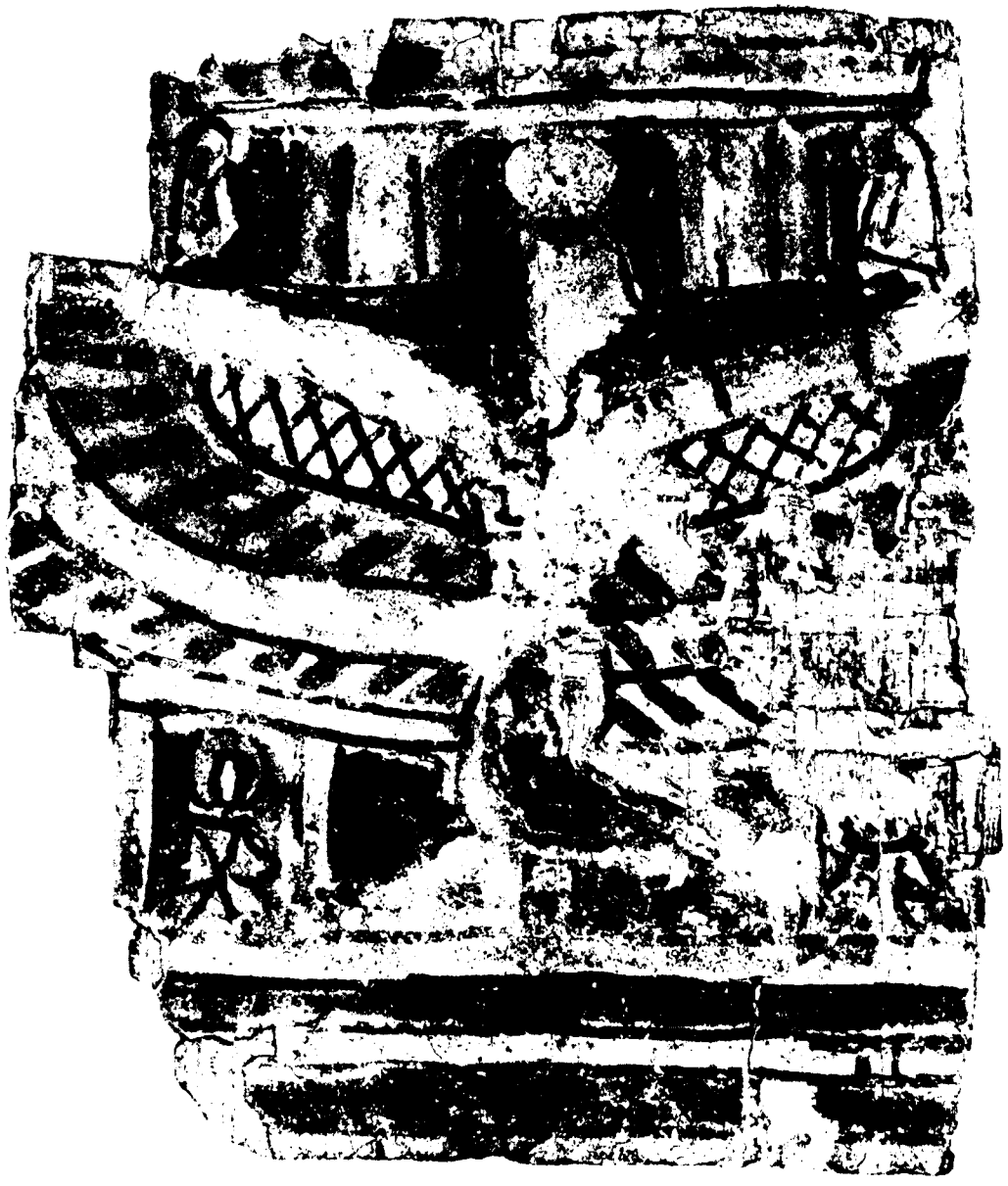

PLATE 1. A papyrus fragment (ca. 12 cm.×16 cm.), about 2100 years old, covered by gesso.

PLATE 2. Same papyrus as shown in plate 1 after enzymatic removal of the papyrus from the cartonnage (a small piece in the right hand corner).

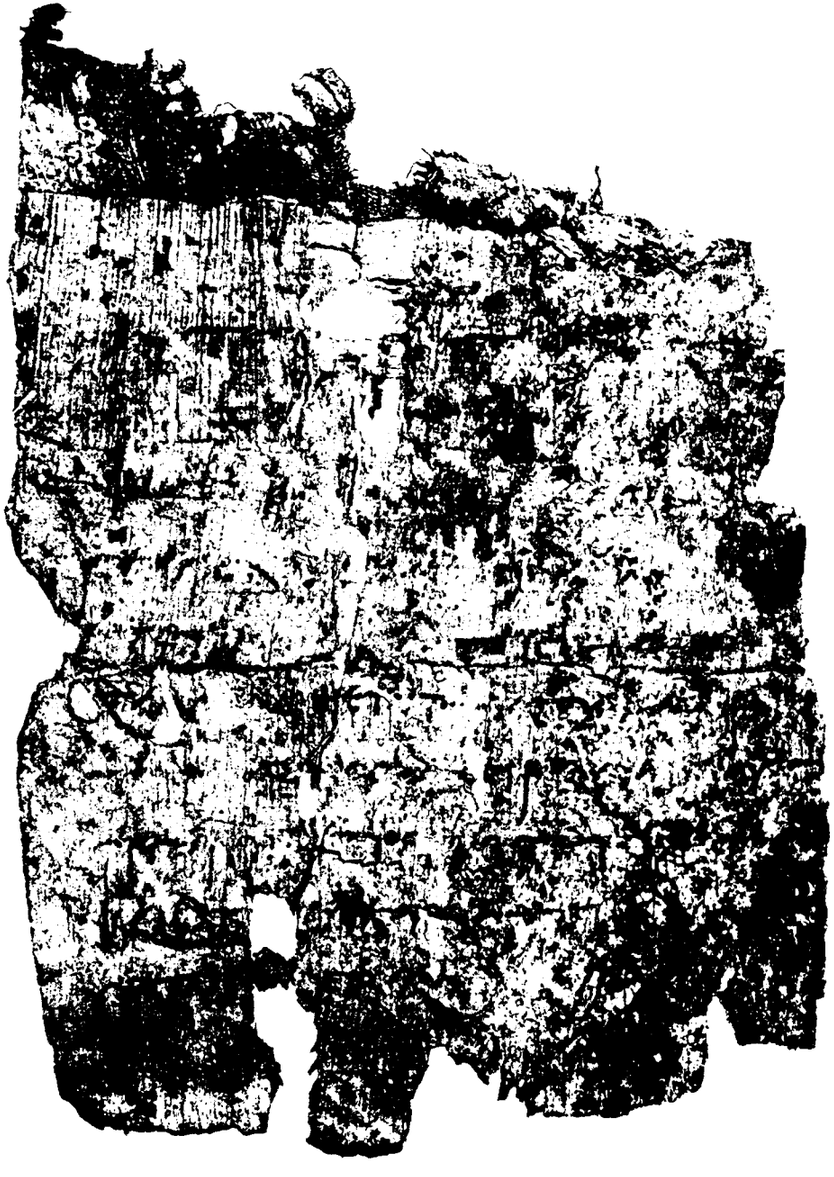

PLATE 3. A papyrus fragment (ca. 11 cm.×16 cm.), about 2100 years old, covered partly by gesso.

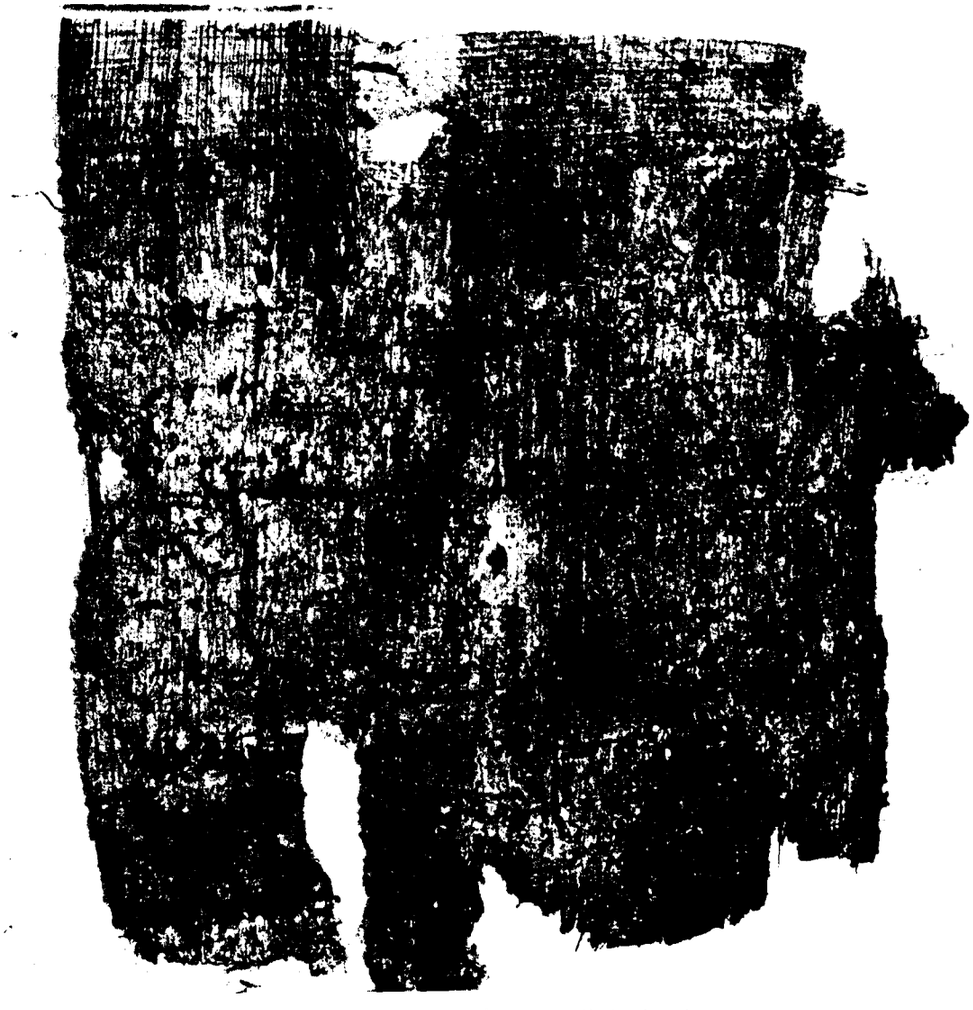

PLATE 4. Same papyrus as shown in plate 3 after enzymatic treatment.

PLATE 5. Pieces of textile after enzymatic removal from the cartonnage (from the top of the fragment shown in plate 3). – Enlarged.

Bergen, for their kind permission to use their laboratories and necessary equipment. The author wants to express his sincere gratitude to Professor Richard Holton Pierce, Ph. D. Department of Classics, University of Bergen, for his initiation and support of this work.

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SUMMARIES

The method for the extraction of papyri from gesso cartonnage by the use of proteolytic enzymes (trypsin and chymotrypsin) is presented. Control studies, supported by light- and electron microscopy have not revealed any detrimental changes, either to the text or to the papyrus material.

Es wird ein Verfahren präsentiert das durch Anwendung proteolytischer Enzymen (Trypsin und Chymotrypsin) die Freimachung von Papyrus aus Mumiekartonage ermöglicht. Kontroll-studien, mit Licht- und durch Elektronmikroskopie unterstützt, haben keine unerwünschte Nebenwirkungen enthüllt.

Un procédé est présenté, par lequel il est possible, à l'aide d'enzymes protéolytiques (trypsine et chymotrypsine) de faire une extraction de papyrus des cartonnages de momies. Les études de contrôle, appuyées par microscopie électronique, n'ont démontré aucun changement destructif, ni au texte, ni au papyrus.

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The Enzymatic Extraction of Papyri from Cartonnage:

A Control Study by Light- and Scanning Electron Microscopy

by PER R. FLOOD & ØYSTEIN WENDELBO

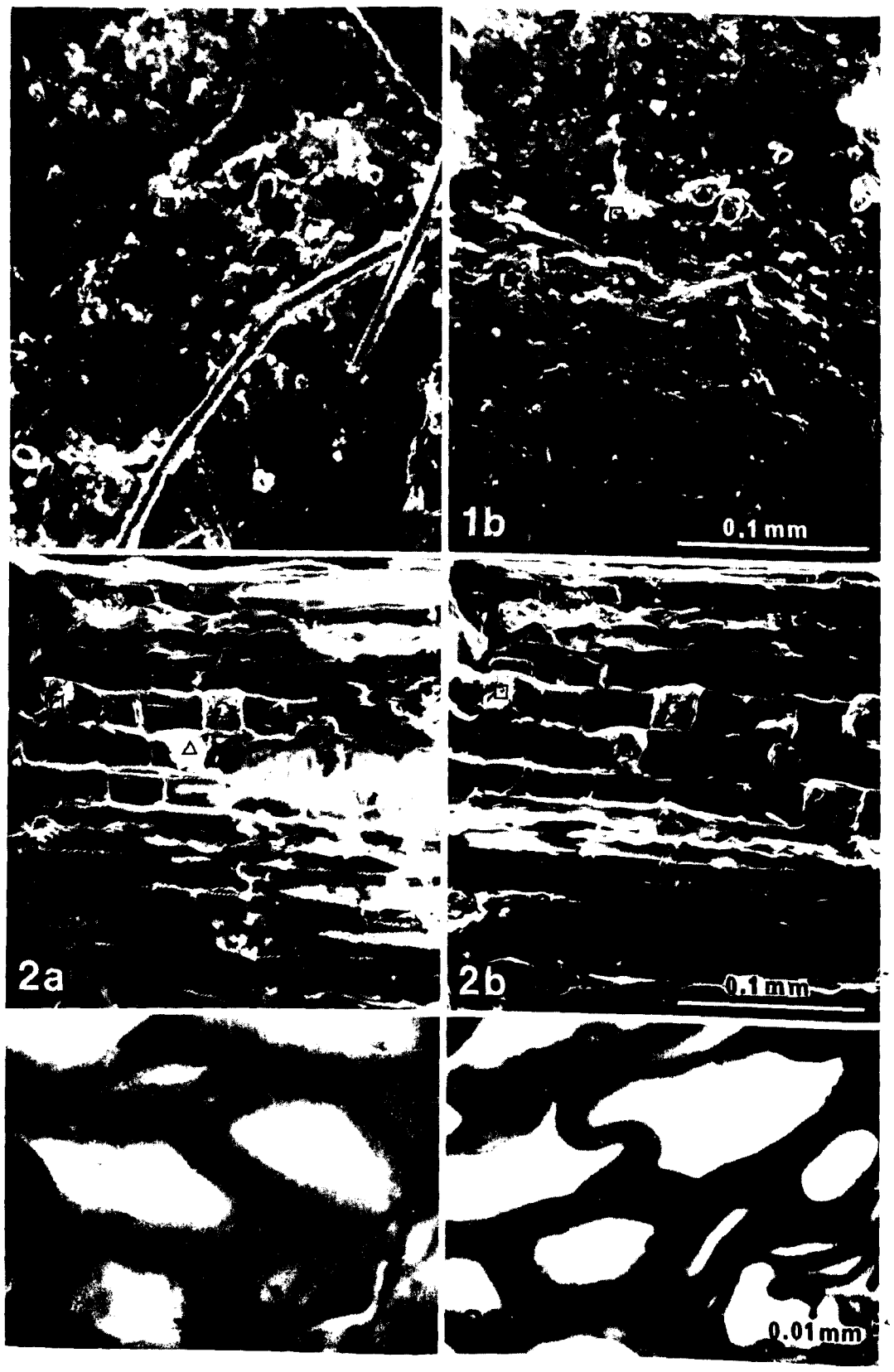
Introduction

As mentioned in previous publications (Wendelbo 1975, a, b, c), there should be no theoretical objections to the use of proteolytic enzymes for the freeing of papyri from cartonnage. The papyrus sheets stem from the pithy material of Cyperus papyrus and consist almost entirely of structural material *e. g.* cellulose, hemicelluloses, lignin *etc.* which are inert to the protelytic enzymes used. Only 2–3 % D. W. of the pithy material may consist of proteins (Grant 1970), which might possibly be attacked by the enzymes. Although it is unlikely that an eventual "digestion" of these proteins should cause any detrimental effects to the structure of papyrus, a light- and scanning electron microscopic study was undertaken, to see if any significant structural differences could be detected between "untreated" and "treated" papyrus.

Material and Methods

Papyrus from the same collection as that used in the previous published works (Wendelbo 1975, a, b) was used (gesso cartonnage, about 2100 years old). By *treated* papyrus is meant papyrus exposed to the same enzymatic preparation (Pancreas Trypsin NOVO, 6 Anson u/ gr.), for the same time (30 minutes) and under the same working conditions (pH, buffer solution, temp.) as we use for the extraction of papyri from cartonnage during restoration; i. e. pH 8, Sørensen's phosphate buffer, temp. + 40° C, concentration of enzymes in the solution, 1 %.

By *untreated* papyrus is meant papyrus that has been exposed to the same procedures with the exception of the use of enzymes. For scanning electron microscopy, small fragments of the two types of papyrus speci-



Text to the Figures

FIGS. 1a and b.

Scanning electron micrographs of the same region of the natural surface of a papyrus fragment a) before and b) after enzymatic treatment. Three granules present in both pictures are indicated by various symbols for ease of orientation. Note that most of the contamination layer in a) has been removed by the treatment b). Magnification × 300.

FIGS. 2a and b.

Scanning electron micrographs of the internal structure of a fragment of papyrus a) before and b) after enzymatic treatment. Details from 3 cells are marked by various symbols for ease of orientation. Note that almost every detail is preserved after the treatment. The diffuse light areas in a) are artifacts due to electrical charging of the specimen. Magnification × 300.

FIGS. 3a and b.

Light micrographs of toluidine blue stained sections through a) untreated and b) enzyme-treated papyrus. The light roundish holes represent the plant cells and the dark meshwork, the walls of two adjoining cells. Note that the internal structure and the total diameter of the walls have not changed after the treatment. Magnification × 1520.

mens were mounted on aluminium studs with the aid of Scotch double adhesive tape (Minnesota Mining and Manufacturing C.). The studs with "untreated" papyrus were first soaked in distilled water, air-dried, and then examined in a JEOL JSM U-3 scanning electron microscope, operated at 25 KV. Photographs were made of easily identifiable details. Later the specimen studs were removed and then exposed to the enzymatic solution. After a brief rinse in distilled water, air drying and evaporation of gold-palladium from a heated tungsten filament at 10^{-4} Torr, these "treated" samples were examined again in the scanning microscope and photographs made of the same easily identifiable details previously photographed.

For light microscopy, small fragments of "treated" and "untreated" papyrus were fixed in glutaraldehyde, rinsed in distilled water, dehydrated in increasing concentration of ethanol, exposed to moderate vacuum to remove air from the interior of the sample, and finally infiltrated by propylene oxide and embedded in Epon (Luft 1961). Polymerization was achieved by incubation at + 60° C for 3 days. Sections were cut 1 μm thick and stained by toluidine blue (Grimley et al. 1965) or a modification of the Periodic acid-Schiff reaction (Pearse 1961).

Results

The scanning electron microscope is particularly suited for the examination of small details in the surface topography of specimens.

The external surfaces of the papyrus revealed abrupt changes from the untreated state to the treated state (Figs. 1a and 1b). The untreated surface (Fig. 1a) appeared to contain numerous granules and fibres partly embedded in an amorphous material. After the enzymatic treatment (Fig. 1b) most of these substances had been removed, revealing a much smoother surface where the orientation of plant fibres could be seen.

When *internal surfaces* were uncovered by stripping off the superficial layer of plant fibres from fragments of the papyrus prior to the enzymatic treatment, no obvious changes from the untreated to treated state were revealed (Figs. 2a and b). Only quite rarely did the details seem to be changed or lost in the latter sample.

The light microscope was used to examine thin *sections* through the papyrus. The outlines of the individual cells of the plant tissue were easily identifiable. No direct comparison of the structure before and after treatment could be made as these sections had to be made from two separate pieces of the papyrus sheet, one untreated and one treated. Although the

size and form of the individual plant cells showed great variability, the structures in their limiting walls were quite similar in the untreated (Fig. 3a) and treated (Fig. 3b) specimens. No tendency to cell dissociation was noted in any of the specimens examined.

Discussion

It may be worthwile to mention a few limitations of the applied techniques.

High quality scanning electron micrographs can only be obtained from specimens coated with heavy metals to enhance secondary electron emission and to prevent electrical charging up. Such metal coating could not be performed on the untreated samples as the coating might prevent the access of the enzyme preparation to the specimen during the subsequent treatment. Accordingly the micrographs of the untreated samples reveal some artifacts not present in the micrographs of the treated samples. The re-soaking and re-drying of the specimens from untreated to treated state may also give slight differences in the surface pattern due to the random collapse of delicate structures. With these two limitations in mind it is concluded that the scanning electron microscopic study revealed no significant differences in the internal structure of treated and untreated papyrus, whereas pronounced differences were seen on the natural surface of the papyrus; or in other terms, even thick layers of contamination could be removed without any visible harmful effects to the plant tissue.

Regarding the light microscopical technique used, it may be said that small quantitative- or patchy differences are difficult to verify, especially when the tissue is as heterogeneous as in the present material. A great number of rather large samples, both treated and untreated, and exact measurements of various structures through the microscope would be needed to achieve this. Unfortunately, our limited supply of papyrus did not allow us to perform such analyses. We can therefore only conclude that no obvious differences between the untreated and treated samples could be detected.

From the reported observations it seems justified to state that the proteolytic enzymes have no light-microscopically visible detrimental effects on the structure of papyrus tissue.

SUMMARIES

The structure of papyrus extracted from cartonnage by means of proteolytic enzymes (trypsin and chymotrypsin), were compared with those of untreated papyrus from the same collection by the use of light- and scanning microscopy. No significant differences were observed, and it is concluded that the enzyme extraction technique causes no microscopically visible detrimental effects to papyrus.

Die Struktur von Papyrus, freigemacht von Kartonage durch die Anvendung proteolytischer Enzymen (Trypsin und Chymoterypsin) wurde mit der Struktur von unbehandeltem Papyrus aus derselben Kollektion durch Licht- und scanning Mikroskopie vergleichen. Keine signifikante Differenzen wurden beobachtet, und es ist konkludiert, dass die Enzymekstraktionstechnik keine mikroskopische sichtbare schâdliche Wirkungen auf Papyrus verursacht.

La structure de papyrus extraits de cartonnages au moyen d'enzymes protéolytiques (trypsine et chymotrypsine) a été comparée par microscopie lumineuse et par scanning avec celle de papyrus non traités de la même collection. Aucune différence significative n'ayant été constatée, on en a conclu que la technique de l'extraction enzymatique n'a aucun effet nuisible, visible au microscope, sur les papyrus.

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A Method for Fastening Single Leaves together for Binding into Volumes

by HENRY PEDERSEN

In order to save archival documents or valuable records from unnecessary wear and tear it is often convenient to use photo-copies, bound into volumes, instead of the originals. Most methods of making such single sheets into volumes, such as pasting together, or the so-called "perfect binding" do not produce durable long-lasting books and it is therefore necessary to have a method of producing a more substantial volume. This paper describes a method of binding designed by the author, which has now been used successfully for several years in the National Archives of Norway, in Oslo.

In this method, the individual leaves are pasted together in groups of four, and four of these groups are inserted one inside the other to make what is, in effect, the normal section of a book. It is essential that a volume should not have an excessive swell at the spine if it is to be structurally sound. The distinctive feature of this method is that the section produced is even in thickness from the inner (spine) side to the outer (fore-edge) side, so that the swell produced is solely that due to sewing, which is normal and under the control of the binder.

The method of producing this is now described, but the following points must be noted. The inner margin, between the text and the edge of the single leaf should be at least 2.5 cm (one inch) to 3 cm (one and a quarter inches) in width. The machine direction (grain) of the paper must be vertical. This rule is a commonplace to any bookbinder, but it is all too often violated. If the machine direction of the paper is not vertical, then the paper, and the finished volume, will be difficult to handle and the individual sheets will break more easily than they should.

Method

Collate the sheets, numbering them consecutively. Take the sheets numbered 1 to 16 and divide them into four piles, called A, B, C and D.

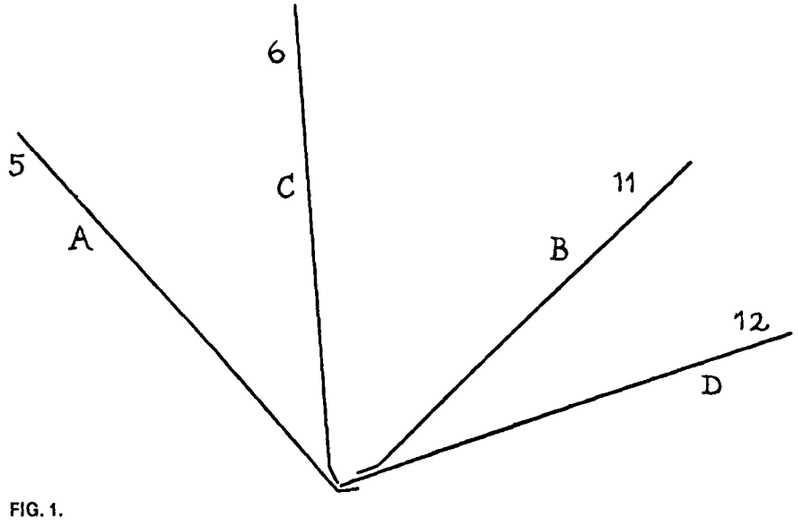

FIG. 1.

In pile A place sheets 1, 3, 5, 7.
In pile B place sheets 9, 11, 13, 15.
In pile C place sheets 2, 4, 6, 8.
In pile D place sheets 10, 12, 14, 16.

From the inner margin of pile B, trim off a strip exactly 8 mm wide, from the inner margin of pile C trim off 5 mm and from the inner margin of pile D trim off 4 mm. Pile A is not trimmed.

Sheets in pile A are not pasted. Sheets in pile C are pasted on the front side and sheets in piles B and D are pasted on the back. Adhesive is applied to a strip, exactly 4 mm wide, of the sheets at the hinge side.

Place sheet no. 1 with the front turned down, and stick the pasted sheet no. 16 to it. (Make no. 16 cover 4 mm of no. 1). Then place no. 2 on no. 1 (both front down) and no. 2 on no. 15. The outer edge of no. 2 and no. 15 should cover the edge of the two sheets beneath. (The result will be a noticeable 5 mm distance between the inner margin edges of no. 2 and no. 15).

When this quarter of a complete sheet is dry, it can be folded. The second quarter-sheet consists of nos. 3, 4, 13, 14, the third of nos. 5, 6, 11, 12, (which is shown in fig. 1) and the fourth of nos. 7, 8, 9, 10.

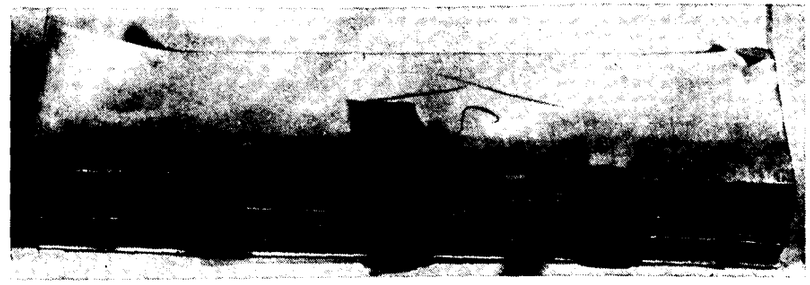

FIG. 2.: There is no swell at the spine except that due to the sewing.

It will be evident that the quarter-sheets should be enclosed in each other to constitute a complete sheet, nos. 1–16. It will also be noticed that cone-shaped back is avoided (see fig. 2).

The subsequent sheets are given the same treatment. It may be helpful to make a list of sheets with odd and even numbers in two separate columns:

1 3 5 7 / 9 11 13 15 / 17 19 21 23 / 25 27 29 31
2 4 6 8 / 10 12 14 16 / 18 20 22 24 / 26 28 30 32
etc.

The loose sheets are sorted in quarter-sheets according to the same procedure as described above. A memo of numbers to be cut, 4, 5 and 8 mm respectively, and uncut ones will also be of great help. The same applies to pasting.

Before the work starts it would be useful to make a practice section, say of A-4 sheets.

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The Technology of Conservation and Restoration of Library Materials

by JU. P. NJUKSHA

Until recently scientific and practical work related to the conservation and restoration of library materials developed in several directions and was applied in several ways. The following is a survey of the various fields in question:

1. A system for control, registration and regulation of storage conditions.
2. Mass disinfection and disinsections treatment.
3. Manual restoration and conservation of paper-materials, combining all operations of strengthening and restoring.
4. Conservation of parchment, vellum and other ancient manuscript materials.
5. Conservation of painted layers and texts written in ink.
6. Conservation and restoration of bindings.

Each type of restoration originates from and has gradually been formulated on the basis of a primitive technique. The word "technique" is here to be understood in its former sense, i. e. a total sum of methods, practical skill, art and craftsmanship. At present, this meaning is becoming still more limited in favour of the new common meaning of this word: technics – as increasingly complex industrial methods, as the whole field of machines, mechanical equipment and apparatus. This development has taken place under the circumstances described below.

In the beginning of the seventies of the last century high-polymer chemistry began to manifest itself as an important factor for the preservation of cultural and historical treasures. To begin with, high-polymer chemistry was only applied to the fibrous materials and to the restoration and cleaning of such materials. Later it developed into a remedy for the protection of paper from ageing and decay. At that time, however, and even for several decades later, the chemical materials such as adhesives and protective films were still applied manually. The methods used in no way differed from the methods applied at work with natural materials.

The idea of applying technics by applying high-polymer materials to

deteriorated paper did not materialize till the beginning of the 1930ies.[1] Gradually the development of this idea formed new principles of technology, which could not be contained within the framework of primitive handicraft.[2] This hindered the full exploitation of synthetic and artificial high-polymer compounds. At that time the science of preserving library and archive stocks took a significant step forward, its theoretical basis broadened, and practical requirements increased. These reciprocal processes resulted in the creation of new conservation and restoration methods, which may be categorized into 4 main groups:

1. Lamination by applying transparent plastic film on the surface of paper or other materials.
2. Impregnation-saturation of paper with other materials – melted or dissolved – to a specific depth.
3. Filling up missing parts of sheets (thickness as well as area) with paper pulp.
4. Paper splitting (thickness) for reinforcement of it "from inside" or for the transfer of text to another base material.

Libraries and archives now have a variety of technical means at their disposal for conservation and restoration. The existing equipment facilitates the most up-to-date conservation and restoration procedures. Though they have been in use for a long time, they are still ardently supported by some, while opposed and criticized by others. The reasonable thing would be to exclude extreme points of view and to evaluate the advantages and disadvantages of each method.

The Department of Book Hygiene and Restoration of the Saltykov-Shchedrin State Public Library has at its disposal six sets of apparatuses for three methods of technical restoration.

Impregnation, lamination and filling-up the missing parts of sheets with paper pulp have become integral parts of the scientific and practical work of the Department. For impregnation we use the latest model of the impregnator produced by "Stroiotechna", (produced in the Socialist Federal Republic of Yugoslavia). This machine has two horizontal plates, which makes it possible to press material measuring 75 × 100 cm² at temperatures at a maximum of 180° C, and a press of two rollers for pressing softened film onto paper. It is equipped with a system of control and regulation of the process.

Lamination is carried out on a little flat press with heated plates measuring 14 × 17,5 cm²,on the laminator "Folietta G" (produced in the

German Federal Republic), and on a two-roller laminator, LD-1 (produced in the USSR). This apparatus is designed only for film with fusible underlayer, for application on both sides of the paper sheet at the moment it passes through rotating rollers, at a maximum temperature of 180° C.

Technology of restoration by paper pulp at the application of a new large-scale clearance-gauge apparatus, is one of the results worked out in the Department of Book Hygiene and Restoration. [3, 4]

This work began to develop in 1956. From then until 1969 the laboratory equipment was in constant use. The idea of creating a small model of an apparatus for filling up the missing parts of sheets with paper pulp was adopted from the laboratory practise of the cellulose-paper industry and was accomodated for restoration needs. The model consists of a casting frame, a pulp mixer, dosing out paper pulp, and a drying arrangement. The maximum area of a sheet that may be restored on this apparatus is 41 × 31 cm². All operations, except water exhausting, are carried out manually.

In 1965 we began the work of designing, mounting and adjusting a new apparatus, which, beside a casting frame and a press for moulded sheets, at present includes a number of auxiliary equipment for the mechanization of several operations such as grinding and stirring the pulp, transportation of moulded sheets etc. The working area of this casting apparatus is 75 × 60 cm².[5]

Design of this apparatus was accomplished by the workers of our laboratory and restoration group in close cooperation with designing and manufacturing organisations. At present the apparatus is used solely for industrial purposes, to which it is a very valuable help.

Fifteen years of experience with the above mentioned equipment in the Department of Book Hygiene and Restoration has resulted in a large number of results and several practical methods. We therefore feel justified in giving our own judgments regarding the advantages and disadvantages of the applied restoration methods. The latter may be characterized as follows.

1. Innovation in Technology

The introduction of specialized machinery signifies not only the mere transition from manual to mechanical restoration but first and foremost a principal change in technology in accordance with the modern development of science and technology, thus involving a transformation of certain concepts. All previous restoration methods were, f. instance, based on the

application of adhesives. At the application of technical methods, the use of adhesive compositions is rejected and substituted by processes based on the physical and chemical reactions of partial penetration of polymers between paper fibres. The polymers form branched configurations, thus ensuring that the strong paper fibres are joined to synthetic polymers and to one another. The application of these methods and materials make it possible to save texts on paper in critical condition, and to turn them into durable monoliths, which will be accessible to future generations.

2. Automation of the Main Procedure

One of the most important features of mechanical restoration is exactness, equal distribution of a material on the whole working area, without special efforts on the part of the restorer. For example, during impregnation of a paper sheet with polyethylene film melted polymer will penetrate into the holes and friable parts, and a levelling of the upper layer will take place. Lacunae, cracks and missing parts of sheets are filled up, and restoration of thickness with paper pulp is carried out in accordance with their dimensions and outline, and according to preliminary calculations. The main procedure thus being automatized, the restorer's work is independent of individual craftsmanship. Preliminary calculations, exact adherence to technological procedures, knowledge of the properties of different raw materials and materials for restoration are the decisive factors with regard to the quality of restoration.

3. Durability and Permanence

Conservation and restoration by mechanical methods are justified only in so far as they ensure greater durability and permanence of library materials during storage and usage. A comparison of results shows that the results of application of all three mechanical restoration methods surpasses those of manual work. The material for addition of missing parts by hand consists of old paper with a folding endurance not exceeding 80. The parts filled up with paper pulp are usually more durable, their folding endurance rates not being below 350 and sometimes reaching 1000 double folds. Undoubtedly, new parts made of the most stable fibres (either of cotton fibre or of refined sulphate cellulose) with a very long lifetime are more durable than added parts made of random old sheets, which have lost a considerable part of their durability and permanence. Further chemical

research on cellulose has shown that, when the original sheet is washed with a large amount of water, the paper ages more slowly.[6, 7]

The impermanence and fragility of newsprint are wellknown, its folding endurance being as low as 3–5. After impregnation by means of polyethylene film with tissue paper the folding strength of newsprint increases a hundred times, viz. up to 1500–2000 double folds. The paper becomes elastic and acquires a high degree of durability. Experience has taught that manually restored newspapers soon require repeated restoration after intensive use by reader over 5–10 years. This repeated restoration is extremely difficult, as it is practically impossible to keep the texts intact. The same applies to reference books, which will "distend" in a year, their right lower corners will wear out, folds will appear on the pages, and the side columns will become unreadable. Laminated dictionaries and indexes to reference books have preserved their original quality for nine years though readers have had free access to the shelves and used the books continuously.

4. Qualitative Features of Material

Outward appearance, legibility of texts and weight of material change when books are restored manually, as restorers will always paste on the sheet to be restored some material which is not light and transparent as desirable. At restoration by paper pulp, thorough washing is part of the technological process; the paper hereby looses all deposits and dirt, and the text becomes more legible. Increase of weight occurs only when missing parts are added, the initial weight thus being restored. Impregnation changes to some extent the outward characteristics of paper, depending on the basic and auxiliary materials applied. Lamination, if it is not a substitution of previous lamination, will cause a great change of the outward appearance of paper. Both methods improve the legibility of the text and always result in an increase of weight by the addition of polymer films.

The weight of the material will also increase after manual restoration, but it should be noted that there is a qualitative difference between these types of additional weights.

5. Biological Resistance

Almost since the beginning of restoration work restorers have frequently been troubled by the fact that an enormous quantity of organic materials are used as adhesives and impregnating compositions, as such raw material

easily yields to biological deterioration. The problem of the biological resistance and preservation of adhesives, which is still unsolved, causes constant anxiety to restorers and binders. No fully satisfactory substance that may be recommended without reservation has been found so far. As search for such an agent goes on, new difficulties are encountered. It is a matter of fact that at manual restoration the danger of attack by microorganisms, insects and rodents is increased, whereas at mechanical restoration which is carried out without application of special preserving compounds, but simply through the technological processes themselves, together with the materials used, imparts greater biological endurance to paper, comparable to its original state, which is in itself of great importance. Synthetic materials will deteriorate less than organic, especially during storage, if changes in storage conditions are of short duration and do not exceed critical limits. But even when exposed to damage synthetic materials will undoubtedly be more resistant to biological deterioration. This is proved by data from tests where parts were filled up with paper pulp: After 10 days' exposure to deterioration by fungi the residual strength of such material was 15 times higher than the strength of original sheets.

The most valuable quality of technical restoration is imparting impermeability to paper, especially as deterioration by microorganisms is always connected with an increase of air humidity as well as humidity of the material. Even at 100 % relative humidity the moisture content of impregnated and laminated materials is significantly lower (6–10 %) than untreated paper (14–15 %).

A comparison of the resistance to fungi of materials restored by artificial adhesives and polymer films gives convincing evidence that there is a direct dependence between the coefficient of resistance to fungi and the moisture capacity of materials.[8]

Adhesives made of cellulose derivatives absorb the moisture of the air and increase the moisture content of paper. The polymer films form a barrier to moisture and microorganisms and prevent destruction of the paper.

6. The Availability and Value of Materials

As distinct from methods of manual repair, where organic materials are used for pastes and adhesives, the above mentioned methods of technical restoration do not include the application of any organic material. The materials used comprise synthetic paper pulp, polymer films, and long-fibred tissue paper, which are manufactured in large quantities by the Russian industry.

As concerns paper for manual restoration, conditions are quite different. Old hand-made paper of past centuries becomes more and more rare, and cannot thus be relied on for general application. Filling up missing parts of paper sheets with paper pulp is preferable in every respect for those who want to prepare their own paper. It is a matter of consequence that at calculations, the costs of machinery, operating costs, as well as auxiliary materials and wages must be allowed for. For an identical amount of work the costs using mechanical methods are two times lower than those for manual restoration. If we take into consideration that the durability of pulp repaired, laminated and impregnated materials is double that of materials repaired by hand, the time of recovering the total expense will not exceed the general adopted standards. However, economical calculations may be discussed only when it is possible to compare it with the effect obtained. What the value of saved materials, if expressed in money, means to society, to future generations and to science and national economy, is not easily understood. Therefore we have nothing to compare with. There is no criterion for estimating the cost of every item kept in a library. In other words, it is, so far, difficult to answer the question how much society looses when a certain edition or manuscript etc. is lost. Moreover, judging from the data of tests, materials restored by paper pulp, impregnated and laminated editions will hardly be returned for repeated treatment within the next fifty years. Whereas many manually restored materials must be treated again in 5–10 years. On these grounds the cost of technical restoration may be considered to be 5–10 times less.

7. Labour Productivity

In the course of a few minutes, or even seconds, and on an area of 0.5–1 m^2 each part of the machinery fulfills specific operations, which cannot be accomplished by manual labour. This produces an impression of enormous activity, which is, however, not quite in agreement with facts. An analysis of the entire cycle of restoration and timing of the separate processes shows that the treatment of material, from the beginning to completion, takes only slightly less time than previously. In other words, the final analysis shows that labour productivity has not increased considerably.

A study of mechanical restoration gives a vivid impression of the specific features of the working process. Like all mechanized processes machine

restoration requires selection of material that is uniform as to thickness, size, colour, purpose, etc. If the equipment is constructed for a specific working process the output will be regular, and the production will be rhytmical. If the material under treatment is substituted by another material the mechanical process will have to be stopped, the equipment to be prepared for a new operation, and new calculations be made. It is therefore necessary to select material very carefully in order to carry out works of restoration in series, treating, for instance, sheets of the same type without interruption, giving mass treatment preference over individual treatment. It is very important to make calculations ensuring the optimal use of the working area, in order to reduce the number of gaps and clearances to a minimum.

The complete cycle of restoration by these methods includes a complex series of operations following one another. At the use of technical methods of restoration 6-20 % of the operations are mechanized. Too much time is still spent on auxiliary manual operations. Undoubtedly, for a sizable increase of labour productivity complex mechanization is necessary. In the restoration practices of different and badly damaged materials it is still completely unsolved, but a considerable part of manual work may yet be mechanized.

The machinery used comprises several types of apparatuses and devices. It is very important to accomodate them in the most rational way, in order to correctly organize labour, make maximum use of technology and, of course, provide the best technical service of the equipment. The optimum combination of conditions ensuring the highest degree of productivity is characterized by:

a. Complex mechanization
b. Regular maintenance of technical equipment with a view to its level of quality
c. Rational accomodation of equipment
d. Keeping a precise technological cycle
e. Use of exact and simple calculation schemes
f. Correct organization of labour
g. Ensuring the presence of standard materials over the necessary range.

8. Psychological Aspects of Labour

Introduction of technology involves breaking of formed habits, as it will change traditional concepts and cause a reorientation of them; likewise the

standards of minimum knowledge of technology will also be altered, and all these factors will, in their turn, have a certain influence on the psychology of workers.

Among other things, history of the technological development of conservation and restoration gives an account of extremely tedious manual work, which had to be done at the time, when instruments were so simple that they just slightly relieved processes which might almost as well be carried out without them.

Technical means permit us to be independant of individual skill. Nowadays the results of work as well as labour productivity are determined, not by the degree of damage to the material, but by its size, its uniformity of composition, the precision of calculations, the regular functioning of apparatus and the exploitation of the entire potential capacity of production inherent in materials and equipment.

Machinery makes the process of production rhythmical. Mechanized labour requires great attention, a high degree of accuracy, much care and speed, as well as unerring decisions and actions. If an experienced restorer with a long record of manual restoration behind him has to proceed to mechanized restoration, a psychological barrier has to be overcome, especially during training. The case is easier if the trainee restorer masters simultaneously new equipment and methods of manual restoration. In other words, manual restoration and mechanized restoration require different mentalities with different qualities.

9. Differentiation of Approach to the Determination of Restoration Methods

The use of machinery to save library materials requires a differentiated approach to conservation and restoration. First and foremost deteriorated materials should be classified according to restoration methods.

Lamination proves its value when applied to jackets and paper bindings, for which it is necessary to ensure elasticity and high resistance to wear, whereas increase of weight and thickness are inessential.

Impregnation is, first and foremost, a means of saving impermanent materials, which will deteriorate easily and are not intended for prolonged storage, such as newspapers, certain types of posters and placards, leaflets, maps used for training, catalogue cards, i. e. new materials to which natural adhesives are alien by nature, and, thus, are not well fit for the restoration of former properties.

Thus, a regeneration of sheets can be obtained by lamination and impregnation as these methods are provided with the measure for saving impermanent and fragile paper, when it is in a critical condition.

Filling up the missing parts of a sheet with paper pulp is a method which may theoretically be applied to all materials and it is the most advantageous as well as the most natural to old books, atlases, prints etc.

These materials require thorough washing out of soluble coloured products of deterioration which have accumulated with time. The outward appearance of such sheets should not be changed, and regeneration should not be aimed at; and therefore, application of films is not expedient. When the missing parts are filled up with paper pulp the original outward appearance is preserved and no adhesives have to be added.

Thus the application of technical means for conservation and restoration successfully solves two problems which are contrary to one another:

1. The problem of imparting new properties to unstable paper by adding to it materials of different nature, and storing it in a completely changed state (by lamination and impregnation).
2. The problem of preserving old manuscripts and printed books, bringing them back to their original state and restoring only the form and the integrity of the sheets (by filling up missing parts with paper pulp).

None of the points of view set forth above have been stated for the purpose of discrediting former methods or of disparaging their importance and value. Manual restoration has at one time played a significant rôle, which it is, indeed, difficult to overestimate, and it will serve for a long time yet. It is, however, very important to explain the reasons why such strenous efforts have been made to create mechanical methods of restoration, illustrating the valuable contribution of modern science to the conservation and restoration of library materials.

Only on the basis of scientific, theoretical analysis, combined with the application of technology the innovation in restoration and conservation has turned out successfully and new qualities of material such as age resistance have been obtained. These achievements are the results of new progress in different sciences which have been synthesized for preservation of the scientific, cultural and historical heritage of mankind, to be passed on to future generations.

Summaries

Until recently scientific and practical work in connection with the conservation and restoration of library materials developed on the basis of primitive technique.

The introduction of high polymer chemistry into the field of preservation of library materials resulted in the creation of four new conservation and restoration methods: lamination, impregnation, filling up – in thickness and area – lacking parts of sheets with paper pulp, and paper splitting. The M. E. Saltykov-Shchedrin State Public Library in Leningrad has at its disposal six apparatuses for the first three methods. Industrial equipment is used for lamination and impregnation. The Laboratory of the State Public Library has the priority of the creation of the technology and the use of original large-scale equipment for restoration by means of paper pulp (the first model was made in 1956, the second in 1965).

Fifteen years of experience with this technical equipment entitles the State Public Library to set forth its own judgements regarding mechanical restoration, viz.:

1. Application of machinery means not only plain substitution of manual work, but, first and foremost the transition to a new technology and new principles of work.
2. Exactness, equal distribution of a material on the whole sheet area, is foreseen, without special efforts on the part of the restorer.
3. Application of machinery is expedient only if it makes the restored material more durable and permanent.
4. Mechanized restoration improves appearance and legibility of text more than does manual restoration.
5. The adapted technology invariably leads to a decrease of moisture absorbability and an increase of the resistance of restored materials to bio-deterioration.
6. Raw materials are more easily available and also cheaper. But financial calculations should not be limited to an estimate of labour, materials and expenses of exploitation. The value of saved materials to society, science, national economy and future generations, as well as the increase in durability and the permamence of restored materials should also be taken into consideration.
7. At present the speed of restoration output is increasing only by 2–4 operations. Complex mechanization of all working processes, including auxiliary processes, is necessary to obtain a stable increase of restoration output.
8. Psychological aspects of labour have become of topical interest; reorientation of concepts and abolition of dependence on individual mastership are taking place, and demands on the personal qualities of workers are changing.
9. A differentiated approach to the determination of the groups of material appropriate for each type of machinery is requisite.

Mechanized restoration is of decisive importance to modern materials, which with their lack of durability are in a critical condition, assisting towards regeneration of their base by the methods of lamination and impregnation, as well as to manuscripts and old books, assisting towards the preservation of the initial quality of their paper (by filling up the lacking parts of sheets with pulp).

The importance of manual restoration can hardly be overestimated. It has served faithfully for a long time, and it will serve for a long time still. But the alliance of science

and technology has given the present generation the chance of innovating the technology of conservation and restoration on a new basis and thus of obtaining a higher quality of restoration. New opportunities are offered to specialists in the preservation of the scientific, cultural and historical heritage of mankind to be transferred to future generations.

Jusqu'à récemment, le travail scientifique et pratique de la conservation et de la restauration des decuments de bibliothèques s'est développé sur la base de techniques primitives.

L'introduction de la chimie des hauts polymères dans le domaine de la préservation des documents de bibliothèques a eu pour résultat la création de quatre nouvelles méthodes de conservation et de restauration: la lamination, l'imprégnation, le remplissage – en épaisseur et en étendue – de parties manquantes de feuilles avec de la pulpe de papier, et le fendage du papier. La Bibliothèque Publique de l'État M. E. Saltykov-Shchedrine, à Léningrade, dispose de six appareils pour les trois premières méthodes. Un matériel industriel est utilisé pour la lamination et l'imprégnation. Le laboratoire de la Bibliothèque Publique de l'État est le premier pour la création de la technique et pour l'usage d'un matériel original à grande échelle pour la restauration par le moyen de la pulpe de papier (le premier modèle fut créé en 1956, le second en 1965).

Quinze années d'expériences avec ces moyens techniques permettent à la Bibliothèque Publique de l'État de former son propre jugement sur la restauration mécanique, à savoir:

1. L'emploi des machines constitute non seulement la substitution complète du travail manuel, mais aussi, d'abord et surtout, la transition à une technique neuve et à de nouveaux principes de travail.
2. L'exactitude, la répartition égale d'un matériau sur toute la surface de la feuille, est obtenue sans efforts spéciaux de la part du restaurateur.
3. L'emploi des machines n'est utile que s'il rend le document restauré plus durable et plus stable.
4. La restauration mécanique améliore mieux que la restauration manuelle l'aspect et la lisibilité du texte.
5. La technique adaptée diminue invariablement l'absorptivité de la moisissure et augmente la résistance du document à la bio-détérioration.
6. Les matières premières sont plus aisées à obtenir et aussi moins chères. Mais pour établir un calcul des frais, il ne faut pas se borner à estimer le travail, les matériaux et les frais d'exploitation. Il faut, en effet, tenir compte aussi de la valeur que les documents sauvés présentent pour la société, la science, l'économie nationale et les générations futures, de même que l'augmentation de la durabilité et de la stabilité.
7. A présent la rapidité de la production de la restauration est augmentée seulement pour 2 à 4 opérations. La mécanisation complexe de tous les processus, y compris les processus auxiliaires, est nécessaire pour obtenir une augmentation stable de la production.
8. Les aspects psychologiques du travail sont devenus d'un intérêt primordial: on constate une réorientation des concepts et l'abolition de la dépendance de la compétence individuelle, et un changement des demandes de qualités personnelles des ouvriers.
9. Il est nécessaire de faire une étude différenciée des groupes de matériaux qui conviennent à chaque type de machine.

La restauration mécanisée est d'une importance décisive pour les matériaux modernes qui, par suite de la manque de durabilité, se trouvent dans une situation critique, en aidant,

par les méthodes de la lamination et de l'imprégnation, à la régéneration de leur base, et autant pour les manuscrits et livres anciens, aidant à la préservation de la qualité originale du papier (en comblant par de la pulpe de papier les trous des feuilles).

L'importance de la restauration manuelle ne saurait être surestimée. Elle s'est déjà montrée efficace depuis longtemps et elle rendra encore d'utiles services. L'alliance de la science et de la technique a donné à la génération actuelle la chance d'innover, sur de nouvelles bases, la technique de la conservation et de la restauration et de porter par là la restauration à un plus haut degré de qualité. De nouvelles facilités sont offertes aux spécialistes pour la préservation du patrimoine scientifique, culturel et historique de l'humanité qui doit être légué aux génération futures.

Bis vor kurzem geschah die wissenschaftliche und praktische Arbeit in Verbindung mit der Konservierung und Restaurierung von Bibliotheks-Material auf der Grundlage einer primitiven Technik.

Die Einführung hochpolymerer Chemie in das Gebiet der Erhaltung von Bibliotheks-Material hatte die Entwicklung von 4 neuen Methoden für die Konservierung und Restaurierung zur Folge: Laminierung – Imprägnierung – Auffüllung (sowohl in Bezug auf Dicke als Fläche) von fehlenden Stücken mit Papiermasse sowie Papierspaltung. Die M. E. Saltykov-Shchedrin State Public Library in Leningrad verfügt über sechs Apparate für die drei ersten Methoden. Für die Laminierung und Imprägnierung bedient man sich handelsüblicher Geräte. Das Laboratorium der vorgenannten Bibliothek in Leningrad war bahnbrechend in Bezug auf die Entwicklung der Technologie und den Einsatz originaler Gross-Geräte für die Restaurierung mit Hilfe von Papiermasse. (Das erste Modell wurde 1956 hergestellt, das zweite 1965).

Eine 15-jährige Erfahrung mit dieser technischen Ausrüstung berechtigt die vorgenannte Bibliothek ihre eigene Auffassung bezüglich einer mechanischen Wiederherstellung wie folgt zu formulieren:

1. Die Anwendung mechanischer Hilfsmittel bedeutet nicht nur eine einfache Erstattung manueller Arbeit sondern vor allen Dingen einen Übergang auf eine neue Technologie und neue Arbeitsprinzipien.
2. Eine exakte d. h. eine gleichmässige Verteilung des Materials über die gesamte Fläche ist vorgesehen, ohne besondere Anstrengungen von Seiten des Restaurators.
3. Die Anwendung von Maschinen ist nur zweckmässig, wenn das restaurierte Material dadurch eine bessere und bleibende Haltbarkeit erhält.
4. Eine mechanische Restaurierung verbessert das Aussehen und die Lesbarkeit des Textes mehr als bei einer Restaurierung von Hand.
5. Die angewandte Technologie führt unweigerlich zu einer verringerten Absorptionsfähigkeit von Feuchtigkeit sowie einer erhöhten Widerstandsfähigkeit des restaurierten Materials gegen biologischen Verfall.
6. Die Beschaffung von Rohmaterialien ist leichter und ebenfalls billiger. Finanzielle Erwägungen sollten jedoch nicht auf eine Berechnung der Kosten für Arbeitskraft, Materialien und Abnutzung der Maschinen beschränkt bleiben. Es sollte ebenfalls der Wert des geretteten Materials für die Gesellschaft, Wissenschaft, Nationalökonomie und zukünftige Geschlechter sowie die Erhöhung der Festigkeit und Haltbarkeit des restaurierten Materials in Betracht gezogen werden.

7. Im Augenblick wird die Geschwindigkeit der Restaurierung nur ungefähr verdoppelt bis vervierfacht. Eine komplizierte Mechanisierung aller Arbeitsgänge einschl. der Hilfsprozesse ist notwendig, um eine gleichmässige Erhöhung der Menge von restauriertem Material zu erreichen.
8. Die psychologischen Aspekte der Arbeit haben aktuelles Interesse: Eine Umwertung der Begriffe und eine Aufhebung der Abhängigkeit von individueller Meisterschaft findet statt, und die Anforderungen an die persönlichen Qualitäten der Arbeiter ändern sich.
9. Eine differenzierte Einstellung zur Bestimmung der Materialgruppen, die sich für die Bearbeitung in den verschiedenen Maschinentypen eignen, is notwendig.

Die mechanisierte Restaurierung ist von entscheidender Bedeutung bei modernen Materialien, die sich auf Grund ihres Mangels an Haltbarkeit in einem kritischen Zustand befinden und bei denen dieser Prozess durch die Methoden der Laminierung und Imprägnierung zu einer Wiederherstellung ihrer ursprünglichen Form beiträgt. Das Gleiche gilt für Manuskripte und alte Bücher, bei denen durch das Auffüllen fehlender Stücke in beschädigten Seiten mittels Papiermasse zu einer Bewahrung der ursprünglichen Papierqualität beigetragen wird.

Die Bedeutung der Restaurierung von Hand kann jedoch kaum überschätzt werden. Hier wurde wertvolle Arbeit schon seit geraumer Zeit geleistet und wird auch noch auf lange Zeit hinaus unentbehrlich sein.

Aber das Bündnis von Wissenschaft und Technologie hat der gegenwärtigen Generation die Chance gegeben, die Technologie der Konservierung und Restaurierung auf einer frischen Grundlage zu erneuern und dadurch eine bessere Qualität der Restaurierung zu erreichen. Den Spezialisten werden hiermit neue Möglichkeiten geboten, das wissenschaftliche, kulturelle und historische Erbe der Menschheit für kommende Geschlechter zu erhalten.

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The Mounting of Fragmentary Metal Scrolls

by W. A. ODDY & C. J. WHEATLEY

Introduction

Of the metals known in antiquity, all except iron may be beaten into a sheet which is thin enough and soft enough to be inscribed with a hard wood or metal point. These were often rolled up to form scrolls which present problems to the conservator because, with the exception of those inscribed on gold, they can suffer severe corrosion and are usually difficult to unroll. The metals usually used were copper, silver and lead, all of which can readily become brittle as a result of oxidation.

Although methods do exist for converting the corrosion products of lead and silver back into coherent metal[1,2] they do not restore its malleability and so cannot be used to facilitate the unrolling of a scroll. Hence the opening of a scroll to reveal its inscription almost invariably involves cutting or breaking the metal into suitably sized fragments. In the case of the well known copper scroll from Qumran, cutting was carried out by using a fine toothed circular saw blade after strengthening the corroded copper with an epoxy resin,[3,4] but it was still impossible to flatten the separated sections.

The usual method of mounting metal scrolls or their fragments is to lay them between sheets of glass the edges of which are bound with a suitable adhesive tape. This method is quite satisfactory for scrolls consisting of only one or two separate pieces, but where a large number of small fragments are involved, there is a danger of the individual pieces of metal moving about within the mount and becoming irretrievably mixed up. In order to overcome this problem two improved variations on this method of mounting have been devised.

The Mounting of a Fragmentary Lead Scroll

Figure 1 shows the condition of a lead scroll mounted in this manner. It consisted of a large number of small fragments bound between two sheets of glass, many of which were loose and moved about whenever the scroll

Restaurator 2 . 1975 : 81-87

Fig. 1. Lead scroll, inscribed in the Mandaean language, showing its condition before re-mounting. (Diminished 50 %).

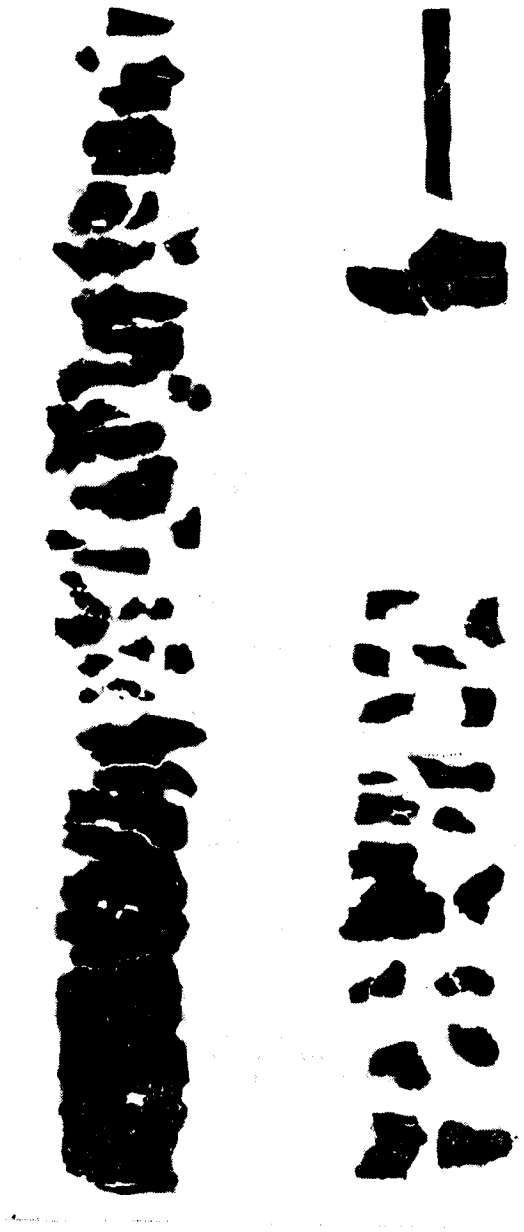

Fig. 2. Lead scroll after re-mounting. (Diminished 50 %).

was examined. It was therefore necessary to devise an alternative method of mounting.

After removal of the upper sheet of glass, the fragments were carefully sorted, and four pieces were found which were inscribed with Roman lettering, while the rest were inscribed with an ancient script, possibly Mandaean. The pieces inscribed with Roman letters were found to fit together to form two separate fragments. They are probably modern, and seem to be the result of technical experiments on processes for engraving lead. A qualitative emission spectrographic analysis indicated the presence of different trace elements in the lead engraved with the Roman and Semitic scripts respectively, confirming their different origins. Careful examination of the "ancient" fragments suggested that in fact the remains of two different Mandaean scrolls are present. This was deduced from the appearance of the corroded metal, but has not yet been confirmed by paleographic study. It was decided to split the fragments into three groups, as indicated above, but to mount the groups together.

The lead inscribed with the Semitic scrip is in an advanced state of corrosion and is too fragile to be conserved by the usual method.[2] Radiographs were taken in an attempt to reveal parts of the inscription which were obscured by the corrosion products, but in general the inscription is less legible on the radiograph than on the object itself. The only way to arrest the corrosion processes under normal museum conditions is to keep the scroll completely dry, so it was decided to mount the fragments in a microcrystalline wax,[5] which will act both as a barrier to water vapour and as an adhesive for the fragments. An acrylic sheet[6] was chosen as the support for the scroll, as this is more robust and easier to cut than glass.

The fragments of lead were mounted by cutting three rectangular holes, of a suitable size to take the three separate groups, in a sheet of Perspex which was of approximately the same thickness as the lead. This was then laid on a sheet of silicone paper and the scroll fragments arranged in the "windows". Molten microcrystalline wax was poured over the fragments until each "window" was just filled to the thickness of the acrylic sheet and then allowed to cool. Excess was then removed from the surface of the lead by use of a hot spatula and absorbent tissue paper. The mount was then turned over, the silicone paper peeled off, and the underside of the metal cleaned in the same way. Finally the Perspex was cleaned with a swab of xylene and placed between two thicker sheets of the same material, whose edges were bound with a transparent tape.[7] It is advisable to use a masking tape which has a long life as normal transparent tapes are unsuitable for this purpose. Figure 2 shows the scroll after mounting.

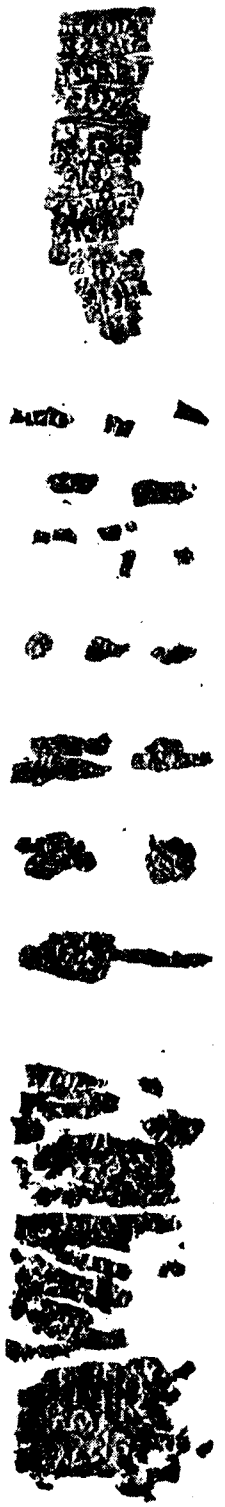

Fig. 3. Sassanian silver scroll after re-mounting. (Natural size).

The Mounting of a Fragmentary Silver Scroll

Unlike lead, silver does not normally suffer from severe corrosion processes once it has been removed from the ground. Hence it is not necessary to embed fragmentary scrolls in wax, although it is obvious that some method of securing them in the mount must be used. Such a problem arose recently in connection with a miniature Sassanian silver scroll which was tightly rolled and very brittle. Two different methods were used in an attemp to anneal the metal prior to unrolling, but neither was completely successful in restoring its malleability. One section of the scroll, illustrated on the left of Figure 3, was unrolled after heating to 105° C for several days, but the metal was still brittle and tended to break into small fragments. Hence the rest of the scroll, which is illustrated on the right of Figure 3, was annealed at red heat for a few seconds with a minute flame and then unrolled. This did improve the malleability of the silver, but some cracks and breaks still resulted from the unrolling process. As the scroll was slowly opened the fragments were stuck down in their correct relative positions on a fine glass fibre matting.

It as again decided to use acrylic sheet as a mount for this scroll and so a rectangular area in the centre of a piece of suitable size was roughened by sandblasting, so that an adhesive would key to its surface. This process renders the plastic opaque, but when the adhesive is applied to the roughened area, it becomes transparent again. Hence the fragments of silver scroll were removed from the temporary backing of glass and stuck to the roughened area of the mount using a cellulose nitrate adhesive.

Apart from the two main sections of the unrolled scroll there were also several loose fragments which were mounted at random in the centre of the roughened area. The mount was completed using two more sheets of Perspex. One was of a similar thickness to the silver scroll, to act as a spacer, and it had a rectangular hole cut from it to match the roughened area of the mount. All three were bound together with a long life tape round the edge.[7] Figure 3 shows the scroll after mounting.

Conclusion

These two methods of mounting fragmentary metal scrolls are a considerable improvement on the standard method of placing the fragments between glass. The use of a transparent acrylic sheet, rather than glass makes the mounts more robust, but they should still be handled with care as the

plastic will scratch more easily. As an alternative to acrylic sheet, it would be possible to use a polycarbonate sheet.[8] The use of a microcrystalline wax or cellulose nitrate mounting medium not only holds minute fragments in position, but helps to protect the metal from further corrosion or tarnishing.

Acknowledgements

We would like to thank Dr. A. E. Werner for his encouragement in this work and Dr. R. D. Barnett for providing the scrolls whose conservation proved so interesting. Particular thanks are due to Paul Craddock who carried out the emission spectrographic analysis on the lead fragments and to Mrs. H. P. Lane and Miss. A. L. Budgen who did the photography.

Abstracts

Two methods are described of mounting fragmentary metal scrolls between sheets of acrylic plastic.

In one method the pieces are embedded in a hard microcrystalline wax, and in the second they are stuck directly to the surface of the acrylic mount, which was first roughened to provide a suitable surface. The first method is illustrated in Figures 1 and 2 in which fragments of a lead scroll which were loosly mounted between sheets of glass have been remounted in wax. Figure 3 illustrates a silver scroll hich has been mounted on a roughened acrylic sheet.

Deux méthodes sont décrites pour monter des rouleaux de métal fragmentaires entre des feuilles de plastique acrylique.

L'une des méthodes consiste à enrober les pièces dans de la cire microcristalline dure et l'autre à les fixer directement sur la surface du support acrylique, qui a été rendue rude au préalable pour offrir une surface convenable. Le premier procédé est illustré par les figures 1 et 2. Des fragments d'un rouleau de plomb, légèrement montés entre deux plaques de verre, ont été enrobés dans de la cire. La figure 3 montre un rouleau d'argent monté sur une feuille acrylique rude.

Es werden 2 Methoden beschrieben für das Anbringen von Bruchstücken von Schriftrollen aus Metall zwischen 2 Platten aus Acrylkunststoff.

Nach der einen Methode werden die Stücke in einer harten, mikrokristallinischen Wachsschicht eingebettet und nach der anderen Methode direkt auf die Oberfläche der Acrylplatte montiert, welche vorher aufgerauht wurde, um eine passende Oberfläche zu bilden. Die Methode No. 1 ist in den Abbildungen 1 und 2 dargestellt, in welchen Bruchstücke einer Blei-Rolle, die lose zwischen Glasplatten montiert waren, jetzt in Wachs montiert sind. Die Abbildung 3 zeigt eine Silber-Rolle, die auf einer aufgerauhten Acrylplatte montiert sind.

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JESPER TRIER

Ancient paper of Nepal. Results of ethno-technological field work on its manufacture, uses and history – with technical analysis of bast, paper and manuscripts

Jutland Archaeological Society Publications Volume 10. 1972.* 271 pp.

Reviewed by JOHN C. WILLIAMS, Research Officer
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This is as much a book about people as about paper, and as much about geography as about people. There are interesting descriptions and striking photographs of ancient caravan trails, venerable ruins, and the mountainous terrain of Nepal. The author covers a wide field in his investigations of the papermaking art, exploring the history, religions, botany, and ethnology of the kingdom. Fine samples of woodcuts on handmade Nepalese paper are bound into the book as illustrations. The volume is a work of art, as well as a scientific text.

Nepal is a land of contrasts, both in climate and people. In the lowlands of the South, there are dense tropical jungles where the population is Indian. In the North, at the roof of the world, the people are Mongoloid. Between these extremes there is at least a score of ethnic groups which differ strikingly in physiognomy, language, and culture. One of Trier's photographs shows an elderly native of Caucasian features who, in other clothes, would fit easily into Denmark or England.

Nepal's early history is obscure. Most of the ancient stone monuments date from the 5th century, while the oldest surviving manuscripts on paper date from the beginning of the 12th century. On the forested mountainsides paper is still made by a group called the Tamangs, using ancient hand methods. The Tamangs and the papermaking art were early migrants from Tibet. Now making paper by hand is fast becoming a dying art. The Chinese invasion and occupation of Tibet in 1959, destroyed the principal marked for Nepalese paper. Today, even in the most isolated valleys of Nepal, machine-made paper is superseding the native product. In addition,

*) Editor's note: Trier's work is out of print, but a few copies are available from The Royal Library, DK-1219 Copenhagen K, Denmark, at a price of Danish kroner 138.00.

as a result of the serious erosion of the mountainsides, the government has introduced severe restrictions on the cutting of forests, and the voracious wood fires used to dry the handmade paper have been forbidden.

Trier considers the oldest method of making paper that which is found in eastern and central Nepal, and states: "It is probably the oldest in the world and can be traced back to the origin of papermaking in China about 2000 years ago".

The author made a twelve-day trek from Kathmandu into the mountains to find the papermakers at work. He describes the scene: "... one late afternoon when we were toiling up a steep and very densely wooded mountain slope above Tiembu, near Junbesi, our eyes caught sight of the thin columns of smoke that disclosed the papermakers. Soon we were standing in front of their huts, and they came forward to greet the peculiar stranger. They were all Tamangs, shy but obliging people who lived here in the spell of the forest".

Husband and wife teams were clustered around the same steeply falling mountain stream. Each maintained a cabin, workshop, floating basin, and the usual papermaking tools, including perhaps a dozen paper moulds. When the forest is exhausted of firewood in one area, the whole assemblage is moved to a new location.

Nepalese paper is made from the white inner bark of the Daphne shrub of the species *Thymelaeaceae*. The branches are cut, the bark peeled, and the inner white layer, the bast fiber, separated for use. This is soaked for twelve hours, drained, and the black flaws cut away. These strips of bast fibers are then boiled in an alkaline solution obtained from wood ashes. The pH of this solution is 12.5 to 13, and the temperature of the cook is 88° C., the temperature of the boiling point at the altitude of the camp. Next, the water is drained off and the fiber beaten for one to two and a half hours with a wooden mallet. Unbeaten bits of bast are then picked out by made, and the mass of fiber is stirred into water. The resulting slurry has a pH of 8.5 to 10.5. In certain operations, the slurry is thickened by the addition of water and solubles from the first soaking of the bark.

Nepalese paper moulds consist of wooden frames under which a coarse linen fabric is stretched. In use, a mould is floated in the water basin, and the slurry carefully distributed by pouring it through the opened fingers of one hand. The mould is then withdrawn from the water and drained. If small holes are visible in the sheet, the mould may be refloated and more fiber added. Much skill is involved in this operation, which Trier calls "scooping".

The mould and the wet sheet of paper are dried in front of the fire. Keeping the fire going is a project in itself. Large trees are felled by the Tamang axman, cut up, and the logs slid down the mountainside for use. The wife re-positions the moulds about the fire as drying progresses. The dried sheet is finally peeled from the mould and stored. The man and wife team operate ten to twelve moulds and produce from 200 to 500 sheets a week. These sheets are 40 to 50 centimeters wide by 60 to 65 centimeters long with a basis weight of from 15 to 35 grams per square meter. Twice a week, the sheets are folded and tied with a thin strip of bast for the trip to market. Another possible reason for the disappearance of handmade paper in Nepal is the low price such paper brings on the marked place. Nepalese papermakers work very hard for only pennies a day in return.

Trier describes an attempt to modernize the ancient Nepalese process in a papermaking workshop near Sundarijal. Surprisingly, instead of using a more advanced mould, the cloth mould was retained; but instead of being floated, it was dipped in a dilute fiber slurry, as in more modern techniques. The sheet was then transferred to a felt on a stack of the work, and the stack pressed to expel the water, after which the sheets were seperated and air dried. The method of transferring the sheet from a cloth mould to a felt was not described.

In describing this innovation, Trier uses the term "scooping", which he previously applied to the floating mould process. This terminology is new to the reviewer, who prefers "dipping" or "pouring", as being a more accurate description of the process.

Nepalese paper is often processed further in the villages. For the lowlands, paper must be treated to protect it from insects and mould. The sheets may be coated, colored, and/or laminated. Ancient manuscripts are often on blue-black paper with gold or silver writing. This paper formerly was dyed with an extract of a plant called *nilotha*, which is evidently quite poisonous. Even very old samples of this paper are never worm-eaten, and no mould damage is seen. Nearly all the non-black paper of the Kathmandu Valley, made since the 16th–17th centuries, has been coated with orpiment, a yellow arsenic sulfide pigment. The mineral, *haridall*, is crushed into a powder, then made into a paste with cooked rice flour and spread on the paper. Such a coating acts as an effective preservative. The papers may also be glazed by means of a block of wood, a stone, or a conch shell.

Trier notes that traditionally Nepalese books have been bound in the elongated shape derived from that of the palm leaf variety. In additions,

books are bound in the style called concertina, in which the paper is folded back and forth. The Nepalese also use paper for ceremonial woodcuts, prayer flags, prayer wheels, ritual cards, paintings, masks, decorations, wrapping, string, windows, incense, and cartridges.

Although not of primary interest in his study of Nepalese paper, Trier gives two formulas for ink used in Nepal. One formula originates from the Lamaist Bodnath near Kathmandu. Here the method is as follows: Soot from pinewood and sugar are mixed and thoroughly ground. Borax is roasted until it becomes slightly reddish, whereupon it is ground and mixed in, together with a glue made of leather boiled in water and filtered; finally flower pollen is added to make the ink fragrant.

Trier provides extensive technical data on Nepalese papers including basis weight, bulk, opacity, brightness, porosity, breaking length, stretch, tear and folding endurance. Fibers are identified under the microscope as swollen in cupric oxide ammonium, or swollen and stained in zinc chloride iodine. Excellent photographs of fibers are included. X-ray fluorescence, x-ray diffractometer and neutron activation analyses of the minerals present in the paper and fibers are reported.

The author is to be complimented on his thorough investigation and his fine presentation, which extended to the design of this book. In several instances he has whetted our appetite for more information. For example, the pH values for the cooking liquids and the fiber slurry were given, but not the pH of the paper itself.

Working with the Beckman flat glass electrode #39182 and avoiding ink or adhesive areas, Mrs. Marta Krasnow of the Preservation Research Laboratory of the Library of Congress determined the pH of the Nepalese paper inserts of the books as follows:

Frontispiece, 7.1; page 149, 7.0; page 151, 7.4; page 153, 7.5; page 155, 7.4.

Such neutral paper should endure well, as indeed the survival of ancient Nepalese manuscripts attest. This train of thought led us to brief accelerated aging study, carried out on a sample of Nepalese paper kindly furnished by Mr. Joseph Weiler of Meriden, Connecticut, U. S. A. The paper had been made by Purna Bahadur near Baglung. Endurance was found to be excellent. The paper was of archival quality.

Ancient Paper of Nepal is a report of one part of the investigations Trier is conducting of the papers and pakermaking of India, Tibet, and the Himalayan region in general. Since he has established such a high standard of performance, Trier's future volumes will undoubtedly be of the greatest interest and value.

News and Activities

Permanence / Durability of the Book. Vol. 7. 1974

The W. J. Barrow Research Laboratory, Inc., Box 7311 Richmond, Virginia 23221, is publishing the seventh in the series "Permanence/Durability of the Book". The title is "Physical and Chemical Properties of Book Papers, 1507–1949". This publication was made possible by the support of the Council on Library Resources.

This study has revealed the deterioration of the permanence and durability of book papers produced during the period from 1507 to 1949, and has traced reasons for this deterioration. The weak condition of many books is demonstrated; the availability of permanent/durable book paper is describeed; and the cost of failure to use such paper on books of lasting value is emphasized. Methods of extending the life of deteriorating book papers are given.

Eighty-five pages of detailed data produced during the study are presented on microfiche. The fiche and its envelope are pasted on the inside back cover of the publication. It is photographed at about a 24:1 reduction ratio.

Copies of the publication are available while the supply lasts to libraries, archives and conservation organizations from which an addressed adhesive mailing label is received by the laboratory. Copies are limited to one per organization.

A New Method of Reproducing Watermarks for Study

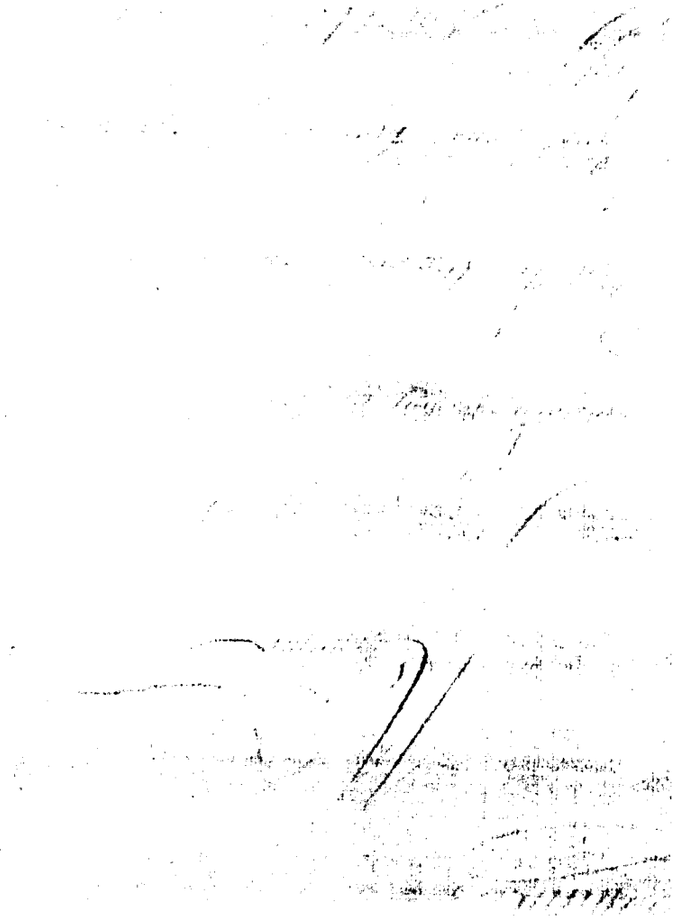
by T. L. GRAVELL

There has always been a scholarly interest in paper watermarks. However, the difficulty of clearly and accurately reproducing them has been a hindrance to their study.

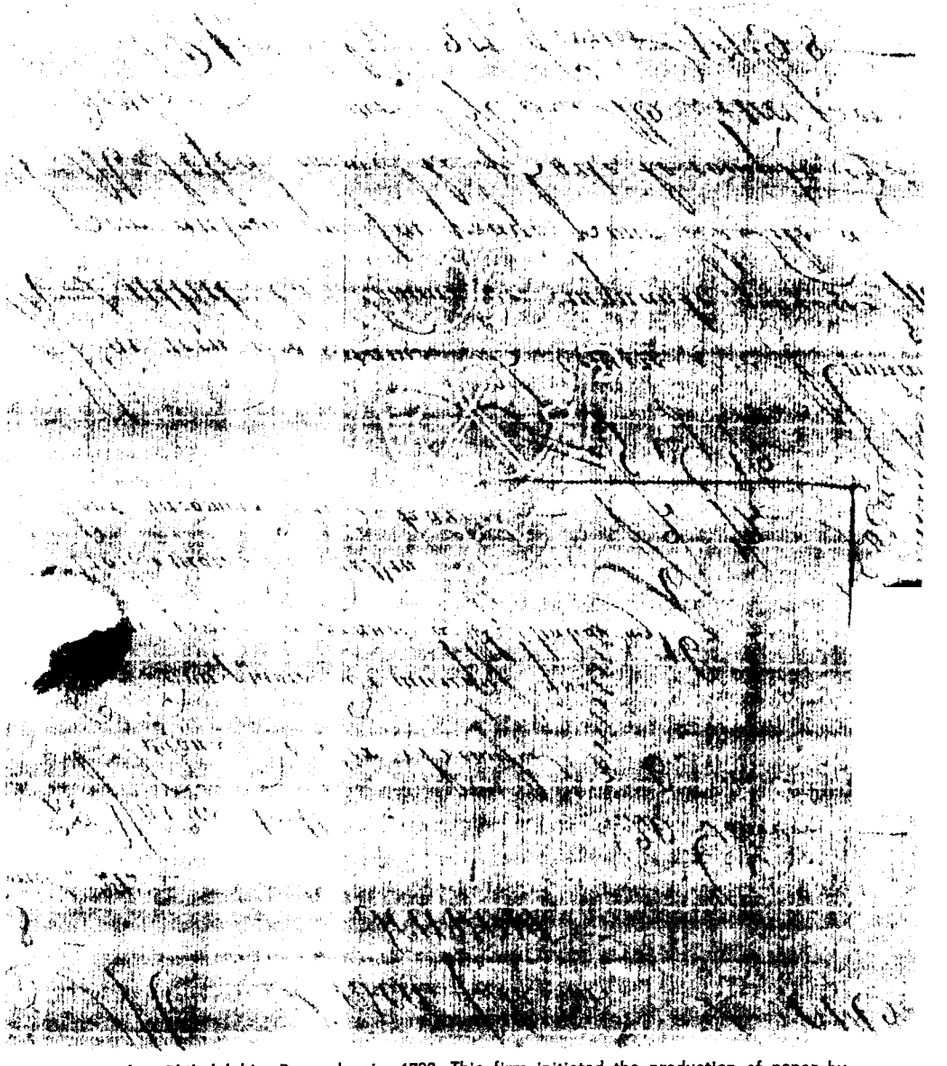
The value of a watermark is realized when something about the history of papermaking is known. Dard Hunter[1] in his text points out that the art of paper manufacture was brought to Spain by the Moors in the 12th century. The first European watermarks appeared about 1150. These were the marks left in the paper by the chain and laid lines of the mold.[2] After Gutenberg published his Bible in 1455–56 on movable type, the demand for paper started an increase in the number of mills throughout Europe and along with them their identifying marks. At first these marks were thought to be a means of communication between the paper workers; others believed them to have a religious significance.[1] But as a different watermark was used by each papermaker, the identity of his product became known and often the dates of its production.

The first of the 15th century marks was made by hand-bending the wire and sewing it to the mold. In the next century, watermarking became a trade and advanced to having the designs traced on wooden blocks and the wire bent around pins set in the angles.[2] The changing shapes of watermarks due to wear, loose and broken wires, broken stitches and the movement of the watermark between the chain lines are all clues to be used in modern-day research into the history of a book and its paper.

The reproduction of paper watermarks for research and bibliographical purposes has always been a costly and time-consuming task, with the images produced often lacking clarity and, in the case of traced watermarks, accuracy. The tracing of a watermark from the page of a bound book is difficult and can cause irreversible damage to the original. The photographing of a watermark is often impossible by ordinary means and in most cases requires expensive and elaborate equipment. The use of beta rays gives the best watermark images but here again the cost in both the time required (up to 20 hours) and the necessary carbon-14 sheets put this method out of the reach of most collectors and researchers.



The watermark J G & Co BRANDYWINE is one of the many used by Joshua and Thomas Gilpin whose mill was located on the Brandywine Creek within a few miles of Wilmington, Delaware. The mill started in production in 1787, and this watermark is from a letter which



originated in Philadelphia, Pennsylvania, 1798. This firm initiated the production of paper by the first endless paper machine in America in the year 1817.

In experiments dealing with the reproduction of the watermark of a stamp which is attached to the envelope, a surprising amount of success was achieved by using a recently marketed photosensitive paper and ultraviolet light. The new product is Du Pont DYLUX 503 paper.[3] This yellow coated paper is sensitive to both visible light in the 400–500 nm range and to ultraviolet light in the 200–400 nm range. The visible light causes the yellow coating to become white and makes it inert to further ultraviolet light exposure. The ultraviolet light causes the unexposed portions of the coating to become a bright blue; the depth of color depends on the length of exposure to the ultraviolet rays.

The ability of DYLUX 503 paper to react as it does is the reason for its success in printing watermarks. Since watermarks are a thinness created in the paper as it is made, light will pass through these places with greater intensity than through the balance of the sheet. Ink creates a barrier which reduces and in some cases prevents the passage of light. Many inks are opaque and some become more so with age. Thus the thickness of the paper and opacity of the ink used in the writing or printing are the two main factors which affect the ability of DYLUX 503 paper to capture a good watermark image.

The equipment necessary is of the simplest and most inexpensive nature:

1. A hinged frame with a glass front similar to a picture frame to hold the item to be printed and the DYLUX 503 paper close together. This will eliminate shifts during the printing process, since any light which reaches the coating without passing through the original will ruin the result.
2. A source of visible light.
3. A source of ultraviolet light – this can be supplied by a 6-watt hand-held lamp or by a 15-watt blacklight fluorescent tube (the ultraviolet light must be derived from a source which emits very little or no visible light).

The time required to print the watermark depends entirely on the ability of the light rays to penetrate the object and reach the photosensitive paper below. Most of the papers, letters and book pages that I have experimented with require from one to five minutes under the visible light in the first step of printing. In developing the blue color to complete the image, the exposed DYLUX 503 paper is held under ultraviolet light. This is a very rapid process and, in order to control the speed of the formation of color so that the contrast between the blue and white is not lost, a low intensity ultraviolet source which is rather slow in bringing out the blue is most effective.

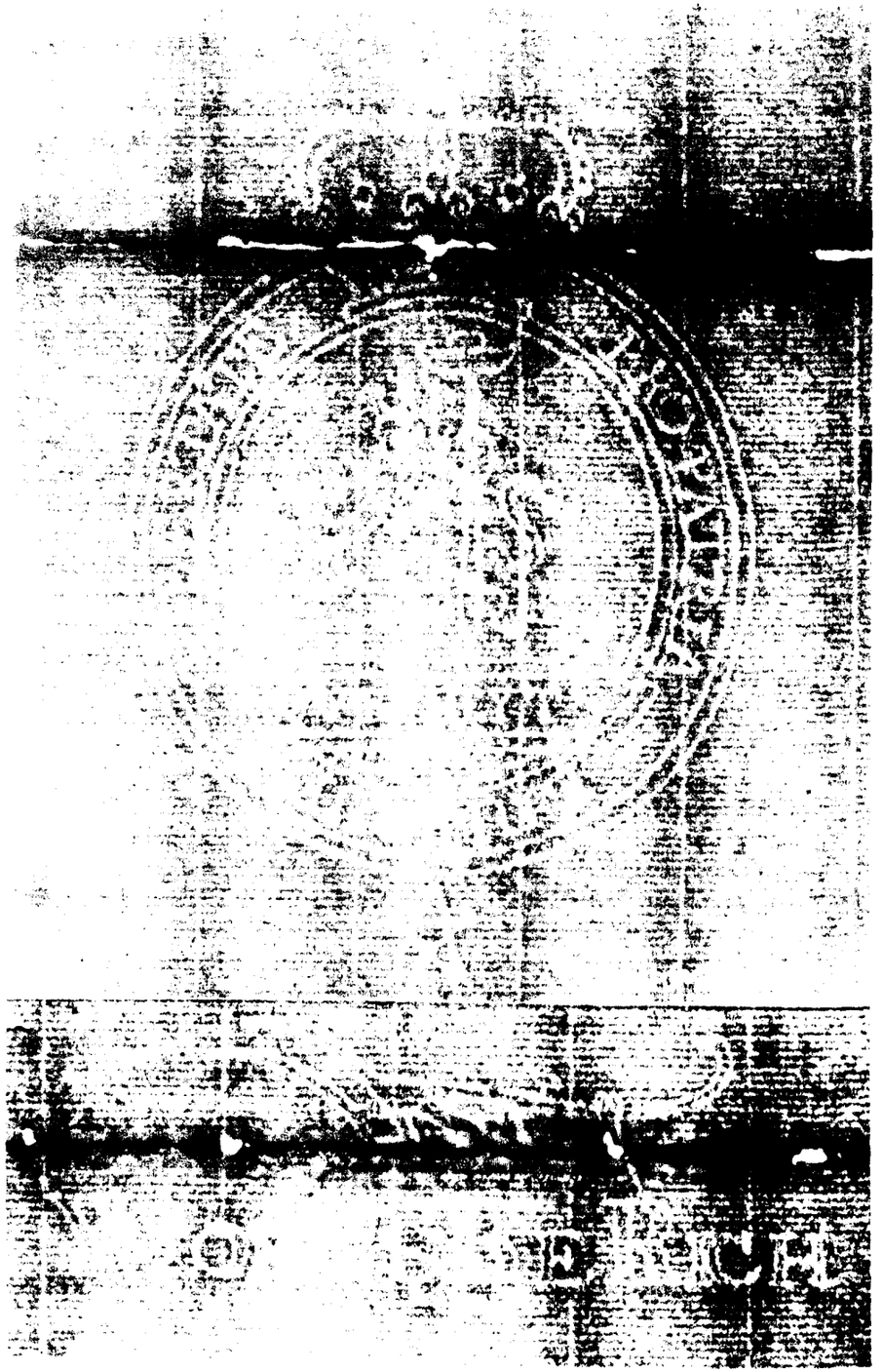
The handling of DYLUX 503 paper requires some care. Sunlight or bright lights will nullify its ability to react. In preparing an object for printing, this paper may be exposed to ordinary room light up to fifteen minutes. This is a very important factor as it allows the handling of fragile items in sufficient light so that the danger of damage is largely eliminated.

The actual printing method is very simple: the DYLUX 503 paper is placed yellow side up in the hinged frame; the original is laid over it and the frame is then closed and put under the visible light source. The high output Super Diazo Fluorescent Lamps,* made by the Sylvania Division of General Telephone and Electronics Company of Danvers, Massachusetts, gives excellent results. These lamps do not spread visible light over a large area and thus must be used in a bank of several tubes so that the printing area is uniformly illuminated. A pair of 15-watt Super Diazo fluorescent lamps, when mounted 10 cm (4 inches) apart under a reflective hood or shield, will illuminate effectively an area approximately 50 cm (20 inches) long by 17,5 cm (7 inches) wide. The light source should be three to four inches from the watermarked paper. Paper watermarks usually cover an area of only 10 × 15 cm (4 × 6 inches) (of course there are exceptions) which means two or three lamps mounted parallel will be sufficient for all but the very large land deeds, maps, and prints. The above mentioned fluorescent lamps emit visible light just above the ultraviolet range and cut off before the infrared range is reached.

In printing the watermarks found on book pages, I did not use the frame but placed the DYLUX 503 paper under the watermarked page and placed a small glass square on top to hold them close together during exposure. This can be done without having the book fully opened.

The second step – imaging or printing – is done by removing the paper from the frame or book and holding it under the ultraviolet light until the blue color is formed. A preferred way is to hold the exposed paper about a foot from the ultraviolet light. A 40-watt incandescent bulb behind me supplied sufficient light (without affecting the print) to allow me to watch the watermark develop and thus enabled me to remove the paper at the right moment for an image with good contrast. Should one remove the print from under the ultraviolet light too soon with the resulting lack of color, one can always put it back to develop a deeper color and greater contrast between the blue background and white lines which will form the watermark. It will be noted that there are great variations in the time

* For European use the fluorescent tubes used in Diazo copying machines should work.



required to make prints. This is due once again to the different materials used by the various papermakers.

Many libraries and museums will not permit the use of ultraviolet light near their valuable papers. In such cases, a different technique is required – one in which the original and the DYLUX 503 paper are exposed only to visible light. The DYLUX 503 paper is then placed in a light-proof envelope and removed to a distant work area for the final exposure to ultraviolet light. The ability of this special paper to retain a latent image for quite some time has proven to be a distinct advantage; however, it is best to make several exposures to be sure of obtaining the best watermark print.

The cost of an 21,5 × 28 cm (8½ × 11 inches) sheet of DYLUX 503 paper is approximately 8 cents (U. S. currency, 1973). The paper may be purchased in larger sizes should they be needed. Its low cost allows many experiments and trials, as practice is required before good prints are obtained.

Since the entire process is a dry one, there is no paper shrinkage as with wet prints; nor are there any distortions as might be expected from some camera work. The DYLUX coating is very thin and thus allows the watermark print to be folded in half without peeling or cracking, thus measurements and comparisons can be made one against another.

The life of the prints is still undetermined since these experiments (my own) were started only in the Spring of 1970. Original prints made at that time have retained their readability and clarity. When necessary, black and white photographs can be made from these prints using a Wratten No. 25 (red) filter and high contrast photographic paper.

A few of the results and observations which I have obtained from my experiments are exact copies of watermarks and of the spacings of the laid and chain lines. In the case of wove paper, careful handling and exposure timing will show the weave of the mold screen. Watersplatters from the vatman's hands show up as round spots. In the few cases where paper has

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This watermark seems to be of Dutch origin and is very like those used by Dutch mills on paper which was to be sold overseas. The English mills were known to have used this same type.

The originator of the »Work & Be Rich« Watermark is said to be the Dewees Mill which was located on the Wissahickon Creek near Philadelphia, Pennsylvania, 1710. To date no proof has been offered to back up this claim.

The watermark is rather well known in America and is usually found with the initials P. P D. on letters dated in the middle of the 18th century. This particular one was found on the loose fly leaf of a book.

been pasted-up, the joining appears as a stripe or band across the print. In the event a repair has been made, such as filling a hole, the repair shows either a dark outline or, in the laid papers, the lines do not match. Often the early printers used their waste paper by pasting it together for use as stiffeners for the book covers. In the event that these paste-ups will allow the light to penetrate, prints can be had which show printing that is not visible otherwise.

The small marks left by broken sewing wires show up as round white dots and are an indication of the amount of usage of a mold. This, in turn, is a clue to the age of the paper.

Antique laid paper is readily identified by the shadows which appear on each side of the chain wire. When the paper has been made on a mold with double chain wires, the distance between them can be measured with accuracy. The portions of writing ink or printing ink which shows up has a very definite value, for as Allen Stevenson states on pages 67–8 of his book, *The Problem of the Missale Speciale,* the experts and students alike should not ignore these reference points for they are a positive means of locating the watermark position on a page and also the exact page of the book.

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ABSTRACTS

The reproduction of watermarks in paper has always been a costly and time-consuming task, the images often lacking clarity and accuracy. A recently developed method has proven successful, provided the watermark is clearly visible by transmitted light. The reproduction is achieved by the use of DuPont Dylux® 503, whose yellow coating is sensitive to visible light (410–500 nm) and to ultraviolet radiation (200–400 nm). The first causes the exposed parts of the coating to become white and makes it inert to ultraviolet; the second causes the unexposed portions of the coating to become bright blue.

This sequence of exposure gives a negative, which is to prefer in watermark detection. The paper with the watermark is sandwiched between glass and Dylux 503. First it is exposed to visible light in front of a pair of 15-watt Super Diazo fluorescent lamps mounted about 10 cm apart and about 10 cm away. Then the Dylux paper is removed and exposed to ultraviolet lamps which emit little visible light. Timing under the first light varies from 1–5 minutes depending upon the thickness and structure of the paper; under the second, 1 minute is usually the average time required to complete. The Dylux paper can be handled in roomlight.

La reproduction des filigranes de papier a toujours été un travail coûteux et qui a demandé beaucoup de temps, et les images ont souvent manqué de netteté et de fidélité. Une méthode récente s'est montrée utile, si le filigrane est nettement visible par éclairage transparent. La reproduction est obtenue par l'usage de DuPont Dylux® 503, dont la pellicule jaune est sensible à la lumière visible (410–500 nan) et à la radiation ultraviolette (200–400 nan). La première source a pour effet que les parties exposées de la pellicule deviennent blanches et que la couche devient insensible à l'ultraviolet; dans le second cas, les parties non exposées deviennent bleu clair. Cet ordre d'expositions donne un négatif qui est préférable pour la détection du filigrane. Le papier filigrané est placé entre une plaque de verre et le Dylux® 503. Il est exposé d'abord à la lumière visible devant une paire de lampes fluorescentes Super Diazo de 15 watt, écartées l'une de l'autre de 10 cm. environ et distantes de 10 cm. environ. Ensuite le papier Dylux 503 est retiré et exposé à des lampes ultraviolettes qui émettent une lumière peu visible. Le temps de pose pendant le premier éclairage varie de 1 à 5 minutes, selon l'épaisseur et la structure du papier; pendant le second, la moyenne nécessaire est, d'habitude, de une minute. Le papier Dylux peut être manié à la lumière du jour.

Die Wiedergabe von Wasserzeichen in Papier ist schon immer eine kostspielige und zeitraubende Arbeit gewesen und oft waren die Bilder unzufriedenstellend in Bezug auf Schärfe und Genauigkeit.

Eine kürzlich entwickelte Methode hat sich als erfolgreich herausgestellt unter der Voraussetzung, dass das Wasserzeichen bei durchfallendem Licht deutlich sichtbar ist. Die Weidergabe wird erreicht durch die Anwendung von DuPont Dylux® 503, dessen gelber Überzug gegen sichtbares Licht (410–500 nm) und ultraviolette Strahlung (200–400 nm) empfindlich ist. Ersteres bewirkt, dass die dem Licht ausgesetzten Teile des Überzuges weiss und gegenüber ultravioletter Strahlung träge werden. Das zweite führt mit sich, dass die unbelicheten Teile des Überzuges hellblau werden. Diese Reihenfolge der Belichtung ergibt ein Negativ, was in der Untersuchung von Wasserzeichen vorzuziehen ist. Das Papier mit dem Wasserzeichen wird zwischen Glas und Dylux® 503 eingelegt. Es wird zunächst sichtbarem Licht ausgesezt und zar in der Form von 2 15-Watt fluoreszierenden Super Diazo Lampen, welche in einem Abstand von etwa 10 cm voneinander und ca. 10 cm vom Papier entfernt angebracht werden. Das Dylux-Papier wird dann entfernt und einer Bestrahlung mit ultravioletten Lampen ausgesetzt, welche kaum sichtbares Licht abgeben.

Die Beleuchtungszeit unter dem ersten Licht schwankt zwischen 1 und 5 Minuten, abhängig von der Dicke und Struktur des Papiers. Für die Bestrahlung mit ultraviolettem Licht ist normalerweise 1 Minute ausreichend. Mit Dylux-Papier kann bei normaler Raumbleuchtung gearbeitet werden.

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Rapid Drying of Water Soaked Books Using a Microwave Tunnel Dryer

by DENISE THOMAS & JAMES M. FLINK

Introduction

The problem of removing large amounts of absorbed water from books soaked during fire fighting, a flood, or any other natural disaster (before the development of mold growth occurs) has been approached in a variety of ways, dependent upon human resources and available facilities. Horton,[3] Wrotenberg,[10] Tribolet,[8] Spawn[7] and Lesmez[5] have described some of the problems faced when natural disasters strike.

Wet books may be air dried in a humidity controlled environment by setting a volume on end, fanning open pages where possible and eventually interleaving manageable pages with thymol impregnated paper to wick out remaining moisture, a method which, attention being paid to control of mold growth, allows a book to recondition gently to a desirable moisture content (roughly 8 % water on a dry paper basis).[3] Much caution must be exercised in the handling of wet pages, as leaves should be turned only where little or no resistance is offered.

Infrared lamps, heat reflectors, effective cross ventilation have been used to speed the air drying rate, while more dramatic methods, such as those used after the 1966 Florence flood, have involved controlled use of industrial drying facilities, experiments with water removal through centrifugal force (at temperatures near 88° C) and the freezing of wet books for long-term, mold-free storage.[3, 8]

A method more recently explored and put to practical use has been the freeze drying of previously frozen books (i. e. sublimation of the ice at low temperatures and low pressures) doing away with an intermediate defrosting.[4, 2] The advantage of the low temperatures involved in the process (temperatures which should not, however, drop below –30° to –35° C) is apparent, as it benefits preservation of paper strength. Books dried by this process generally tend to be overdried (to approximately 2 % moisture) and should be properly reconditioned before being reshelved. Freeze drying also tends to be expensive and time-consuming, with the average sized volume requiring up to several days to be freeze dried.

The research reported here explored the possible use of microwave heating in the drying of water soaked books. Dielectric heating at high frequency (microwave heating) generates heat in areas of highest dielectric constant and loss, i. e. where water exists in highest concentration. Consequently, unlike other drying methods, heat is generated from within a material. While microwaves have been extensively tested for industrially drying machine-made papers, and in conjunction with the drying of food items (to a much lesser extent), they have not been used to dry water-soaked books or other archival materials; however Solechnik *et al.*[6] reports the use of dielectric heating to destroy mold in book paper. At present, a number of technical difficulties exist, and like freeze drying, equipment and operation are costly. It is, however, an area in which continued research, such as reported upon here, can lead to development of an efficient and practical method for rapidly drying wet papers.

Experimental

The drying of soaked books was conducted in a Cryodry Model 1–2LC Microwave Research System, which consists of a microwave power generator, a cavity for sample placement, a heated-air circulation system and a conveyor for continuous operation, if desired. (In concept, it is similar to a combination of an air dryer and a microwave oven).

Books used for testing purposes ranged from 19th century rag paper to 20th century books representing a variety of wood pulp papers. Table 1 presents paper properties of books used in the final drying studies. Glossy, coated paper (i. e. art paper) was not evaluated. The majority of the books tested were wetted uniformly by immersion in cold tap water until saturated, while several samples were only partially wetted in order that the effect of microwave drying on half-dry, half-soaked books might be observed. Dry weights (prior to soaking) and wet weights were recorded, the wet book was opened at the center where least resistance was offered and placed in the drying tunnel, open face down, on a wooden frame (constructed with glue, No Metal) (Figure 1). In the case of very wet books which cannot be safely opened for processing, the closed book may be exposed to several minutes of microwave energy, effectively steaming pages apart to allow the initial opening. The horizontal dowels of the frame served as a support for the spine of the book, allowing the pages to fan open during the drying process. For larger books than tested here, a 3 dowel system would cause less strain on the wet spine. Hard covers of

Table 1: Paper properties of books used in microwave drying tests.

Sample no.	Book type[a]	Paper type[b]	Year printed	Cover removed[c]	Page size (cm)	Area	Paper weight g/100 cm²	Drying[d] sample
1	HC-S	WP	e. 20th c.	+	11.3×17.4	195.92	0.72	S
2	HC-S	WP	1900	+	12.0×17.9	214.80	0.55	S
3	HC-S	WP	1900	+	12.6×19.3	243.18	0.73	S
4	HC-S	WP	1969	+	13.3×20.2	269.99	0.70	S
5	HC-S	R	1857	–	12.5×18.6	232.50	0.84	EB
6	PB-G	WP	1954	–	10.8×16.8	181.44	0.62	EB
7	PB-S	WP	1960's	–	11.7×18.3	214.11	0.84	EB
8	PB-G	WP	1962	–	10.5×17.8	186.90	0.64	EB
9	PB-G	WP	1960	–	10.5×17.7	185.85	0.57	EB
10	PB-S	WP	1962	–	12.3×19.4	238.62	0.81	EB
11	PB-S	WP	1956	–	10.9×17.4	189.66	0.73	EB
12	HC-S	R	1844	+	11.3×18.8	212.44	0.69	S
13	HC-S	R	1846	+	12.3×19.7	242.31	0.69	S
14	PB-G	WP	1968	–	10.9×16.7	182.03	0.55	EB

a) HC: Hard cover
PB: Paperback
S: Sewn signatures
G: Glued signatures

b) WP: Wood pulp
R: Rag

c) + yes
– no

d) S: Sectioned book into signatures
EB: Entire book

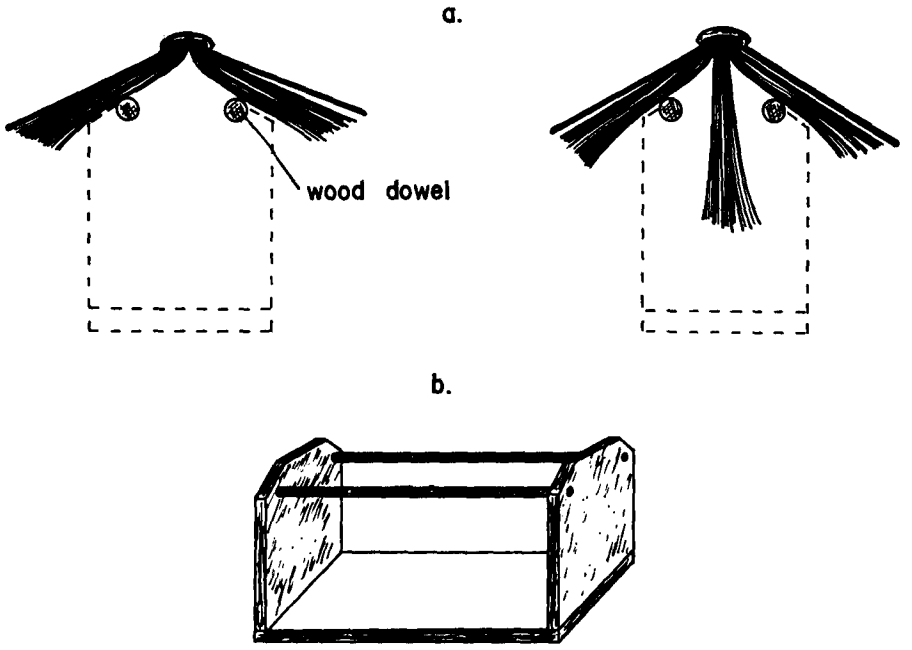

Fig. 1. Book support frame for use in microwave dryer a) End view, b) Side view.

books were usually removed before soaking; paper covers were generally left intact. Covers are detrimental to vapor escape, and due the nature of microwave drying, may literally be steamed away from the bound spine during the initial stages of drying. In many cases, water soaked covers are generally unsalvageable.

The maximum power input was limited to 2000 watts, beyond which mass transfer of the vaporized water became less efficient relative to the energy inputed, allowing unfavorably high temperatures to develop in the book. The hot air system was adjusted to run at room temperature (23°–25° C) supplying a constant stream of air over the sample in the cavity. (An increase in temperature of the air stream to as much as 100° C showed little effect on drying rates). The cavity position for several samples was varied some being placed at mid-cavity, other at cavity floor level.

Each sample was dried by a series of one minute microwave exposures; after each minute the sample was removed from the microwave cavity for weighing and temperature readings. Temperatures were measured (these being usually highest at the center of the book nearest the spine where vapor escape paths were "negligible") using an electornic thermometer with a 24 ga copper-constantan thermocouple as sensor. This interruption requires,

at most, from one to two minutes, and during this interval some water vapor escaped and temperature gradients within the book decreased.

When the semi-dried book became manageable (i. e. careful turning of the damp pages possible) it was opened at three new places after each minute of exposure and resituated on the wooden support in order to expose new surface area to the air flow and to facilitate fanning of the pages. Drying was continued until absorbed moisture was reduced to within several percent of the initial dry weight, a point at which localized charring occurred in some samples.

Following completion, the drying rates and final water content were calculated. Assessment of quality changes occurring during the process consisted of visual evaluation of charring and cockling plus evaluation of representative samples for changes of pH (cold extraction method) and paper strength using the TAPPI standard procedure for the Elmendorf Tear Tester.

RESULTS AND DISCUSSION

Typical behavior is shown in Figures 2 and 3. It can be seen that the drying proceeds rapidly, though there are significant differences in the time required to dry the various samples.

Figure 2 shows three aspects of drying behavior for sectioned books of 2 different types of paper, wood pulp and rag (2 samples). All three books have the same weight of paper per unit of page area (Table 1) so that potential surface area effects should not influence this comparison. In Figure 2C it can be seen that only small variations of drying times exist, and these differences are related primarily to differences in the initial moisture content of the samples. This means that the drying rates are approximately equal for these books, which can be observed in Figure 2A. Book temperatures remain constant (80–90° C) throughhout most of the drying process, rising abruptly only when the books are very dry. This will be described in more detail below. It should also be noted that two sections of a single book, dried at different times but using identical conditions (samples 13a, 13b) demonstrated almost identical drying behavior, indicating good reproducibility of the process.

Figure 3 presents normalized weight loss curves for a number of wood pulp paper back books. These books, which have varying values of weight of paper per unit page area, were dried as whole books (i. e. not in sections). One sample from Figure 2C (sample 4), which was dried as a section

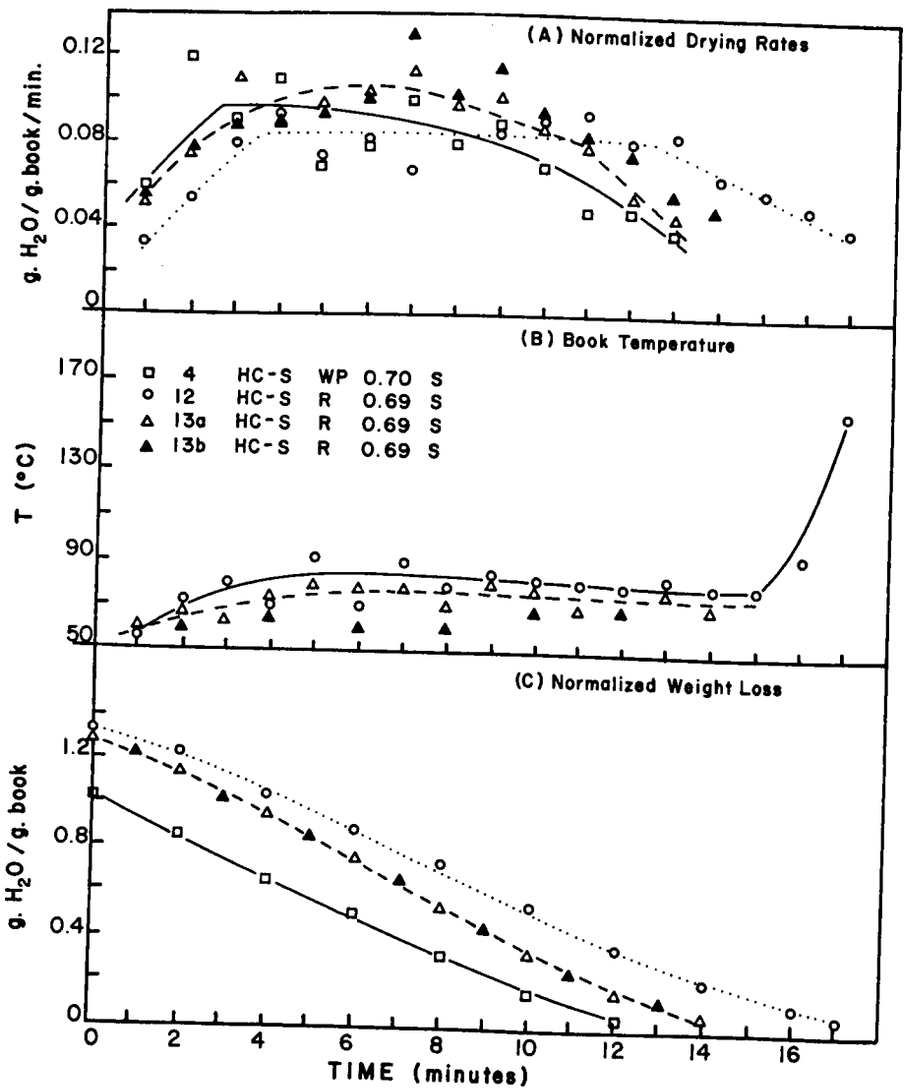

Fig. 2. Behavior of water soaked books during microwave drying at 2000 watts (see Table 1 for sample code).

and has a paper weight per unit area similar to sample 11, is included for comparison. Again, it can be seen that rapid drying is possible, with the time required appearing to depend primarily on the initial moisture content. Little effect of weight of paper per unit page area on drying rate was

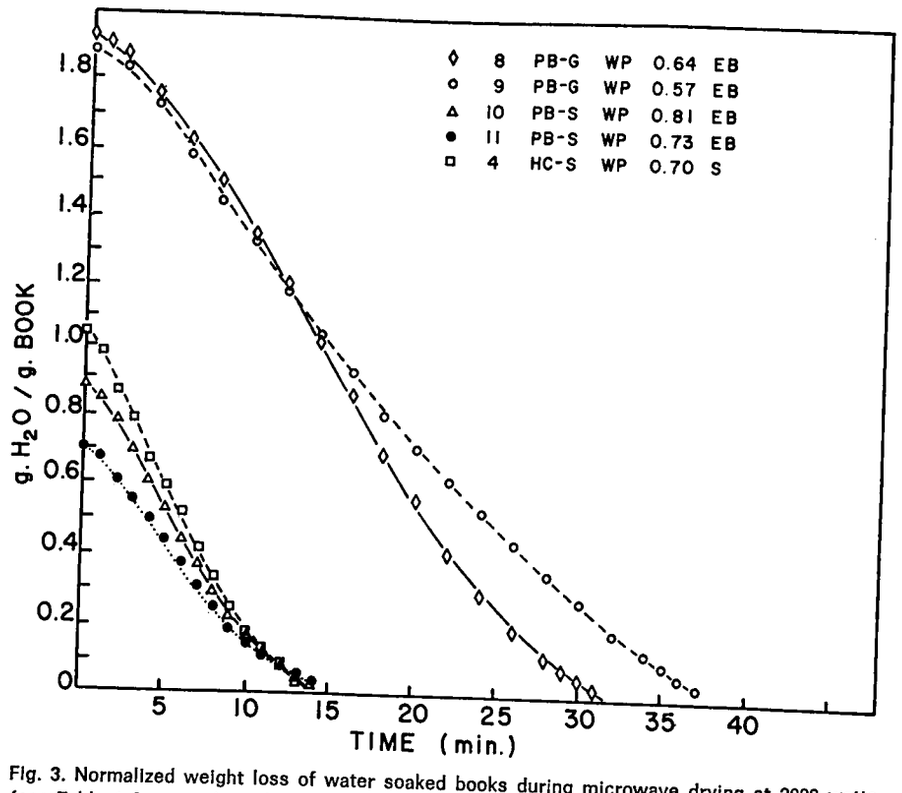

Fig. 3. Normalized weight loss of water soaked books during microwave drying at 2000 watts (see Table 1 for sample code).

noted, though it may have an effect on water uptake in the soaking process. (The only other difference between samples 8,9 and 10,11 are the the use of glued vs. sewn binding). The possible influence of this factor on the observed difference in water uptake was not ascertained.

The rates of drying for a number of books microwave dried at 2000 watts is shown in Figure 4. The overall drying behavior can be divided into an increasing rate period in which the temperature of the initially wet book is rising and some drying occurs, a constant rate period in which water is being removed at essentially constant temperature, and a falling rate period in which the final amount of water is being desorbed.

With the onset of constant drying rate, the paper temperature levels off, with the values being about 80° C in the book center nearest the spine (location of highest temperature). Temperatures elsewhere in the book range from 40° to 60° C. Lower temperatures are observed with an energy

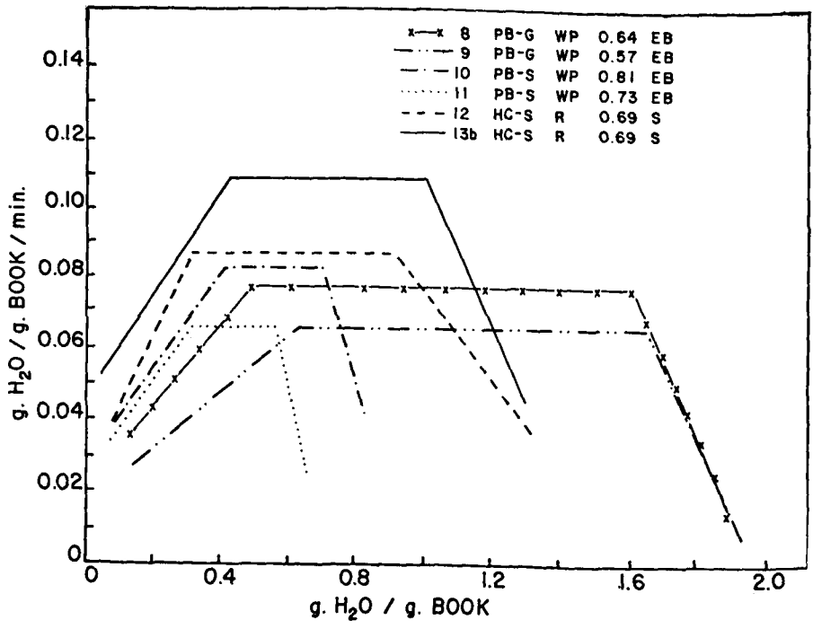

Fig. 4. Dependence of normalized drying rates on book moisture content during microwave drying at 2000 watts (see Table 1 for sample code).

input of 1000 watts, but for this case drying times are doubled. As the drying rate begins to drop off, the temperature at the center begins to ascend from 100° to 160° C as the residual water content drops below 0.15 to 0.20 g water/g paper. When the temperatures reach 130—160° C, localized charring begins. This is primarily due to non-uniform moisture distribution, which results in overheating in the most energy absorptive (high moisture content) regions. Vapor tends to become trapped within the bound pages nearest the spine, and when a large fraction of the absorbed water has been removed (when the drying rate begins to drop off) temperatures in the center of the book nearest the bound edge will rise and localized charring may eventually occur. A large, dense book, tightly bound is most susceptible to burning in this in manner, while a smaller, more loosely bound book may escape scorching even during the last stages of the drying process. The accumulation of the heat in the bound areas may be especially harmful to the paper, depending upon the type and chemical stability of the glue present.

The chance of charring can be reduced in a number of ways. If books are separated and dried as signatures, the pages are less subject to this effect, since the moisture is more able to distribute itself uniformly throughout the dyring procedure. Consequently, single pages may be fully dried without charring. We have successfully demonstrated this for both single pages and signatures. A drawback to this approach is the fact that *very* wet books are not easily unbound. Other approaches are based on control of the drying process. If mass transfer is controlled such that moisture is able to redistribute itself (such as by alternating periods of energy input with periods of no energy input) or by withdrawing the book from the microwave drying tunnel before the drying rate begins to drop off (i. e. it is easily handled but not "fully dry") the paper temperature in the book should not reach dangerous levels. This latter seems like a good approach since it is observed that as the drying rate becomes constant, the book pages become more easily manageable, and may be handled safely (Table 2). From Table 2 it appears that there exists some relationship between the amount of water a paper can soak up and the moisture content at which the paper can be safely handled. In particular, a number of important changes in book handling quality can be related to the percentage moisture loss, and also to the time of exposure to microwave energy. This behavior would tend to indicate that during the increasing rate period, "free water" (not absorbed in the paper, but adhering) is being removed, and that the constant rate period is related to the removal of water associated with the pages. With the onset of removal of this water, the book can be opened more easily for placement on the microwave drying support, and finally may be handled safely. Note particularly that less than 1/2 of the water present (and generally less than 1/4) needs to be removed for the book to be opened easily and thumbed through, though, at this point, it will still be damp. Also note that for the books tested, all opened in 3 minutes or less, were handleable in about 6 minutes, though the time for easy handling varied with the initial water content.

Tests with partially soaked books showed behavior similar to that observed with completely soaked books. They char only during the last stages of the drying process and in the same areas (center near the spine) as the uniformly soaked books.

The drying rates of several samples placed at the cavity floor level are improved somewhat, although the trend is not constant for all samples tested. This is most likely due to improved air flow characteristics of our particular drying unit, though this effect is somewhat dependent on the

differences in mass transfer resistances of the various book papers and their mode of binding. These results indicate the importance and limitations of the mass transfer characteristics.

Other than the small area of localized burning (from about one to four centimeters in length) which occurred on occasion in the tests, and occasional water stains in older books, formed by an uneven accumulation of dirt and acids, no general discoloration was noted. Paper strength (Elmendorf Tear Tester) measurements and pH determinations (both on uncharred samples) do not indicate any noticeable deterioration or change in paper quality. Anderson *et al.*[1] note similar findings for industrial microwave drying of papers, although Solechnik *et al.*[6] have detected some small changes in cellulose polymer structures due to dielectric heating of wet book papers.

From the results and observations presented, it appears essential to control the process so that the books be removed with a moisture content of at least 0.10 g/g dry book so that charring is avoided. From the results presented in Figures 3 and 4, it appears that initial moisture levels can vary widely, so initial wet sample weights alone will be useless to predict drying times to reach the desired final moisture level. One approach to a solution would have each book catalogued with its dry weight so that moisture contents could be easily calculated. Another approach which yields an approximate value makes use of the fact that as shown in Table 1 page weights per unit of page area are similar for most papers (0.69 ± 0.10 g/100 cm^2), though dividing the paper types into two classes, glued wood pulp (0.64 ± 0.08) and others (0.77 ± 0.07), yields narrower distributions of values. This, together with the weight of the wet book is sufficient to calculate the moisture contents required as process control inputs.

As shown in Figure 4, for a given set of drying conditions (microwave energy level, air flow conditions, cavity loading factor, process energy cycling time, etc.), drying rates in the constant rate period are for the most part between 0.065 and 0.09 g water/min/g dry book and an average value of 0.08 g water/min/g dry book can be assumed. Under these same drying conditions, the time spent in the increasing rate period should be independent of the type of the individual book (results in Table 2 bear this out). This information together with the moisture contents should allow calculation of an approximate time to achieve the desired degree of dryness. Using the following definitions, the total period for microwave exposure (i. e. not including energy off periods for moisture redistribution) is:

TABLE 2: Moisture and time dependence on handling properties of microwave dried books.

Handling property	Sample Number 8		9		10		11		12		13	
	% Water[a]	Min.[b]	% Water	Min.	% Water	Min.	% Water	Min.	% Water	Min.	% Water	Min.
Opens in 3 places when held by spine	95	3	96	3	–	–	97	1	87	3	90	3
Handable without danger of tearing	81	7	88	5	79	3	62	5	74	5	–	–
Easily handled and leaved	62	12	77	8	69	4	52	6	–	–	59	6

a) Percentage of initial water remaining

b) Minutes of microwave energy input

$$t = t_i + [(\frac{W-PAK}{PAK}) - M_f]\frac{1}{R}$$

Where:
- t = total microwave energy "on" time
- t_i = time in increasing rate period
- W = weight of wet book (excluding covers)
- P = total number of leaves (generally pages/2)
- A = area per leaf
- K = weight of leaf per unit of area
- M_f = desired final moisture content of book
- R = rate of loss in constant rate period

It must be stressed that the constants determined above are applicable for prediction, only if the drying conditions and microwave dryer remain the same.

While it may appear that the equation is quite involved, in fact it is quite simple, requiring only measurement of one weight (W) and two dimensions (A) and knowledge of the number of pages (P), as well as predetermined values of the constants (t_i, K, M_f, R) for the drying conditions to be used.

Choice of the value of M_f will depend on the extent of drying desired. As already noted, a value of about 0.10 g water/g book is the practical lower limit, since charring will begin about 0.05 g water/g book. Reference to Table 2 and Figure 4 shows that books are easily handled at moisture levels well above this value, and apparently the particular level is dependent on the initial moisture content for throughly soaked books.

For practical implementation of the ideas presented here, we can envision a number of physical designs. For example, 4 microwave tunnels could be operated in series, with a fixed time spent in each tunnel. (This would be the "energy on" part of the cycle). Upon exiting from a tunnel the book is opened to new locations and replaced in its holder and after the desired delay (i. e. "energy off" period) enters the next tunnel. Temperature measurements could be made if desired during the delay period. An essentially continuous stream of books would be dried. A complete system could be mounted in a truck trailer, and requiring only electrical connections (or have a selfcontained generator system), could be driven to the disaster scene to immediately process the books. Further studies, however, are needed before capacity analyses or cost studies can be initiated.

Conclusions

It has been demonstrated that microwave energy can be used to rapidly dry water soaked books, though improved process control will be necessary to prevent charring when "complete drying" (less than 5 % moisture) is desired of bound books. "Complete drying" of thin signatures or single leaves is possible without charring. Partial drying, which is achieved without any charring, yields books which are easily manipulated for further processing (Waters, 1972).

The methods of drying books with microwave energy is most useful for book papers holding over 50–60 % of their weight in water. It is best for books which are uniformly soaked, and especially useful in the case of books intermediately washed to remove dirt and acids which might accumulate unevenly, leaving stains once the book has dried. The process is limited to ungilded books since pages will burn along the gilded edges when exposed to several minutes of microwave energy. (Metals must not be placed in a microwave cavity! – i. e. no stapled pamphlets).

The proportion of the drying in which the rapid drying rates achievable with microwave energy should be used will depend in part on ability to institute process controls to prevent the onset of charring and additionally, upon cost factors which will enter into any ultimate decision regarding usage.

While it is desirable to be able to dry a book directly to a moisture content allowing reshelving, microwave heating, even when only used to a very limited extent, is effective in rapidly removing the initial bulk of water, resulting in partially dried pages which may be easily handled. A book semi-dried by microwaves may then be easily interleaved or left to air-dry in a humidity controlled environment. It would seem that the ability to very rapidly remove enough water so that books can be safely opened and handled is an important step in improving procedures for conservation of water-damaged books and papers.

Abstracts

Current methods for drying of water soaked books are generally slow and tedious, and it is often necessary to freeze large numbers of volumes to prevent mold growth while awaiting time to conduct the drying. We have investigated the possibility of using microwave drying (which is successfully used in the food industry) to achieve rapid water removal from water soaked books, so that freezing and other slow treatments may be unnecessary.

Results show that sufficient water can be rapidly removed so that the books may be opened and handled without evident danger to the pages. The books can be dried using microwave energy, but accurate determination of the end of the constant rate drying period is essential to insure against charring of the paper. No noticeable changes in paper quality have been observed following the microwave drying process.

Les méthodes courantes de séchage des livres trempés d'eau sont généralement lentes et fastidieuses et il est souvent nécessaire de congeler un grand nombre de volumes pour prévenir l'invasion de parasites pendant l'attente du moment où le séchage peut être entrepris. Nous avons étudié la possibilité d'employer le séchage par micro-ondes (utilisé avec succès par l'industrie alimentaire) pour obtenir rapidement l'expulsion de l'eau de livres trempés, de manière à éviter la congélation et autres traitements lents.

Les résultats ont montré qu'on peut enlever rapidement suffisamment d'eau pour que les livres puissent être ouverts et maniés sans risque apparent pour les pages. Les livres peuvent être séchés en utilisant l'énergie des micro-ondes, mais il est essentiel de déterminer avec précision la fin de la période du séchage constant pour prévenir le déchirement du papier. On n'a constaté aucune altération notable de la qualité du papier par suite du procédé des micro-ondes.

Die gegenwärtig angewandten Methoden für das Trocknen von wassergetränkten Büchern sind im allgemeinen langsam und beschwerlich, und es ist häufig erforderlich, eine grosse Anzahl von Bänden einzufrieren, um Schimmelbildung zu vermeiden, während das Material auf das Trocknen wartet. Wir haben die Möglichkeiten untersucht, Mikrowellen – die z.B. in der Nahrungsmittelindustrie mit Erfolg verwandt werden – für den Trocknungsprozess einzusetzen, um eine schnelle Wasserentfernung aus durchtränkten Büchern zu erreichen und damit das Einfrieren und andere langsame Behandlungsmethoden überflüssig zu machen.

Die Ergebnisse zeigen, dass genügend Wasser schnell genug entfernt werden kann, so dass die Bücher geöffnet und ohne sichtbare Gefahr für die Seiten behandelt werden können. Die Bücher können also mit Hilfe von Mikrowellen-Energie getrocknet werden, eine genaue Festlegung der Trocknungsperiode bei konstanter Einwirkung ist jedoch notwendig, um ein Ankohlen des Papiers zu vermeiden. Spürbare Veränderungen in der Papierqualität konnten nach Anwendung des Trocknungsprozesses mittels Mikrowellen nicht festgestellt werden.

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An Evaluation of Poly(vinyl Acetate) Adhesives for Use in Paper Conservation

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Introduction

Modern polymer technology has provided a large number of new products and formulations which are recommended for the conservation and repair of important paper objects. The evaluation of some of these materials has been undertaken in this laboratory. In previous papers a study of paper impregnating agents and a preliminary report of the results of this investigation have been presented.[1,2] In this paper the results of a study of the accelerated aging[3,4] of ten poly(vinyl acetate) emulsion preparations mounted on standard paper and glass substrates are presented. Poly(vinyl acetate) emulsion is present in many commercial formulations and its use has been considered in the literature of conservation.[3,5,6] It is easily applied, readily available, and in some cases claimed by suppliers to be reversible.

Though this material and its properties under conditions of accelerated aging have been examined previously,[3] little work has been reported in which the adhesive and paper were considered as a system. In this study, evaluation of changes in mechanical properties was obtained by folding tests; surface pH measurements were obtained; objective color and reflectance were measured; and studies of reversibility in both water and toluene were made. A further study of poly (vinyl acetate) emulsions (2 homopolymers, 3 vinyl acetate/ethylene copolymers, and 3 vinyl acetate/dibutyl maleate copolymers) has recently been completed by the authors. The results will be reported in the near future.

Experimental

Materials and Methods of Application. All paper samples were a buffered wood sulfite paper, Gracie & Sons Acid-Free Lining Paper – Lot 3 supplied by Charles R. Gracie & Sons, Inc., New York, New York 10022.

TABLE 1: Poly(vinyl acetate) emulsion examined.

Designation	Supplier	Suppliers comments
403	Jade Adhesives 2929 Campbell Ave. Chicago, Ill. 60618	Poly(vinyl acetate) copolymer; viscosity 6000–7000 cps; solids 50%; additives-plasticizer, solvent, inhibitor (none)
5714	S. Schweitzer Co. 1314 W. 21 St. Chicago, Ill. 60608	Poly(vinyl acetate) copolymer; additives-solvent(none).
436	S. Schweitzer Co. 1314 W. 21 St. Chicago, Ill. 60608	Modified poly(vinyl acetate); additives-aromatic and aliphatic solvents.
454	Jade Adhesives 2929 Campbell Ave. Chicago, Ill. 60618	Poly(vinyl acetate) copolymer; viscosity 40,000–45,000 cps; solids 38%; additives-plasticizer, inhibitor(none), medium volatility solvent.
R131	Manhattan Adhesives 425 Greenpoint Ave. Brooklyn, N. Y. 11222	Poly(vinyl acetate) emulsion; additives-10% medium boiling ketone solvent, phthalate plasticizer, chlorinated biphenol inhibitor, defoamer; pH 4.5.
A-1023	Process Materials Corp. 329 Veterans Blvd. Carlstadt, N. J. 07072	Poly(vinyl acetate) emulsion; viscosity 16,000-18,000 cps; solids 63-64%; additives-dibutyl phthalate plasticizer, inhibitor, pH 4.6-may be supplied neutralized; may be diluted to 40% with water.
Sobo Glue	Slomons Lab. Inc. 3245 Hunters Point Ave. Long Island City, N. Y. 11101	Poly(vinyl acetate) emulsion; solids 50%; additives-dibutyl phthalate plasticizer.
Elmer's Glue All	Borden Inc. Chemical Div. 103 Foster St. Peabody, Mass. 01960	Poly(vinyl acetate) emulsion; viscosity 3500–4500 cps; solids 50–52%; additives-ester plasticizer, other minor ingredients; pH 4.0–5.0.
Texicote VJC555	Talas 104 Fifth Ave. New York, N. Y. 10011	Poly(vinyl acetate) emulsion; solids 54–56%; additives-15% 2-ethyl hexyl acrylate plasticizer, inhibitor, filler (none).
Mix	Private Conservator *Standard Chemical Products Hoboken, N. J. 07030	Poly(vinyl acetate)-*5714;* Methyl cellulose-*Culminal.**

TABLE 2: General applications and properties of the tested adhesives.

Designation	Uses in paper conservation
403	Backing, mending, and bookbinding. High tack strength, remains flexible, non-warping. Clear and glossy when dry.
5714	Mounting paper backed with rag on honeycomb panels. High tacking strength, remains flexible, non-warping. Clear and glossy when dry. Mold has developed on storage.
436	Lining and mounting. Easy spreading, slow drying, does not pull paper. Opaque, creamy, non-glossy when dry. Mold has developed on storage.
454	Similar to 436.
R131	Mounting-especially smooth surfaces. Non-warp, fast drying, low water content. Clear and glossy when dry.
A-1023	Mounting, mending, binding. Fast drying, high tacking strength. Clear and glossy when dry. Often diluted with water.
Sobo Glue	Mounting papers on smooth surfaces, use with tissue paper (when thinned with water). Remains flexible. Clear and glossy when dry.
Elmer's Glue All	Similar to Sobo Glue. White opaque when dry.
Texicote VJC555	Heat set tissue for dry mounting. Clear, hard gloss when dry.
Mix	Repair of paper with Japanese tissue, strip repairing of book signatures. Non-warping. White opaque when dry.

Samples were cut in 0.5 × 6 inch strips in the same machine direction. The adhesives tested, suppliers, and their comments as to content are listed in Table 1. Table 2 lists applications and properties of the tested adhesives. Test data for the unaged and artificially aged untreated paper are reported for aging times of 0, 1, 5, 9, and 16 days in Table 3.

Two procedures for applying adhesives for the paper were employed, depending on the viscosity of the emulsion. Unless otherwise specified, the paper sample was laid for one minute on top of a portion of adhesive in a watchglass. For samples of the more viscous emulsions, referred to as brushed samples, a loaded 3/4 inch brush was brought back and forth over the paper sample for a total of 5 strokes. For the preparation of adhesives on glass slides only, the brushing procedure was used. Slide specimens desig-

TABLE 3: Tests of artificially aged[a] untreated paper.

Aging time Days	Fold tests Double folds to rupture[b]	pH	Color Munsell[d]	Reflectance[f] (%)
0	13 ± 2[c]	7.5	> 5Y9/1 – 5PB9/1[e]	86
1	15 ± 1	7.2	> 5Y9/1 – 5PB9/1	81
5	16 ± 3	7.2	> 5Y9/1 – 5PB9/1	79
9	17 ± 5	6.1	> 5Y9/1 – 5PB9/1	77
16	13 ± 2	6.1	> 5Y9/1 – 5PB9/1	72

a Oven temperature 100° C; all specimens equilibrated at 21 ± 1° C, 65 % relative humidity for 24 hrs. prior to measurement.
b 1½ lb. counterweight.
c Average and standard deviation of six measurements.
d Observed under »Tensor« incandescent illumination.
e The symbol > means brighter than.
f At 457 nm.

nated L (light) were coated with a single stroke of the loaded brush while the specimens designated M (medium) were prepared in the same manner as the brushed paper samples. In general for the adhesive samples prepared on glass slides the thickness was less than 0.15 mm for the L (light) samples and between 0.15 and 0.3 mm for the samples designated M (medium).

Aging of samples. The treated and untreated samples were placed in an oven at 100° C for periods of 1, 5, 9, 16 days. On the completion of each aging period 6 replicate paper specimens and specimens on glass slides were removed and equilibrated at 21 ± 1° C, 65 % relative humidity for 24 hours.

Folding endurance tests. Measurements were performed on a Tinius-Olsen Model No. 2 instrument (also known as Folding Endurance Tester (M. I. T.).) according to ASTM method D 2176–63 T on samples cut in the same machine direction. A dead weight of 1½ pounds was used for all samples. Results are reported as the average of six measurements together with standard deviation. The large standard deviation observed (compared to untreated papers) reflects nonuniformity in sample thickness achieved by the above methods of adhesive application. Generally it was observed that the treated paper ruptured within 3–5 double folds. The reported

data therefore correspond mainly to the strength of the adhesive alone. All tests were performed in a constant temperature/humidity room (21 ± 1° C, relative humidity 65 %). In recent work, the standards 500 g dead weight and conditioning at 23° ± 1° C and 50 % relative humidity have been employed. This has caused no change in relative performance.

pH measurements. Duplicate readings were taken on both sides of the test strips with a Beckman # 39182 Flat pH Bulb combination electrode with a 2 minute equilibration period.[7,8] Results are reported as the average of 6 readings on the adhesive side and the average of 2 readings on the paper side. These averages have an uncertainty of 0.2 pH units on the paper side and 0.3 pH units on the adhesive side.

Color changes. The color of the test strips was compared with that of the standard Munsell colors[9] with incandescent »Tensor« lamp illumination. Where the observed color corresponded to no single designation the two nearest bounding colors were recorded.

Reflectance. The reflectance was measured at 457 nm with a Bausch and Lomb Color Analyzer Reflectance Attachment on a Spectronic 20 Colorimeter. Results are reported as the average reading for three samples. Observations are reported for the uncoated side only.[10] These values have an uncertainty of ± 2 units.

Reversibility. Qualitative observations of the reversibility of the aged adhesive mounted on glass slides were made in two solvent systems, water and toluene. The specimen was immersed in the solvent for 1, 2, and 24 hour periods, removed, and probed with a glass rod.

The behavior of the adhesive was recorded on a scale of 1 (insoluble, no change) to 6 (soluble). Gradations of swelling and mechanical behavior were given intermediate designations. The solvent temperatures were maintained at 21 ± 2° C.

DISCUSSION OF RESULTS

Folding endurance tests. Table 4 presents the data for the folding tests on the paper-adhesive systems reported as double-folds to rupture. (For Tables 4–9 the data for untreated papers are included for comparison). With the exception of the mix-treated samples all of the adhesives apparently caused a marked weakening of the system. For example, the systems designated 436 and Elmer's Glue All ruptured after an average of 3 folds or less

TABLE 4: Folding tests on artificially aged paper – poly(vinyl acetate) adhesive-systems.

Aging time Days	Double folds to rupture[a]										
	403	5714	436[b]	454[b]	R131	A1023	Sobo Glue	Elmer's Glue All	Texicote VJC555	Mix[c]	Untreated
0	531±383	1556±696	N. S.[d]	N. S.	48±10	16,166±5131	1538±605	1±1	217±49	122±48	13±2
1	352±254	813±265	3±2	32±11	41±11	1467±721	1442±542	1±1	1±1	112±25	15±1
5	612±296	506±230	2±1	15±3	105±45	432±347	2094±483	1±1	0	34±8	16±3
9	1703±1105	65±96	1±1	12±2	122±75	1±1	315±1216	1±1	0	117±15	17±5
16	638±412	111±136	3±2	8±5	116±122	12±29	1±1	0	11±25	75±20	13±2

a Refers to rupture of the paper-adhesive system; in most cases the paper ruptured within 5 folds (see discussion section).
b Brushed samples.
c Paper and adhesive ruptured simultaneously.
d N. S. denotes no sample.

TABLE 5: pH of artificially aged paper – poly(vinyl acetate) adhesive-systems.

Aging time days	403	5714	436[a]	454[a]	R131	A1023	Sobo Glue	Elmer's Glue All	Texicote VJC555	Mix	Untreated
0	6.6[b] (7.1)[c]	6.8 (6.1)	N. S.[d]	N. S.	6.1 (6.1)	5.6 (5.3)	7.1 (7.0)	5.8 (5.9)	6.4 (7.9)	6.4 (7.1)	7.5
1	7.4 (6.9)	7.8 (6.8)	4.0 (5.9)	5.4 (6.6)	6.7 (6.3)	5.2 (6.4)	7.1 (7.3)	6.1 (5.6)	7.0 (7.4)	6.1 (7.1)	7.2
5	7.4 (7.3)	7.6 (7.0)	4.8 (6.0)	4.8 (6.1)	6.5 (6.5)	5.3 (6.6)	7.0 (7.0)	5.8 (5.7)	7.0 (7.4)	6.1 (7.1)	7.2
9	6.3 (7.0)	6.9 (7.2)	5.4 (5.9)	5.5 (6.8)	6.1 (6.7)	5.0 (6.4)	6.6 (7.9)	5.9 (5.7)	7.0 (7.4)	5.5 (6.9)	7.0
16	5.7 (6.8)	5.9 (7.2)	5.4 (6.1)	5.4 (5.6)	6.4 (6.6)	4.5 (6.5)	6.5 (7.0)	5.5 (5.4)	7.0 (7.5)	5.5 (6.9)	7.0

a Brushed samples.
b The average of six readings on the adhesive side.
c The average of two readings on the paper side.
d N. S. denotes no sample.

TABLE 6: Munsell Colors[a] of artificially aged paper – poly(vinyl acetate) adhesive-systems.

Aging time days	Adhesive side 403	5714	436[b]	454[b]	R131	A1023	Sobo Glue	Elmer's Glue All	Texicote VJC555	Mix	Untreated
0	5PB9/1 *white*	5Y9/1 *white*	N. S.[c]	5Y9/2–5Y8/4 *yellow*	5PB9/1 *white*	7.5Y9/2 *light yellow*	5PB9/1 *white*	7.5Y9/4–7.5Y9/2 *yellow*	7.5Y9/4–7.5Y9/2 *yellow*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
1	5Y9/1–N9/ *white*	7.5Y9/4–7.5Y9/2 *light yellow*	10YR6/6–2.5Y8/4 *brown*	7.5YR5/8–10YR7/8 *brown*	5Y8/6–5Y8/4 *light yellow*	7.5Y9.5/4–7.5Y9/2 *light yellow*	7.5Y9/2–5PB9/1 *yellow-white*	7.5YR5/8–7.5Y9/2 *brown-yellow*	5Y9/2–5Y8/4 *yellow*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
5	5Y9/1–N9/ *white*	7.5Y9/4–7.5Y9/2 *light yellow*	10YR6/6–2.5Y8/4 *brown*	2.5YR3/6–7.5YR6/8 *brown*	7.5Y8.5/5–7.5Y9/4 *yellow*	7.5YR5/6–5Y8/6 *yellow-brown*	7.5Y9/2–5PB9/1 *yellow-white*	7.5YR5/8–2.5Y8/6 *brown-yellow*	5Y8/4 *yellow*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
9	7.5Y9/4–5Y9/1 *light yellow*	5Y7.5/8–10Y9/1 *yellow*	10YR6/6–2.5Y8/4 *brown*	2.5YR3/6–7.5YR6/8 *brown*	2.5Y6.5/8–2.5Y8/8 *yellow*	7.5YR5/6–5Y8/6 *yellow-brown*	7.5Y8.5/5–7.5Y9/2 *yellow*	7.5YR4.5/6–2.5Y8/8 *brown-yellow*	2.5Y8/7 *yellow*	5Y9/1 *white*	5Y9/1–5PB9/1 *white*
16	7.5Y9/4 5Y9/1 *light yellow*	N. S.	10YR6/6–2.5Y8/4 *brown*	2.5YR3/6–7.5YR6/8 *brown*	2.5Y7/10 *yellow-tan*	7.5YR5/6–5Y8/6 *yellow-brown*	10YR7/10–2.5Y8/6 *tan*	5YR3.5/6.5–10YR7/9 *brown*	2.5Y8/6–5Y9/1 *yellow*	5Y9/1 *white*	5Y9/1–5PB9/1 *white*

a Observed under »Tensor« incandescent illumination.
b Brushed samples.
c N. S. denotes no sample.

for all aging periods as contrasted with a lowest average of 13 folds for untreated aged paper. This weakening of the system was the general case as the paper ruptured (within the first 5 double folds) substantially before the adhesive. Of the commercially available emulsions only 403 for the periods 0 and 1 days appeared not to affect the paper. In this case the paper ruptured after an average of 15 double folds, considerably before the adhesive. The samples treated with a mixture consisting of methyl cellulose and a small amount of the adhesive 5714 (designated in all tables as Mix) caused a substantial increase in the strength of the systems. Here the paper and adhesive invariably ruptured simultaneously. On the basis of these fold-strength data one must conclude that of the commercial adhesives only 403, for short aging times, does not substantially affect the paper support. The Mix shows promise of providing an adhesive which does not affect the paper support.

pH measurements. Table 5 presents data for the measurement of surface pH of the untreated paper and the paper-adhesive systems. The data are reported for both the adhesive treated side and the untreated side of the specimen. The initial pH's of the unaged adhesive ranged from 5.6 to 7.1. The penetration of the adhesive through the paper is indicated by comparability of the pH's measured on the treated and untreated sides of the specimen. This also indicates that it is the adhesive rather than the paper which is determinating the pH measured by the surface electrode. It is clear that no great changes in pH occur with aging so that the specimens which are initially acid remain acid while the initially neutral systems

remain neutral or become only very slightly acid. As observed in a previous study of impregnating agents,[1] no correlations between the pH measured and the mechanical properties of the system are apparent.

Once again, the Mix was somewhat atypical in behavior as the untreated side remained neutral while the adhesive side became more acidic with time.

Color changes. Tables 6 and 7 present the Munsell color designation for the artificially aged treated and untreated paper-adhesive systems. On the adhesive side, only the 403 and Mix did not show a dramatic yellowing. This was most pronounced in the specimens designated 436, 454, and Elmer's Glue All which on aging for 16 days at 100° C turned a deep brown. The untreated side of the specimen showed substantial darkening only in the case of 454 and Elmer's Glue All which became tan and brown in color, respectively. For all other systems the untreated side of the paper remained white. The discoloration is probably a combination of air oxidation and the chemical action of the many additives present in the adhesives. On the basis of the objective color evaluations, only the 403 and Mix demonstrated acceptable aging properties.

Reflectance. The reflectance measurements (%) at 457 nm of aged untreated paper and paper-adhesive systems are presented in Table 8. The results are given only for the untreated side of the paper since any uneveness in the coating would have produced a significant error in reflectance reading on the coated side. In two cases, Elmer's Glue All and Texicote VJC 555, the adhesive had visibly seeped through the paper leading to a further reduction in the reflectance measured.

Comparison of the data for the paper-adhesive system with the data for the untreated paper shows a greater rate of decrease in reflectance for 436, 454, Sobo Glue, Elmer's Glue All, and Texicote VJC 555. The reduction in brightness is a combination of the results of oxidation and degradation of the cellulose and seepage of the adhesive through the paper. These effects lead to a darkening of the paper which render such adhesives unsuitable for paper conservation. The other adhesives, i. e., 403, 5714, R 131, A-1023, and Mix demonstrate a rate of reduction in reflectance sufficiently similar to that of the untreated paper to consider them acceptable.

Solubility (reversibility). The generally accepted criterion for solubility of materials used in paper conservation requires complete reversibility, that is, complete solubility of the aged adhesive in a suitable solvent. The data

TABLE 7: Munsell Colors[a] of artificially aged paper – poly(vinyl acetate) adhesive-systems.

Aging time days	Untreated side										
	403	5714	436[b]	436[b]	R131	A1023	Sobo Glue	Elmer's Glue All	Texicote VJC555	Mix	Untreated
0	10PB9/1–5PB9/1 *white*	10PB9/1–5PB9/1 *white*	N9/ *white*	N9/–10PB9/1 *white*	5PB9/1–10PB9/1 *white*	10PB9/1–5PB9/1 *white*	5PB9/1 *white*	N9/ *white*	N9/–10PB9/1 *white*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
1	10PB9/1–5PB9/1 *white*	10PB9/1–N9/ *white*	10YR9/1–5Y9/1 *white*	N9/ *white*	10PB9/1 *white*	N9/ *white*	5PB9/1 *white*	N9/ *white*	N9/ *white*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
5	10PB9/1 *white*	10YR9/1–N9/ *white*	10YR9/1–5Y9/1 *white*	5Y9/1 *white*	10PB9/1–N9/ *white*	N9/ *white*	10PB9/1 *white*	10YR9/1–5Y9/1 *white*	N9/ *white*	5PB9/1 *white*	5Y9/1–5PB9/1 *white*
9	N9/ *white*	N9/ *white*	10YR9/1–5Y9/1 *white*	5Y9/2 *tan*	5Y9/1 *white*	5Y9/1 *white*	5Y9/1–N9/ *white*	10YR7/3 *brown*	5Y9/1 *white*	N9/ *white*	5Y9/1–5PB9/1 *white*
16	5Y9/1–N9/ *white*	5Y9/2 *white*	5Y9/2–5Y9/1 *white*	5Y9/2 *tan*	5Y9/1 *white*	5Y9/1 *white*	10YR9/1–5Y9/1 *white*	5Y9/2–10YR8/2 *brown*	5Y9/1 *white*	N9/ *white*	5Y9/1–5PB9/1 *white*

a Observed under »Tensor« incandescent illumination.
b Brushed samples.

TABLE 8: Reflectance (%) at 457 nm or artificially aged paper – poly(vinyl acetate) adhesive-systems.

Aging time days	403	5714	436[a]	454[a]	R131	A1023	Sobo Glue	Elmer's Glue All	Texicote VJC555	Mix	Untreated
					Untreated side						
0	79	82	N.S.[b]	N.S.	86	83	83	N.S.	81	82	86
1	79	80	76	74	84	80	80	68[c]	73	80	81
5	72	75	69	62	81	74	77	63[c]	69[c]	80	79
9	72	72	64	59	70	71	70	59[c]	57[c]	70	77
16	70	70	60	60	67	68	63	55[c]	55[c]	67	72

a Brushed sample.
b N. S. denotes no sample.
c Seeped through paper.

TABLE 9: Solubility of artificially aged adhesives mounted on glass slides.

Adhesive	Aging time days		
	0	1	16
403	(L) 5/2–4,5/2–4,5/2–4	(L) 3/2–4,3/2–4,3/4–6	(L) 1/2,1/4,1/4
5714	(L) 5/2–4,5/2–4,5/4–6	(L) 3/2–4,3/2–4,5/4–6	(L) 1/4,5/4,5/4–6
436	(M) 5/2–4,5/2–4,5/2–4	(L) 5/2–4,5/2–4,5/3	(M) 1/1,5/1,5/2
454	(M) 5/2–4,4/2–4,4/2–4	(L) 3/2–4,3–5/2–4,3–5/3	(M) 1/1,5/4,5/4
R131	(L) 5/2–4,5/2–4,5/2–4	(L) 3/1,5/1,5/2–4	(L) 5/1,5/2,5/2
A1023	(L) 4/2–4,4/2–4,4/2–4	(M) 3/3,5/3,5/3	(M) 5/1,2/4,4/4
Sobo Glue	(L) 5/2–4,5/2–4,5/2–4	(M) 1–2/2–4,3/2–4,5/3	(L) 1/4,1/4,1/4
Elmer's Glue All	(L) 4/2,4/2–4,4/2–4	(M) 5/1,5/1,5/3	(L) 5/1,5/1,5/5
Texicote *VJC555*	(L) 5/4,5/6,4/6	(L) 5/4,5/4,5/6	(L) 1/4,1/4,5/4
Mix	(L) 4/2–4,4/2–4,4/4–6	N. S.	(L) 2/2,2/2,2/4–6

The meaning of the numbers and symbols is given below. The three number sets, for each aging period, indicate soaking times of 1, 2, and 48 hours respectively. The first number(s) in each set are for soaking in water (21 ± 2° C) while the second is for toluene (21 ± 2° C). At times a specimen demonstrated a range of behavior as indicated by the presence of more than a single number.

(L) Light coat of adhesive (see discussion).
(M) Medium coat of adhesive (see discussion).
1 No change at all.
2 Gel-like but adherent on contact with a glass rod.
3 Dislodges only at point of contact.
4 Gel-like but breaks up on contact with a glass rod.
5 Layer peels off fairly easily on contact with a glass rod.
6 Soluble.
N. S. denotes no sample.

for qualitative observations on the solubility of these adhesives are given in Table 9. If complete reversibility is required none of the adhesives tested is completely satisfactory with water and toluene, commonly used solvents for poly(vinyl acetate).

It is interesting to note that the Mix which is made up of components which are ordinarily soluble in the solvents employed (methyl cellulose in water and 5714 in toluene) is nearly insoluble in either water or toluene. A possible mechanism for this consists of the encapsulation of the bulk of the Mix which is methyl cellulose by a film of poly(vinyl acetate). Thus, when water is used as a solvent the film of poly(vinyl acetate) protects the water soluble methyl cellulose, while when toluene is used as a solvent only the thin poly(vinyl acetate) film dissolves leaving the methyl cellulose behind. The use of a sequence of solvents or a mixed solvent may obviate this difficulty. Preliminary experiments indeed suggest acceptable reversibility by using toluene followed by water.

TABLE 10: Summary of results.

Adhesive	Test					
	Fold Strength	pH	Munsell Color (Adhesive)	Munsell Color (Paper)	Reflectance	Solubility
403	I–U	I	I–U	S	S	I–U
5714	U	I	U	S	S	I
436	U	U	U	S	U	I
454	U	U	U	U	U	I
R131	U	S	U	S	S	I
A1023	U	U	U	S	S	I
Sobo Glue	U	S	U	S	I	I
Elmer's Glue All	U	U	U	U	U	I
Texicote VJC555	U	S	U	S	U	I
Mix	S	I–U	S	S	S	I–U

S – satisfactory.
I – inadequate test for evaluative purposes.
U – unsatisfactory.

SUMMARIES

The results of the several experimental methods; fold strength, pH, objective color, reflectance, and solubility (reversibility) are presented in Table 10. Here each system is evaluated in terms of the individual test and graded as satisfactory (S) for meeting the specifications of the given test or unsatisfactory (U) clearly failing that test. When the test results are not sufficiently distinctive for placement in one of these two categories the designation I is used. It is evident from Table 10 that the poly(vinyl acetate) emulsions commercially available are not recommended for general use in paper conservation. The results permit the judgment that the adhesive designated 403 is least objectionable. A promising possibility is a mixture suggested by a private conservator: a small amount of poly(vinyl acetate) for tack strength used in combination with a large amount of purified methyl cellulose. This combination provided a system which behaved best in terms of mechanical strength, discoloration, and reflectance. Reversibility properties of this combination might be controlled by use of sequential solvent extraction; the acidic nature of the mix might be altered by the addition of a buffer. The optimum ratio of poly(vinyl acetate) to methyl cellulose, the proper buffering system and the correct solvent system for reversibility are currently under investigation in this laboratory.

Les résultats des différentes méthodes expérimentales: résistance à la pliure, pH, couleur objective, réflectance et solubilité (réversibilité), sont résumés dans le tableau 10. Chaque système y est évalué en terms du test individuel et qualifié de satisfaisant (S), s'il répond aux spécifications du test, ou de peu satisfaisant (U), s'il répond mal au test. Quand les résultats ne sont pas suffisamment distinctifs pour l'inscription dans l'une ou l'autre de ces deux catégories, le résultat est marqué par I. Il ressort à l'évidence du tableau 10 que l'emploi généralisé des émulsions poly(vinyle-acétate)s qu'on trouve dans le commerce n'est pas recommandable pour la conservation du papier. Les résultats permettent de conclure que l'adhésif désigné 403 est le moins à critiquer. Une possibilité prometteuse est un mélange proposé par un conservateur privé: Une petite quantité de poly(vinyle-acétate) pour le pouvoir adhésif en combinaison avec une grande quantité de cellulose méthylique purifiée. Ce mélange offre un système qui agit le mieux au point de vue de la force mécanique, la décoloration et la réflectance. Les propriétés de réversibilité de ce mélange peuvent être contrôlées par une extraction de solvant consécutive, la nature acide du mélange peut être modifiée par l'addition d'un tampon. Le dosage optimum de poly(vinyle-acétate) par rapport à la cellulose méthylique, le système tampon propre et le système solvant correct pour la réversibilité font l'objet de recherches courantes dans le laboratoire.

Die Ergebnisse diverser Experimentalmethoden: Falzstärke, pH, objektive Farbe, Reflexion und Auflösbarkeit (Reversibilität) sind in der Tabelle 10 dargestellt. In dieser Aufstellung ist jedes System als Einzeltest bewertet und entweder mit "S" (Zufriedenstellend) bezeichnet, wenn die im Test gestellten Anforderungen erfüllt wurden, oder mit "U" (Unzufriedenstellend), wenn das Ergebnis klar unzufriedenstellend war. Wenn die Prüfresultate nicht eindeutig genug waren, um das Ergebnis in einer dieser beiden Gruppen anzubringen, sind dieselben mit "I" bezeichnet. Aus der Tabelle 10 geht hervor, dass die handelsüblichen Poly(vinylacetat)-Emulsionen nicht für den allgemeinen Gebrauch in der Konservierung von Papier empfohlen werden können. Die Testergebnisse lassen den Schluss zu, dass das mit der No. 403 bezeichnete Klebemittel die wenigsten Minuspunkte aufweist. Eine vielversprechende Möglichkeit ist eine Mixtur, die von einem privaten Konservator vorgeschlagen wurde: Eine geringe Menge von Poly(vinylacetat) für die Klebewirkung in Verbindung mit einer reichlichen Menge von gereinigter Methylcellulose. Diese Mischung ergab ein System, das in Bezug af mechanische Stärke, Verfärbung und Reflexion am besten war. Die Reversibilitätseigenschaften dieser Kombination könnten mit Hilfe einer fortlaufenden Lösungsmittel-Extraktion kontrolliert werden. Die Säurenatur der Mischung liesse sich durch Zusatz einer Buffer-Flüssigkeit ändern. Das optimale Verhältnis von Poly(vinylacetat) zu Methylcellulose ein geeignetes System für die Buffer-Flüssigkeit sowie das korrekte Lösungsmittel-System für die Reversibilität werden im Augenblick in diesem Laboratorium untersucht.

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An Evaluation of Pastes for Use in Paper Conservation

by N. Indictor, N. S. Baer & W. H. Phelan

Introduction

As part of continuing program at the Conservation Center of the Institute of Fine Arts of New York University in testing materials used in paper conservation this report presents test results on artificially aged samples of four cellulose derivative preparations and seven wheat and rice derivative formulations on a buffered wood sulfite paper. In earlier work we have evaluated the effects of artificial aging on impregnating agents[1], such as soluble nylon and poly(vinyl alcohols), and the effects of artificial aging on poly (vinyl acetate) emulsions used as adhesives.[2, 3, 4] The adhesives tested previously showed preponderantly unsatisfactory results under identical test conditions to which samples are subjected. Tests on the adhesive materials used in this study gave a greater number of satisfactory results under identical test conditions. Some of the data included here have been presented in preliminary form.[2, 3] Our experimental results include data on fold testing, surface, and cold extraction pH measurements; objective color; reflectance; and reversibility (solubility) in distilled water.

Experimental

Materials and methods of application. All paper samples were a buffered wood sulfite paper, Gracie & Sons Acid-Free Lining Paper; Lot 3 supplied by Charles R. Gracie & Sons, Inc., New York, New York 10022. Samples were all cut in $1/2 \times 6$ inch strips in the same machine direction.

Table 1 lists the formulations used in this study along with source of supply. For a more detailed description of the formulations see Appendix 1.

All pastes were applied to paper with a loaded $3/4$ inch brush brought back and forth over the paper sample for a total of 5 strokes. Glass slides used in reversibility studies were prepared in a similar fashion.

Aging of samples. The treated and untreated samples were placed in a dry oven at 100° C for periods of 1, 5, 9, 16 days.[5, 6, 7] On the completion of each aging period 6 replicate paper specimens and specimens of glass

TABLE 1: Designations and suppliers of pastes studied.*

Paste designations	*Suppliers*
Methyl cellulose (CC)	City Chemical
Methyl cellulose (P)	Process Materials
Carboxyethyl cellulose (BM)	ICI America
Methyl cellulose (SC)	Standard Chem. Products
Wheat flour (formalin)	General Mills
Wheat starch (eugenol)	General Mills
Wheat starch (thymol)	General Mills
Wheat starch	General Mills
Rice flour (formalin)	Byrd Mills
Rice flour (formalin, alum)	Local Purchase. Japan
Rice starch (gelatin, glycerin, thymol)	TALAS
Rice starch	Manhattan Adhesives

* The complete designations, formulations, and suppliers comments are provided in Appendix 1.

slides were removed and equilibrated at 21 ± 1° C, 65 % relative humidity for 24 hours.

Folding endurance tests. Measurements were performed on a Tinius-Olsen Model No. 2 instruments (also known as MIT folding test meter) according to ASTM method D2176-63T on samples cut in the same machine direction. A dead weight of 1½ pounds was used in all tests. Results are reported as the average of six measurements together with standard deviation. All tests were performed in a constant temperature/humidity room (21 ± 1° C, relative humidity 65 %). These test conditions vary somewhat from TAPPI standards. In recent experiments in which TAPPI standards were appoximated for previously tested systems, no change in relative performance were observed.

pH measurements. Three different kinds of pH measurement were performed. Duplicate readings were taken on the treated side of three test strips and the untreated side of the test strips with a Beckmann No. 39182 Flat Bulb pH combination electrode with a 2-minute equilibration period.[8,9] Results were obtained for the average of eight reading on two test strips. A universal pH indicator solution (Harelco Wide Neutral Range Indicator Solution) was applied to test strips according to the procedure described by King *et. al.*[10] Cold aqueous extraction was performed on test strips according to the standard TAPPI procedure.[11]

TABLE 2: Folding tests on artificially aged[a] papers treated with pastes.

Adhesive	Aging time Days	Double folds to rupture[b, c] 0	1	5	9	16
Methyl cellulose (CC)		33±10	35±11	46±7	31±6	27±10
Methyl cellulose (P)		29±4	44±11	27±14	25±6	23±8
Carboxymethyl cellulose (BM)		N.S.[d]	22±3	17±3	17±2	14±3
Methyl cellulose (SC)		21±6	20±4	21±6	21±7	19±4
Wheat flour (formalin)		16±3	18±5	16±3	14±2	10±2
Wheat starch (eugenol)		18±4	19±3	20±3	14±3	13±4
Wheat starch (thymol)		18±4	18±2	15±2	14±3	12±1
Wheat starch		16±3	20±5	21±3	17±3	13±2
Rice flour (formalin)		17±3	15±5	15±5	12±2	13±1
Rice flour (formalin, alum)		15±5	19±4	17±2	14±3	11±2
Rice starch (gelatin, glycerin, thymol)		16±3	16±1	14±2	10±4	8±1
Rice starch		21±3	27±4	22±3	20±3	25±5
Untreated paper		13±2	15±1	16±3	17±5	13±2

a Oven temperature 100° C; all specimens equilibrated at 21 ± 1° C, 65 % relative humidity for 24 hours prior to measurement.
b Average and standard deviation of 6 measurements.
c 1½ pound counterweight.
d Denotes no sample.

Color changes. The color of the test strips was compared with that of the standard Munsell colors under incandescent "Tensor lamp" illumination.[12]

Reflectance. The reflectance was measured at 457 nm with a Bausch and Lomb Color Analyzer Reflectance Attachment on a Spectronic 20 Colorimeter. Results are reported as the average reading for at least three samples. These averages have an uncertainly of ± 2 % units.[13]

Reversibility. Qualitative observations of the reversibility of the aged adhesive mounted on glass slides were made in water. Specimens were immersed 1, 2, 24 & 48 hour periods, removed, and probed with a glass rod. Temperatures were maintained at 21 ± 2° C.

RESULTS

Folding endurance tests. Table 2 presents numerical data for the folding tests on artificially aged Gracie papers treated with pastes. The initial fold

TABLE 3: pH[a] of artificially aged[b] paper – paste systems.

Adhesive	Aging time Days 0	1	5	9	16
Methyl cellulose (CC)	6.0	6.0	6.0	6.0	6.0
Methyl cellulose (P)	6.0	6.0	6.0	6.0	6.0
Carboxymethyl cellulose (BM)	6.0	6.0	6.0	6.0	6.0
Methyl cellulose (SC)	6.0	6.0	6.0	6.0	6.0
Wheat flour (formalin)	6.0	6.0	6.0	6.0	6.0
Wheat starch (eugenol)	6.0	6.0	6.0	6.0	6.0
Wheat starch (thymol)	6.0	6.0	6.0	6.0	6.0
Wheat starch	6.0	6.0	6.0	6.0	6.0
Rice flour (formalin)	6.0	6.0	5.5	5.5	5.5
Rice flour (formalin, alum)	6.0	6.0	6.0	5.5	5.5
Rice starch (gelatin, glycerin, thymol)	6.5	6.0	6.0	5.5	5.0
Rice starch	6.5	6.5	6.5	6.5	6.5
Untreated paper	7.5	7.5	7.5	7.0	7.0

a pH measured with indicator solution (see discussion).
b Oven temperature 100° C; all specimens equilibrated at 21 ± 1° C, 65% relative humidity for 24 hours prior to measurements.

strength of all the samples painted with paste appears to be greater than that of the untreated paper. Unlike poly(vinyl acetate) emulsion adhesives,[4] the paper support invariably ruptured simultaneously with the adhesive.

Among these adhesives the methyl cellulose preparations imparted the greatest initial strength to the system and even after 16 days of aging, the system appeared not to be weaker than the paper itself. The rice and wheat derivatives performed less well, giving fold-strengths not significantly different from that of untreated paper indicating the limited strength of these adhesives. The single exception was unmodified rice starch which gave fold strengths comparable to those of the methyl cellulose pastes.

pH measurements. Measurements of pH with the surface electrodes were generally unsatisfactory due to clogging of the electrode membrane by the water soluble adhesives. Estimates of pH by use of universal indicator solution (Table 3) gave values above 6.0 for the cellulose and wheat derivatives for all aging times. The specimens treated with rice derivatives and glues gave pH estimates of 5.5 on aging for more than 5 days. Experiments

TABLE 4: Colors[a, b] of artificially aged papers treated with pastes.

Adhesive	Aging time Days 0	1	5	9	16
Methyl cellulose (CC)	5PB9/1 white	N9/ white	N9/ white	5Y9/1–N9/ white	5Y9/1–2.5Y9/2 white
Methyl cellulose (P)	5PB9/1 white	N9/ white	N9/ white	N9/ white	N9/ white
Carboxymethyl cellulose (BM)	5PB9/1 white	N9/ white	N9/ white	N9/ white	2.5Y9/2 yellow-white
Methyl cellulose (SC)	5PB9/1 white	N9/ white	N9/ white	N9/ white	N9/ white
Wheat flour (formalin)	5PB9/1 white	5PB9/1 white	5Y9/2–N9/1 yellow-white	5Y9/1–10YR7/6 yellow-white	5Y9/1–5Y9/2 yellow-white
Wheat starch (eugenol)	5PB9/1 white	5PB9/1 white	5Y9/1–N9/ yellow-white	5Y9/1–N9/ yellow-white	5Y9/1–N9/ yellow-white
Wheat starch (thymol)	5PB9/1 white	5PB9/1 white	N9/ white	N9/ white	5Y9/1–N9/ yellow-white
Wheat starch	5PB9/1 white	5PB9/1–N9/ white	5PB9/1–N9/ white	5PB9/1–N9/ white	5Y9/2 yellow
Rice flour (formalin)	5PB9/1–N9/ white	5Y9/1–N9/ yellow-white	5Y9/1–5Y9/2 yellow-white	5Y9/1–5Y9/2 yellow-white	5Y9/1–5Y9/2 yellow-white
Rice flour (formalin, alum)	5PB9/1–N9/ white	5PB9/1–N9/ white	5Y9/2 yellow	2.5Y8/6 yellow	2.5Y8/6 yellow
Rice starch (gelatin, glycerin, thymol)	5PB9/1 white	5Y9/2–2.5Y8/6 yellow	2.5Y8/4-10YR6/9 brown	2.5Y8/4-10YR6/9 brown	2.5Y8/4-10YR6/9 brown
Rice starch	N9/–5PB9/1 white	N9/–10B9/1 white	N9/ white	N9/ white	N9/ white
Untreated paper	5Y9/1–5PB9/1 white	5Y9/1–5PB9/1 white	5Y9/1–5PB9/1 white	5Y9/1–5PB9/1 white	5Y9/1–5PB9/1 white

a) Observed under "Tensor" incandescent illumination. b) Munsell Book of Color. c) Oven temperature 100° C.

TABLE 5: Reflectance (%) at 457 nm of artificially aged[a] papers treated with pastes – adhesive side.

Adhesive	Aging time Days 0	1	5	9	16
Methyl cellulose (CC)	85	82	79	73	71
Methyl cellulose (P)	84	79	79	74	73
Carboxymethyl cellulose (BM)	84	77	68	66	60
Methyl cellulose (SC)	84	79	79	74	76
Wheat flour (formalin)	85	81	77	71	65
Wheat starch (eugenol)	84	79	76	72	73
Wheat starch (thymol)	85	81	75	74	73
Wheat starch	86	80	77	76	69
Rice flour (formalin)	83	76	76	71	72
Rice flour (formalin, alum)	86	80	74	73	73
Rice starch (gelatin, glycerin, thymol)	84	70	61	52	52
Rice starch	85	84	82	81	81
Untreated paper	86	81	79	77	72

a Oven temperature 100° C.

with cold extraction gave higher pH values (6.6–7.3) for all systems implying extraction of the buffer from the paper. An evaluation of the procedures employed for pH measurements and a consideration of the significance of pH measurements on adhesive-paper systems is in preparation.[15]

Color changes. Table 4 presents color changes on the adhesive side of artificially aged papers treated with adhesives. Qualitative correlation between these data and fold-test strength data may be observed. Cellulose formulations remained substantially unchanged as did the untreated Gracie paper. The wheat and rice derivatives (except for the unmodified rice starch formulation) tended to yellow.

It may be noted in a few examples tested in this group that the presence of additives in the wheat and rice formulations produced little discernible alternation of the behavior of the adhesive-paper system. The presence of thymol or eugenol apparently reduced yellowing in the wheat starch during 16 days of artificial aging.

Reflectance. Table 5 present reflectance measurements (%) at 457 nm of artificially aged papers treated with adhesives. Results are reported only for the treated side. Reflectance measurements on the untreated side in

general showed no change from the behavior of untreated paper. The cellulose adhesives and the wheat and rice derivatives gave results close to those of untreated paper. Only the rice starch formulation containing gelatin, glycerin, and thymol gave unusually low reflectance values implying that the additives (probably glycerin) served to accelerate deterioration of the adhesive.

Solubility. The adhesives in this group showed no change in solubility characteristics on aging. Three of the cellulose formulations (CC, P, and BM) were easily soluble in water while the fourth (SC) became gel-like and easily removable by mechanical methods but only sparingly soluble. The rice and wheat dervatives, in general, behaved in a manner comparable to the "SC" methyl cellulose. It has recently been observed that the addition of 5 g of Na_2CO_3 per liter of methyl cellulose of carboxymethylcellulose paste greatly increases the reversibility of these materials.[14]

SUMMARIES

The generally satisfactory behavior of this group of adhesives is to be noted. Although the apparent fold strength of the system was not markedly improved by the addition of adhesive to paper, the rate of deterioration of the system as observed by fold strength measurements was low and alteration of color and reflectance properties was small. In sharp contrast poly(vinyl acetate) adhesives[3, 4] which impart considerable initial strength and flexibility to the system, deteriorate rapidly and visibly and the paper itself deteriorates independent of the adhesive. The paper ruptures within the first few double folds even though the adhesive does not. Although this latter class of adhesives clearly shows initial strength and flexibility and has many important applications, poly(vinyl acetate) emulsions cannot be recommended as adhesives for the conservation of valuable paper objects. The pastes as a group are nearly equivalent to each other. The cellulose derivatives and an modified rice starch showed slightly enhanced strength properties over those of the other pastes tested. The chief drawback in the use of all pastes is the limited strength and flexibility imparted to the system by their application.

L'action en général satisfaisante de ce groupe d'adhésifs est à noter. Bien que la résistance apparente à la pliure de ce système ne fût pas sensiblement améliorée par l'addition d'adhésif au papier, le taux de détérioration du système observé par des mesures de la résistance à la pliure était bas et

l'altération de couleur et les propriétés de réflectance étaient petites. Par un contraste net, les adhésifs de poly(vinyle-acétate), qui donnent une résistance et une flexibilité considérables au système, se détériorent rapidement et visiblement et le papier se détériore lui-même, indépendamment de l'adhésif. Le papier se rompt après les premiers doubles pliages, même si l'adhésif ne le fait pas. Bien que cette dernière classe d'adhésifs montre clairement une résistance et une flexibilité au début, et a beaucoup d'applications importance, les émulsions poly(vinyle-acétate) ne sauraient être recommandées pour la conservation d'objets précieux en papier. Les pâtes, dans l'ensemble, s'égalent presque. Les dérivés cellulosiques et un amidon de riz modifié montrent des propriétés de résistance légèrement supérieures aux autres pâtes essages. L'inconvénient principal de l'emploi de toutes les pâtes est que leur emploi donne au système une résistance et une flexibilité limitées.

Das im allgemeinen zufriedenstellende Verhalten dieser Gruppe von Klebemitteln ist bemerkenswert. Obgleich die scheinbare Falzstärke des Systems nicht merkbar durch die Zugabe von Klebstoff zum Papier verbessert wurde, war der Zerstörungsgrad dieses Systems, gemessen an der Falzstärke, niedrig und die Änderungen in Bezug auf Farbe und Reflexions-Eingenschaften gering. In scharfem Gegensatz hierzu werden Poly(vinylacetat)-Klebstoffe, die dem System eine beträchtliche anfängliche Stärke und Biegsamkeit verleihen, schnell und sichtbar zerstört und das Papier selber geht zu Grunde, unabhängig vom Klebemittel. Das Papier bricht schon nach wenigen Doppelfalzen, auch wenn der Klebstoff hält. Wenn auch diese letztgenannte Art von Klebemitteln deutlich eine anfängliche Stärke und Biegsamkeit zeigt und viele wichtige Anwendungsmöglichkeiten hat, sind Poly(vinylacetat)-Emulsionen als Klebemittel für die Konservierung wichtiger Papiere nicht zu empfehlen. Die Pasten als Gruppe gesehen sind nahezu gleich. Die Cellulose-Derivative und eine verbesserte Reis-Stärke zeigten etwas höhere Belastungseigenschaften im Verhältnis zu den anderen getesteten Pasten. Der Hauptnachteil beim Gebrauch aller Pasten ist die begrenzte Stärke und Biegsamkeit, die dem System durch deren Anwendung verliehen werden.

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APPENDIX 1: Preparation of formulations tested.

Designation and supplier	Formulation	Suppliers comments	Remarks
Methyl cellulose (CC). City Chemical, W.22 St. NYC 10011.	2g Methyl cellulose (USP-1500) + 30 ml cold water (ambient temp. or below). Combine with stirring. Let stand at least 20–30 min. Mix before application.		Difficult to mix. High foaming. Clots easily. Slightly yellow in solution.
Methyl cellulose (P). Process Materials, 329 Veterans Blvd, Carlstadt N. J. 07072.	Same as Methyl cellulose (CC).	High purity methyl cellulose powder, neutral pH. can be mixed 1: 60 by wt. with cold water. Soluble and reversible in cold water. Manufactured from alkali cellulose + methyl chloride.	Little foaming. Easily mixed. Readily soluble.
Carboxymethyl cellulose (BM). ICI America, 151 South St. Conn. 06904.	25 g Carboxymethyl cellulose, Cellofas B, Grade B 3500 per liter cold water.	Use distilled water for increasing shelf life. Any solution less than 2 % is a poor adhesive.	Same as methyl cellulose (P).
Methyl cellulose (SC). Standard Chemical Products, 1301 Jefferson Hoboken, N. J. 07030.	1 g Methylan methyl cellulose (Culminal K 52) to 30 ml cold water.	High viscosity. Can be mixed 1: 50–1 60 by weight in cold water. Manufactured from akali cellulose + methyl chloride. Currently available as Culminal C 1525 5000.	Same as methyl cellulose (P).
Wheat flour (formalin). General Mills, Minneapolis Minn. 55440.	Gold Medal All Purpose Enriched flour. Used according to procedure of H. J. Plenderleith: *The conservation of antiquities and works of art*, London, 1962, p. 347–348.		Slightly yellow and granular.
Wheat starch (eugenol) General Mills, Minneapolis Minn. 55440.	Presoak Aytex-P Unmodified wheat starch with water (1: 2 by volume) under refrigeration at least 24 hrs. Cook in enamel double boiler 4: 10 presoaked starch. water for 1 hr. Stir with wooden spoon. Add 3 drops eugenol. Cool pan with damp towel, strain. Dilute 1: 1 with water before use.		May be diluted to desired consistency. Should be freshly prepared after one week. Avoid overcooking. Should appear translucent with short strings of white.
Wheat starch (thymol) General Mills, Minneapolis Minn. 55440.	Same as wheat starch (eugenol).	Same as wheat starch (eugenol) except that thymol is used in place of eugenol.	Same as wheat starch (eugenol).
Wheat starch General Mills, Minneapolis Minn. 55440.	Same as wheat starch (eugenol)	Same as wheat starch (eugenol) except that eugenol is absent.	Same as wheat starch (eugenol).
Rice flour (formalin) Byrd Mills, Louis. Va.	Same as wheat flour (formalin).		Less smooth than wheat flour or starch pastes.
Rice flour (formalin, alum).	Mix 125 g rice flour, 125 g cold water and 9 g alum. Bring to boil stirring with wooden spoon. Remove from heat after 4–5 min. Add 5 ml formalin.		Less smooth than wheat flour or starch pastes.
Rice starch (geletin, glycerine, thymol) Talas, 104 Fifth Ave. NYC 10011.	52 g Rice starch + 344 ml deionized water stirred in double boiler over medium heat until paste becomes translucent. Remove from heat, add 50 ml 10 % (w/v) gelatine/deionized water solution, 10 ml glycerine, and 20 ml deionized water. When paste is cool add 5 ml of thymol in alcohol.	Remains flexible when dry. Good for paper to paper adhesion.	Easy to work with. Slightly yellow.
Rice starch Manhattan Adhesives Corp. 425 Greenpoint Ave., Brooklyn N. Y.	Belgian rice starch B-220 used in same formulation as wheat starch.		

Report of the joint consultation between the ICA and IFLA on the physical protection of books and documents, Paris, 19–21 November 1973

1. The participants delegated by IFLA and ICA (list attached app. I) wish to express their gratitude to Unesco for sponsoring this consultation and for having made available accomodation and the necessary technical services.

2. They wish to record that this has been the first joint specialised consultation between the two bodies, arising from an understanding of the great number of problems which they have in common and being moved by a common will to overcome these problems by rational and economical means.

3. They also wish to record that this consultation has been between representatives of three professions, namely archivists, librarians and scientists and that they feel that such triple co-ordination must continue in order to achieve progress in this common field.

4. This interprofessional approach must cover the following aspects of problems:

(i) the prevention of deterioration;
(ii) the treatment of deteriorated material;
(iii) the training of qualified personnel;
(iv) fundamental and applied research into the mechanisms of deterioration.

5. This interprofessional approach and co-ordination would provide to the participating institutional networks of archives, libraries and laboratories the possibility of rapid bibliographic control, the dissemination of information on national standards, current research projects and technical innovations and also the evaluation of priorities.

6. Without attempting to make an exhaustive inventory of their common problems, the participants feel that the following topics should receive priority of consideration and effort.

(i) The enforcement of national and international standards for the storage, treatment and exhibition of documents and for the methods and materials to be used in their preparation and treatment.
(ii) The critical re-examination of those materials and methods for the conservation of documents that are suspected to be inadequate or unsafe.
(iii) The development of standards and methods adapted to the environmental conditions, needs and economic capacities of developing countries especially in regard to the prevention of biodeterioration during storage.
(iv) The evaluation of existing methods for the mass-conservation of library and archival material and the development of new techniques for this purpose, both for material undergoing slowdecay and for material damaged in disasters.
(v) The training of adequate numbers of personnel at all levels within the general discipline of library and archival conservation together with the provision of curricula designed to achieve an acceptable standard of education within this discipline. There should also be the promotion of a proper understanding, by curatorial and administrative staff, of conservation needs, both during training in library and archive schools and in post.

7. In order to create the necessary inter-professional cooperation and in order to implement the project mentioned in paragraph (9) below, it is proposed to the International Council on Archives and the International Federation of Library Associations to set up, as an immediate and provisional measure, under the general supervision of the Liaison Committee of these two organisations, a joint steering committee and a secretariat for the planning and management of action in the field of library and archival conservation.

It is proposed that the Steering Committee shall consist of the following persons:

M. Pierre DURYE, Chairman	Mme M. HUSARSKA
Dr. H. BANSA*	Mme F. MORANDINI**
Mr. A. D. BAYNES-COPE	Mr. F. D. POOLE
Dr. H-J. BUSLEY	Mr. P. A. CHRISTIANSEN, Secretary

8. It is recommended to the Steering Committee that they should work out a scheme for the creation of a group of experts (Archivists, Craftsmen, Librarians, Scientists etc.) to be entrusted with the carrying out of the studies and projects that will be settled by the Steering Committee, through an appropriate structure of sub-committees.

The International Federation of Library Associations should negotiate the involvement of the International Council of Museums through its Conservation Committee in the interprofessional co-operation in the conservation of library and archival material. Until these negotiations have been finalised, the Steering Committee and its Secretariat should maintain contact with the co-ordinator of the Working Group on illuminated manuscripts and books.

9. It is recommended that the immediate projects to be undertaken by the Secretariat should be:

(i) the compilation of a list of laboratories workshops, research institutions and training centres active in the field of library and archival conservation and the principal current work upon which they are engaged;
(ii) the compilation of a selective bibliography of available standard publications upon library and archival conservation which can be recommended as authoritative for those practising in this field;
(iii) evaluation of programmes for the training of personnel engaged in all levels of library and archival conservation together with a study of the feasibility of initiating regional training centres in Africa, Asia, Latin America, the Arab States and the Caribbean are invited to collaborate in these projects;
(iv) the compilation of a bi-annual calendar of events and meeting relating to library and archival conservation.

10. It is recommended to the Steering Committee that they should, before January 1st, 1975, produce a long-term plan for interprofessional co-operation in the field of library and archival conservation bearing in mind the following needs:

(i) permanent bibliographic control;
(ii) methods for mass-conservation, including bulk de-acidification;
(iii) coordination of research projects and the production of equipment;
(iv) the ready availability of material suitable for library and archival conservation, such as paper, parchment, leather, adhesives, inks and photographic material;
(v) an adequate multi-lingual glossary of terms.

11. In order to ensure the implementation of these tasks, an annual budget of not less than US$ 4,500 would be required. It is therefore recommended that the International Council on Archives and the International Federation of Library Associations should each grant US$ 500 per annum towards this end and that a mandate should be given to the Steering Committee and the Secretariat to approach potential funding organisations.

12. It is requested by the participants in this consultation that the working documents which will be submitted to the Intergovernmental Conference on the Planning of Overall National Documentation, Library and Archival Infrastructures by Unesco should take into account the prospects that are now opened up by interprofessional co-operation in the field of library and archival conservation.

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